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Assessment of Treated Vs. Untreated Oil Spills

Final Report

February 1981

Prepared for:
U.S. Department of Energy
Assistant Secretary for Environment
Environmental and Safety Engineering Division

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Kingston, Rhode Island 02881

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U.S. Department of Energy
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Environmental and Safety Engineering Division
Washington, D.C. 20585

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16. Abstract

This report describes the results of a series of studies conducted to determine the practicability and feasibility of using dispersants to mitigate the impact of an oil spill on the environment. The method of approach is holistic in that it combines the physical, chemical, microbial and macro-fauna response to a spill treated with dispersants and compares this with spills that are left untreated. The program integrates mathematical, laboratory, meso-scale (three 20 foot high by three feet in diameter tanks, described in Section 1), in-situ experiments and analyses to determine if the use of dispersants is an effective oil spill control agent.

In summary, it appears viable to use dispersants as determined on a case by case basis. The case for using dispersants has to be based on whether or not their use will mitigate the environmental impact of the spill. In the case of an open ocean spill that is being driven into a rich inter-tidal community, the use of dispersants could greatly reduce the environmental impact. Even in the highly productive George's Bank area at the height of the cod spawning season, the impact of the use of dispersants is well within the limits of natural variability when the threshold toxicity level is assumed to be as low as 100 ppb, a level which is often found in the open ocean. Thus, it appears that dispersants can and should be used when it is evident that their use will mitigate the impacts of the spill. Their use in areas where there is poor circulation and therefore little possibility of rapid dilution is more questionable and should be a subject of future studies.

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Preface

This study was undertaken over a period of four and one-half years, carried out under Department of Energy Contract No. E(11-1) 4047, through the Environmental and Safety Engineering under the direction of Dr. William E. Mott and Dr. John Cece.

Acknowledgements

This is perhaps the most difficult section of any report to write. In a project of this size many people played important roles. Discussions with scientific personnel outside the project had beneficial influences on the project.

A special thanks to Dr. William E. Mott for the foresight in establishing the project and to Dr. John Cece who later became DOE Project Manager for his many helpful suggestions and his patience. Many people worked on the project whose names do not appear as authors in this final report. Dr. Sheila Bhattacharya and Paul Griffin worked on the initial biodegradation studies, Margaret Brady-Campbell, Daniel Goldfarb and Mark Maris contributed to the chemical analysis. The meso-scale facilities were constructed by Charles Young and operated and maintained later by Peter Pohlot and Richard Heavers. Dr. Peter Cornillon initiated the rain drop experiment. He was aided by David Konigsberg and Scott Paul . David Zinni, Steve Csenge and William Jasper worked on the entrainment experiment. Dr. Raymond Teyssandier also worked on entrainment and various other portions of the report.

Last but far from least, is the office staff who enabled this rather voluminous to come to fruition in the form of a report. A special thanks to Ms. Corinne Carr who supervised the construction of the report and editing. Her patience, organization skills and thoroughness added greatly to reduce the difficulty of the formidable job of collecting and organizing the sections of this report. Other office staff who contributed much to this report are Ms. Tracy Miller who painstakingly did many of the flow charts and Denise Klein. Many thanks to the College of Engineering Word Processing personnel and especially to Mary Costa who did the bulk of the typing.

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EXECUTIVE SUMMARY

ASSESSMENT OF TREATED VERSUS UNTREATED OIL SPILLS

Mason P. Wilson, Jr.
Program Director

Executive Summary and Results

This report describes the results of a series of studies conducted to determine the practicability and feasibility of using dispersants to mitigate the impact of an oil spill on the environment. The method of approach is holistic in that it combines the physical, chemical, microbial and macro-fauna response to a spill treated with dispersants and compares this with spills that are left untreated. The program integrates mathematical, laboratory, meso-scale (three 20 foot high by three feet in diameter tanks, described in Section 1), in-situ experiments and analyses to determine if the use of dispersants is an effective oil spill control agent.

A series of physical and physical-chemical studies and experiments were conducted to determine the emulsification properties, including emulsion stability of the treated and untreated oil, and its rate of evaporation. Various natural entrainment processes were also investigated to compare natural entrainment of the oil with chemically dispersed oil. Emulsified oil exhibits properties in between those of a true solution and a suspension of immiscible phases. Experiments to typify the drop size distribution, mixing energy and to evaluate the effect that dispersants have on interfacial tension were conducted. The results of these tests indicated that only a fraction of the energy goes into the formation of droplets. Typical drop sizes were in the range of 2 to 10 microns for both the treated and untreated dispersed oil. This is well within the particle size range in which emulsions are classified, i.e., 0.25 to 25 microns, whereas butterfat particles are in the 7.5 to 8.5 micron range. The major difference between the dispersed oil and the chemically treated dispersed oil was not the drop size distribution but rather the concentration of oil in the dispersed phase. The amount of oil in the dispersed phase (hold-up) was approximately two to three times greater than the untreated dispersed oil for these tests. Consequently, the interfacial area of the treated dispersed oil was approximately two to three times greater. Entrainment was also observed without mechanical energy input with Corexit 9527, although the hold-up was slightly less than with mixing. As much as 86% of the oil that could be accounted for went into the water column when dispersants were used. A rather small amount of dispersant is required to decrease the interfacial tension (see Section 1).

The stability of the dispersed oil was investigated in several experiments, some of which produced conflicting results. The stability of an oil-in-water emulsion can be easily determined by measuring its settling or creaming rate. Most of the droplets follow a Stoksian flow. In the drop size range experimentally determined, it would take from 40 hours to 1000 hours (1 to 10 micron size) for the droplets to rise to the surface of a 0.6 meter tank. The amount of oil in the water column after twenty four hours of quiescent conditions remained relatively constant, however, the amount of oil in the water column when dispersants were used with mixing remained approximately twice that when no dispersants were used. In two separate tests, one with no mixing, the amount of entrained oil remained relatively constant. However, in these experiments chemical analysis of the dispersed phase indicated a ratio of dispersant to oil of approximately one to one. In Section 4.4, the experiment with no mixing is reported, and similar results were found in the latest meso-scale tests reported in Section 8. Somewhat unusual results in terms of stability were also observed in the wind/ wave experiments to be discussed in a later paragraph. Coalescence of the dispersed phase was found to be negligible (Section 1) and therefore did not affect the stability characteristics of the emulsion. It was found that very little agitation was required to maintain the chemically dispersed oil in the water column, (Section 4), however, it should be noted that in these tests the ratio of dispersant to oil in the water column was approximately one to one, even though application was on a twenty to one ratio. It should be noted, also, that these low ratios of dispersant to oil were only observed under quiescent conditions or when there was very little mixing energy applied. The mixing experiments had shown that almost all of the oil could be incorporated in the dispersed phase when mixing energy was applied and subsurface circulation was sufficient to maintain the dispersed oil from reforming at the water/air interface. It thus appears that more stable emulsions are formed when the dispersant/oil ratio is in the neighborhood of unity, however, natural turbulence and subsurface circulation in many instances could be sufficient to maintain almost complete entrainment of the dispersed oil.

The subsurface circulation and entrainment was investigated analytically and conditions for various drop sizes to remain in suspension were established. These results are presented in Section 4 of this report.

Several evaporation tests from an oil slick were conducted throughout the duration of this project and reported in Section 4, Section 7 and Section 12.2. In Section 7, laboratory and meso-scale tank evaporation tests are reported. The laboratory study using the self mixing dispersant Corexit 9527 indicated that the evaporation of the n-alkanes from the treated and untreated slicks were similar when the water was not agitated. However, when mixing was applied, the evaporation of the light n-alkanes, n-C_7 to n-C_{10}, from the treated slick were slower than from the untreated slick. The greater the mixing the greater the effect the dispersant had on depressing the evaporation rate. The dispersant affected the evaporation rate of the lighter n-alkanes to a greater extent than the heavier ones. The slower evaporation of the treated slick could be due to the mixing of some of the oil in the water column. Results of the meso-scale experiments were in agreement with the laboratory scale experiments when mixing was not applied. Evaporation was faster in the meso-scale (open tank) experiments because of the wind and more natural environment although mixing had little effect on decreasing the evaporation rates. Experimental results with treated and untreated oil showed that components lighter than C_{12} evaporated from both slicks after three hours and after seventy-two hours all of the components up to C_{16} had disappeared. The effect various wind speeds had on evaporation rates of Kuwait crude were investigated by using a wind tunnel. These results show that approximately 75 percent of the total evaporation occurs within the first two hours and that evaporation essentially ceases after twenty four hours with a weight loss of 32.3 percent. These results are in substantive agreement with the results reported in the preceding paragraph. Thus, if dispersants are applied two hours after the spill, most of the lighter weight hydrocarbons would have evaporated; furthermore, when dispersants are applied to the outer edges of the spill, it is being applied generally to the portion of oil that has undergone the maximum amount of evaporation. Thus, the major portion of the more volatile and toxic fractions of the oil could be expected to be evaporated by the time dispersants would or could be applied in most situations.

Natural entrainment experiments were conducted in the wind/wave tank and in the rain drop experiment. Tests in the wind/wave exeriments described in Section 3 of this report were conducted with fresh water and sea water with Kuwait crude. It was found that the oil weathers much differently in the fresh water than in natural sea water. In fresh water, it rapidly forms slicklets which appear to be stable emulsions and very little oil gets into the water column. In the salt water tests much more oil entered the water column and increased with time, except at a higher frequency where after weathering for 24 hours, the concentration of oil in the water column showed a dramatic decrease. This is attributed to the formation of stable emulsions that had an affinity to the droplets which took them out of solution. The appearance of the oil in the higher wave frequency tests showed a stringiness as though it had been shredded or torn apart after 24 hours. This did not happen with the lower frequency waves during the same period where the concentration increased with time in all salt water tests. The effect of an increase in temperature is to increase the amount of oil getting into the water column. Doubling the quantity of oil in the slick did not change the percent concentration of oil in the water column. Therefore, the actual concentration almost doubled. In the ocean, currents would carry some of the oil from under the slick. Tests using the dispersant did not show sudden increase in concentration of the oil in the water column immediately after adding the dispersant as might be expected. The visual properties of the slick and the waves changed, but the oil did not disperse into the water column until it had weathered over eight hours after adding the dispersant. After twenty-two hours of weathering, practically all the oil entered the water column.

Entrainment of oil into the water column by rain was investigated and reported in Section 4.4 of this report. The results indicate that substantial oil can be incorporated into the water column by this process. Concentrations as high as 45 parts per million were observed in these experiments, however, the concentration of oil in the water column drops off when either subsurface circulation or the rain is terminated. Consequently, natural entrainment by rain, like other entrainment phenomena, requires subsurface circulation to maintain the droplets in suspension.

A number of analytical chemistry techniques were developed throughout the duration of this project. These are reported in Sections 7, 9 and 12.2. Infra-red analysis of the petroleum hydrocarbons extracted from the water column were analyzed quantitatively as well as qualitatively. Several solvent systems were investigated in an attempt to separate the oil from the dispersant prior to infra-red analysis. Thin Layer and Column Chromatography were also used with various solvent systems to effect the separation; however, even with this system, a complete separation of the oil from the dispersant could not be realized. Because of this and of the time required to perform this separation, it was decided that development of computer techniques to effect spectral separation of these two components was required. This technique is reported in Section 12.5.

A quantitative analytical infrared technique to determine the ratio of dispersant to oil was also developed and is reported in Section 12.2 of this report. It involves the ratio of absorbance of the mixture at a wave number of 3600 (cm^{-1}) which corresponds to the OH stretching. This represents a strong peak for most dispersants, while the peak for most oils occurs at a wave number of 2930 (CH stretching). Mixtures were prepared to establish calibration curves and a procedure was developed to determine the ratio of dispersant to oil in the mixture and the total amount of hydrocarbons present in the sample. In Section 8, a quantitative gas chromatograph method is described that determines the total peak area of Corexit 9527 in the water stock solutions. This area was converted to concentration of oil and substracted from the integrated total hydrocarbon in the oil-dispersant mixture. This gave ratios of oil to dispersants almost identical to those determined by the infra-red method mentioned above. A GC Mass Spectrum system was also used in portions of the analysis as reported in Section 7 of this report.

The chemistry of the treated and untreated oil slick was investigated rather extensively and is reported in Section 7 of this report. Some of these results were discussed in the preceding paragraphs on evaporation and entrainment. Most of the chemical analyses were conducted on tests run in the meso-scale tanks. These tests were run in the tanks under the following conditions (1) batch, with no mixing or forced circulation (2) batch with mixing provided by the wave maker and (3) with dilution (flow-through) and mixing. Salt water from Narragansett Bay was used as the test medium and the salt water temperature was maintained to within 1°F of the Bay temperature to eliminate any thermal stresses on marine organisms that were present. One series of tests were conducted to determine the effect of various modes of application of oil and dispersant to the seawater on the concentration of oil in the water column. It was found that the effectiveness of the dispersant in carrying the oil into the water column is proportional to the amount of contact of the dispersant with both the polar water fraction and the non-polar fraction of the oil/water system. The most intimate contact between these fractions was achieved when the dispersant was premixed with the oil. In all experiments, agitation of the water surface in the tanks also aided in mixing the oil/dispersant complex into the water column. Controls were used throughout the duration of these tests and remained within the hydrocarbon levels found in the Bay. In the dispersant treated tank, the highest concentrations were found generally in the top and middle layers after one hour, with a relative reduction in concentration after twenty-four hours (in some cases reduction to control levels). The level of hydrocarbons was determined more by the mode of application than by the amount of oil/dispersant added. In the untreated tank the oil concentration increased initially but often fell below control levels after twenty-four hours. The cause for this behavior is not fully understood but it is believed that the oil droplets suspended in the water column combine with the surface slick and do not get re-entrained.

Analysis of sediments in flow-through experiments had indicated no significant increase in concentrations of petroleum hydrocarbons over a three week period for either the treated or untreated surface slicks.

Microbiological studies were conducted throughout the program in order to determine whether the degradative capacity of the petroleum hydrocarbons and natural microorganisms were enhanced by the use of dispersants. It was determined that the Viable Plate Count (VPC) and Most Probable Number (MPN) methods were suitable for enumeration of marine heterotrophic bacteria and hydrocarbanoclastic bacteria. Use of these methods demonstrated that the percentage of oil degraders within the "total heterotropic population" increased with exposure time of the "total population" to oil and/or dispersant.

Oxygen depletion by the Modified Biological Oxygen Demand method is a valuable tool which provides a general picture of biological response to materials suspended in the water column. The procedure was used to demonstrate the biodegradable nature of Corexit 9527 and provide a rough index of degradation potential. This method confirmed VPC and chemistry data in the meso-scale experiments.

Oxygen depletion has certain limitations, the greatest being that it cannot be directly correlated with actual oil degradation rate or the rate of degradation of specific oil components. An alternate approach is chemical analysis by gas chromatography which has been used in this project. The use of this technique for water column samples, while quantitative for bulk oil, has certain limitations for component analysis. It is possible to demonstrate loss of classes of compounds by this method but is too expensive and time consuming for routine degradative rate determinations. The use of ^{14}C labeled hydrocarbons allows a fairly simple method for measuring mineralization (conversion of organic carbon to carbon dioxide by metabolism) as an index of biodegradation. Representative hydrocarbons provide an estimate for the rate at which the mixed natural population achieve mineralization of aliphatic and aromatic hydrocarbons. The mineralization rate studies demonstrate turnover rates ranging from approximately 20 to 90 mg of substrate per hour. These values compare with results by other investigations in similar systems.

A more accurate approach using ^{14}C methodology is to measure not only mineralization, but also the production of water soluble intermediates which carry the ^{14}C label and the amount of ^{14}C incorporated into cell biomass. The importance of this approach was apparent in one typical experiment as discussed in Section 8 of this report.

Studies by the VPC for the surface film, water column and sediment were performed at 13 and 4°C. The bacterial numbers increased in the surface film during day 1 and 2 then remained essentially constant throughout the 21 day experiment. We interpret this increase not as bacterial growth per se but rather the formation of the microlayer. The sediment bacterial population increased through a period of nine days in the control, dispersant and oil-dispersant trials but not in the oil tank. The numbers remained constant in the sediment of the oil-dispersant tanks following these nine days but declined in the control and dispersant tanks. It is believed that the hydrocarbon degrading bacteria are carried into the oil film in the oil treated tank, removing them from an active role at the oil water interface. This might be expected because the oil destroys the surface microlayer.

The water column studies at 4° and 13°C provide evidence for two different bacterial populations in the natural seawater which was at 1°C. The total heterotrophic population shifts somewhat but the most significant observation is a rapid increase in the number of hydrocarbanoclastic bacteria through day 7 followed by a decline to original numbers due, we conclude, to exhaustion of the nitrogen, phosphorus and iron centers of the seawater.

The studies showed a decline in colony diversity with time in the tank system suggesting enrichment for specific organisms which is supported by the studies on the ratio of hydrocarbanoclastic to heterotrophic bacteria. Population dominance is more significant than population size which is a fairly constant value.

The long term flow through experiment showed no significant correlation between the number of total heterotrophic bacteria and hydrocarbon concentration, but a significant correlation was found between total heterotrophic and total hydrocarbanoclastic bacteria which indicated selection for hydrocarbon-utilizing bacteria.

A negative relationship was found between hydrocarbon content and hexadecane or naphthalene mineralization rates, suggesting inhibition of mineralization at high hydrocarbon and/or dispersant values. However, there was a decrease in hydrocarbon turnover time in the oil and/or dispersant tanks. This decrease in the turnover time is more apparent for aliphatic hydrocarbons than for aromatic hydrocarbons.

The variation in mineralization rates is minimal ranging from 8.6 to 11.9 ng/hr for hexadecane and 8.3 to 19.6 ng/hr for naphthalene. Thus, in the determination of degradation time the most important function is hydrocarbon concentration.

Investigation of phosphate and nitrogen in the test systems reveal values which were always nutrient limiting for the amount of degradable carbon available.

It is our conclusion that hydrocarbon degradation potential in nutrient limited seawater is a relatively constant value independent of the presence or absence of oil in the water column. There is selection for hydrocarbanoclastic bacteria with time but their overall degradation activity as a mixed population is not significantly affected by the enrichment process. Preliminary evidence indicates that nutrient supplements (nitrogen, phosphorus and iron) do have a significant effect on the size of the seawater microbial population and yield a rather homogenous population of hydrocarbon utilizing bacteria in the presence of oil.

A brief discussion of nutrient seeding suggests this is not a viable approach to increased hydrocarbon degradation potential. The danger of increased pathogenicity in nutrient enriched oil-water systems is a real possibility which must be more fully investigated.

Natural microbial hydrocarbon degradative processes are active in the water column of dispersed or non-dispersed oil. These processes will eventually lead to the turnover of the biodegradable oil components. The rate at which oil degradation occurs is not materially enhanced by the dispersion process but dispersion of the oil into small micelles (1-2 m) suspended in the water column does make the oil more available to microbial action. Due to the physical inaccessibility of microorganisms to the bulk of the oil in a heavy slick, dispersion of the oil is an adjunct to the hydrocarbon degradative capacity of a mixed natural marine water column population.

This project has not shed much light on the affect of microbial populations on dispersed oil entrained into sediments or oil solubilized or suspended as sub-micron micelles in surface microlayers. Limited data from this project indicates that hydrocarbon degradative potentials in sediments and the surface microlayer may be significantly higher than degradative potentials in the water column.

An investigation into the effects of realistic concentrations of oil and oil-dispersant mixtures on marine life was conducted. The results are reported in Section 9 of this report. The investigation of short term exposure of bay scallops, Argopecten irradians, and two scallop predators, the oyster drill Urosalpinx cinera and the common starfish Asterias forbesi, to oil and oil-dispersant mixtures suggested that predator and prey have different lethal susceptibilities. Scallops were most sensitive to dispersant and dispersant mixed with oil, starfish were only sensitive to the dispersant while the oyster drill seemed unaffected even though all were exposed to dilutions of identically prepared stock solutions. Scallops were least susceptible during winter months and most susceptible at summer temperatures. Treatment had less effect on predators than on scallops at summer temperatures. Sublethal concentrations of dispersant and oil-dispersant mixtures diminished the behavioral ability of scallops to recognize drills and starfish. The degree of effect increased with temperature. Predator detection of prey at the same concentrations was more complex. The feeding response, or posturing reflex of starfish was significantly slowed by all treatments. In contrast, drills were unaffected in their recognition of scallop effluent in a choice chamber after treatment. The results indicate that scallop populations may suffer more than the direct impact of a pollutant which selectively affects scallops but not all of the scallop predators. The differential susceptibilities of the various species investigated in this study points out a problem biologists face when conducting and interpreting a bioassay. Because not all animals are affected by the same chemicals at the same concentrations and that animals have ecological relationships which should be considered, indicates that knowing the response of one species to a number of pollutants is not always sufficient for ecological assessment.

In light of the differential susceptibilities demonstrated in the simple three animal system investigated, the concept of an indicator species is difficult to defend. It would seem that because each organism can have its own array of chemical compound and concentration response, there is no logical reason to assume that one animal could possibly be used to accurately judge susceptibility arrays for other species.

In order to have conducted the above reported study, it was necessary to study the behavioral recognition of the scallop to its predators. It was necessary to develop a method for quantifying the scallop's response to prey. This resulted in defining a "clap index" which is a measure of the scallop's escape response. This study is reported in Section 9.2 of this report. Field and laboratory studies of the intensity of predation by the oyster drill on the bay scallops are reported in Section 9.3 of this report.

The investigation of community type responses discussed above suggested that sublethal concentrations of dispersants had adverse effects on scallop behavioral escape responses and starfish posturing reflexes. These results led to the construction of a simple community to determine what would happen if both predator and prey were dosed and placed together in large laboratory tanks. How many scallops would survive each treatment? Is it possible to detect changes in individual spacing with treatment? The purpose of the experiment was to determine the answer to these questions. The results of this study show that when both predator and prey were treated as a community, scallop survivorship was significantly reduced in the dispersant and oil-dispersant mixtures beyond that expected because of hydrocarbon treatment or starfish predation alone. Since scallop survivorship in the oil treated tank was not different from the control, the slowed ability of the starfish to respond to food did not appear to affect their ability to feed on scallops. The results of this experiment show that at concentrations far below the LD_{50}, dispersant treated scallops suffer greater than 50 percent mortality in the presence of starfish. Chemical analysis of the scallops at the end of this experiment showed that there was no significant increase of petroleum hydrocarbons in scallops as compared to the control. These results are not predicted by the classical bioassay methods. Community studies are rare to non-existent in bioassay work but could prove extremely useful in the prediction of ecological impacts by dispersants.

The validity of the results of any environmental research program rests on its ability to be applied to the real environment. This program is no exception; consequently, in the formative stages, it was decided to respond to spills of opportunity to determine the validity of the bench scale and meso-scale tests. This portion of the program has proved to be very beneficial, and has validated a number of the results that were obtained throughout the various phases of the program. The team responded to three spills of opportunity.

The first of these spills was the Argo Merchant in 1976, the largest recorded spill in U.S. history. This first spill of opportunity served as a proving ground to field test the techniques developed in the laboratory. A portion of this work was reported in the Interim report of April 1977, and in a host of other places, included the proceedings of the Argo Merchant Symposium held at the University of Rhode Island in January 1978.

The second spill of opportunity occurred late in January 1977 in the ice-choked Buzzards Bay at the entrance to the Cape Cod Canal. This spill of No. 2 fuel oil, the result of a grounding of a barge, gave us another opportunity to test our developments under a series of circumstances quite different from those of the Argo Merchant. The material spilled, a No. 2 fuel as compared to a No. 6 for the Argo Merchant, and extreme icing posed many new problems to be solved. Sampling under these conditions more resembled a response to a spill in the Arctic than what would normally be expected to occur in the North Atlantic. Both of these spills served to confirm the experimental results that were being obtained in the laboratory. Very early in the feasibility study, attempts were made to mimic a spill in a natural environment. Under the simulated natural environment tests, it was found that very little of the oil was getting into the water column, far less than is normally used for bioassay and LD_{50} type tests. These results were also confirmed in the field by other investigators. The Buzzards Bay spill also provided air, surface, and water column samples at the spill site. A sample of oil was obtained from the barge and exposed in the laboratory under simulated conditions. The resulting chromatograms of these laboratory tests were almost identical to those found in the field. To our knowledge, this was the first time that a complete set of air, surface, and water column samples taken in the field were duplicated in the laboratory. Furthermore, it confirmed that the lighter fractions, i.e., C_{10}- C_{12} and below, enter the atmos- phere in the field. This leads one to question the validity of many toxicity tests where these components were not allowed to evaporate and were forced into the water column. This work has been continued in the laboratory and the meso-scale tanks, with and without the use of dispersants, during this second year of the contract. This work confirms the validity of the approach that was instituted in the early phases of this project. The major result of this additional work shows that the effect of the use of dispersants is to delay the evaporation of the lighter components by as much as 24 hours in the laboratory; however, they eventually evaporate. These results are essentially duplicated in the meso-scale tests; however, on a much more compressed time scale. This compression of the time scale in the meso-scale tests, which more closely approximates the field, is very significant. Processes that require 24 hours to occur in the laboratory occur in approximately two hours in the meso-scale tanks. Evaporation is enhanced in the meso-scale tests because of their exposure to a more natural wind and atmospheric environment.

Chemical analysis of the water column in these tests also shows some interesting results. Oil concentrations in the water column of the untreated tanks never exceeded 0.8 ppm, and very rapidly would return to the control values. The general trend when dispersants are used is that the oil concentration approaches the control value after 72 hours at most levels in the tank. The chromatograms of these water column samples also support the evaporation results mentioned above, which show that very little of the lighter fractions (below C_{12} - C_{14}) remain in the water column.

The third spill of opportunity to which this team responded was the September 21, 1978 West Hackberry, Louisiana, incident.

During the recent West Hackberry #6 cavern decompression accident, an estimated 72,000 barrels of oil were released. Of this amount, an estimated 52,000 barrels of oil were recovered, and an estimated 20,000 barrels were burned or were unrecoverable from the diked area.

The University of Rhode Island (URI) project relating to the treatment of oil spills contains a task involving response to "spills of opportunity." Having participated in the Buzzards Bay and Argo Merchant incidents, the URI project team was easily assembled and rushed to the scene.

Upon arrival in West Hackberry, they were joined by Department of Energy (DOE) personnel and representatives from Dames & Moore (Houston Office) and the University of New Orleans. This incident presented an opportunity to put into practice some of the "contingency plans" developed by these groups.

The Department of Energy (DOE) organized the assemblage into an Environmental Assessment Team whose objectives are to:

- determine the geographical area covered by the DOE effluent
- assess the environmental impact caused by the DOE effluent

To meet these objectives, an Environmental Assessment Plan was drafted and presented to the Regional Response Team (RRT) which had convened in West Hackberry. The RRT reviewed and accepted the plan.

Having established its procedures and sampling requirements, the team collected more than 500 scientific samples. The sampling was conducted in affected as well as unaffected areas of water, marsh, and terrain. The samples were appropriately preserved, indexed, catalogued, and rank ordered into priority categories. The high priority samples were analyzed for the presence of oil, generally, and DOE oil, specifically.

Based upon the results of these analyses the team returned to West Hackberry at approximately 3,6, and 12 months after the incident. The re-visits and selected re-sampling will assist in documenting the overall affect of the incident. The results of this investigation are reported in a separate report.

As part of the project for assessing the environmental impact of treated versus untreated oil spills, a fates model was developed which tracks the surface and subsurface oil. The approach used to spread, drift and evaporate the surface slick is similar to that in most other oil spill models. The subsurface technique, however, makes use of a modified particle-in-cell method which diffuses and advects individual oil-dispersant droplets representative of a large number of similar droplets. This scheme predicts the time dependent oil concentration distribution in the water column which can then be employed as impact to a fisheries population model to be discussed later. In addition to determining the fate of the untreated spill, the model also allows for chemical treatment and/or mechanical clean-up of the spilled oil. With this capability, the effectiveness of different oil spill control and removal strategies could be quantified.

The model was applied to simulate a 34,840 metric ton spill of a No. 2 type oil on Georges Bank. The concentration of oil in the water column and the surface slick trajectory were predicted as a function of time for chemically treated spills occurring in April and December. In each of these cases, the impact on the cod fishery was determined.

The important distinguishing feature between a wind driven surface slick and a chemically treated slick is that in the treated slick the oil enters the water column directly beneath the slick and is subject solely to local advective currents and diffusion. The wind driven surface slick can be beached in the intertidal zones, estuaries and marshes which are highly productive, while the treated oil remains in the water column. Various cases were studied in this modeling behavior and concentration profiles were calculated over a period of a thirty day simulation of a 34,840 metric ton oil spill at a time when the cod were at their spawning peak. Experimentally determined subsurface currents were used, as well as, average wind data collected for the area for the time of year the spill was assumed to occur. The analysis shows the divergence of the trajectories of the treated and untreated spills. The results of these simulations are presented in Section 5 of this report.

A fisheries-oil spill interaction model was developed to estimate first order effects of the impact of a treated versus an untreated oil spill on the commercial fish catch over ensuing years. The primary effect is assumed to occur through egg and larval mortality. The biological model formulated contains as subcomponents; a population model of the fishery, a model for advection and diffusion of oil, and fish larvae, and is coupled to the oil behavior and fates model described previously.

A two day 34,840 metric ton oil spill occurring on December 15 was simulated and a sensitivity analysis using the fisheries model was conducted. Impact predictions were conducted under three theoretically acceptable piecewise-smooth larval mortality curves, three threshold toxicity values of 1,000 and 50,000 parts per billion (ppb) and three application scenarios in which 0%, 50% and 100% of the oil is chemically treated.

Decreasing impact is associated with increasing larval resistance to oil toxicity (increasing threshold values), with decreasing entrainment and with increasing mortality modes (three different natural mortality modes were used). For a given treatment scenario and toxicity threshold, although the same number of eggs and larvae are lost from the system due to the spill, the effect of different natural mortality modes can show quite different results.

One of the most significant findings was that the natural mortality regime for the population was more important than either threshold toxicity values or the percent of oil dispersed in the water column. The importance of determining appropriate mortality regimes and threshold values is manifested from the results. The results indicate that if an oil spill was driven towards the islands of Nantucket and Martha's Vineyard rather than out to sea, dispersants would be used with little cost to the fishery, using a toxicity threshold as low as 100 ppb. The results do show, however, that the use of dispersants have a greater effect on the cod than the untreated case. This is not surprising since making the oil more available to local marine biota is expected to increase mortality. The principal decision for using dispersants has to be made on the basis of whether or not their use will prevent more significant damage if the spill is allowed to come ashore and into highly productive intertidal zones and marshland where the oil can be expected to remain over an extended period of time. The other consideration is the time response of the ecosystem. Will the ecosystem recover more quickly to its prespill state than if the oil is left untreated?

The magnitude of the impacts estimated in this study range from 0% to 10% of the annual maximum sustainable yield of approximately 25,000 metric tons or up to $2.5 million in reduced income to the fishing fleet. Simulation of a 30 day oil well blowout shows impacts four times as large, so that the specific scenario is of considerable importance.

Another significant result of this simulated study is that even in the worst case, the expected mortality due to the spill is well within the limits of the observed natural variability of adult cod. This sheds some doubt on the use of an abundance of a particular species as a measure of the impact of a spill.

In Table I the results of this project are summarized. Inspection of this Table reveals that little evidence was found to support some common beliefs of the effects of the use of dispersants. For example, dispersants were expected to drive the lighter, more toxic components of the oil into the water column. In this study, it was found that this effect was insignificant. It was also expected that the use of dispersants would enhance biodegradation and it was found that the hydrocarbon degradation potential in nutrient limited seawater is a relatively constant value, independent of the presence or absence of oil in the water column. Expected results were that the use of dispersants increases mortality in the immediate vicinity of the spill but could mitigate a greater impact had it been allowed to reach the rich intertidal communities.

In summary, it appears viable to use dispersants as determined on a case by case basis. The case for using dispersants has to be based on whether or not their use will mitigate the environmental impact of the spill. In the case of an open ocean spill that is being driven into a rich inter-tidal community, the use of dispersants could greatly reduce the environmental impact. Even in the highly productive George's Bank area at the height of the cod spawning season, the impact of the use of dispersants is well within the limits of natural variability when the threshold toxicity level is assumed to be as low as 100 ppb, a level which is often found in the open ocean. Thus, it appears that dispersants can and should be used when it is evident that their use will mitigate the impact of the spill. Their use in areas where there is poor circulation and therefore little possibility of rapid dilution is more questionable and should be a subject of future studies.

TABLE I.

Summary of the Characteristics of Treated versus Untreated Oil Spill.

Untreated Spill	Treated Spill
1) The 'drifting' and spreading oil slick continually moves over new water.	1) Since treating agents disperse oil into the water column, the dispersed oil moves with the water column as a direct result of currents and diffusion.
2) Microbial Utilization.	2) Hydrocarbon degradation potential in nutrient limited seawater is a relatively constant value independent of the presence or absence of oil in the water column. There is a selection for hydrocarbanoclastic bacteria with time but their overall degradative activity as a mixed population is not significantly affected by the enrichment process.
3) Suspended sediment transport and sediment contamination.	3) There was no evidence for increased sustained sediment contamination when dispersants were used.
4) Evaporation.	4) Treating agents caused slight delays in evaporation when compared with the untreated spill; however, the difference was not significant.
5) Dissolution and emulsification.	5) The use of dispersants does increase the amount of oil in the water column.
6) Toxicity and Subacute toxicity.	6) The use of dispersants increases the availability of oil to marine organisms and results in higher mortality in the immediate vicinity of the spill. Predator-prey relationships can be altered in such a way that mortality can be much greater than expected from acute toxicity considerations.
7) Impact on selected species.	7) A sensitivity analysis of a 34,840 metric ton spill at the height of spawning season estimated that the maximum expected impact would be 10% of the annual fish catch, well within the expected natural variability of this particular species.

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2. "Assessment of Treated Versus Untreated Oil Spills (Interim Report)" University of Rhode Island, June 1978, HCP/W4047-02, NTIS.

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4. "Effect of a Chemical Dispersant on Microbial Utilization of Petroleum," R.W. Traxler and L. Bhattacharya, ibid., University of Rhode Island.

5. "Chemical Analysis of Dispersed Oil in the Water Column," M. Ahmadjian and P.F. Lynch, ibid., University of Rhode Island.

6. "Drop Size Distributions in a Treated Oil-Water System," W. Jasper, T.J. Kim, M.P. Wilson, Jr., ibid., University of Rhode Island.

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1.0 Introduction, Background, and Program Description

Mason P. Wilson, Jr.

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Introduction, Background
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1. BACKGROUND

In 1976, the U.S. Office of Technology Assessment presented an interim report on the coastal effects of offshore oil and gas development (1). One of the factors stated in this report of concern to coastal states, involves basic uncertainties about environmental and economic impacts. Studies estimate that the total probable oil spills from offshore continental shelf operations ranges from a low of 85,000 barrels to a high of one million barrels and that one out of ten spills from a drilling or production platform would reach a beach in New Jersey or Delaware. Present United States policy for combating oil spills is concentrated on physical containment with mechanical or sorbent removal techniques. When these means fail, the uncontrolled, untreated spill can cause considerable damage to the marine environment, especially to birds, saltwater marshes and beaches, where marine life is most plentiful, and where the juvenile forms of many commercial fish have their origin. It is these juvenile forms that appear most susceptible to oil pollution. The use of treating agents for final clean-up and for preventing the spills from reaching the shore and mitigating the environmental impact, when mechanical means fail, has been minimal because of the lack of information concerning the use of these agents and their affect on the environment. Since the Torrey Canyon spill in 1969 off the coast of England, where dispersant use produced disastrous results, there has been considerable development of treating agents that are far less toxic than those avilable at that time. Furthermore, it has since been determined that it was not the dispersants that caused the extensive damage in this spill, but rather the toxic solvents in which the dispersants were dissolved. New dispersants either use non-toxic solvents or sea water for their solvent base.

The debate over whether to use dispersants to treat oil spills has been long and controversial. The truth about dispersants, their use and effectiveness has often been obscured by undocumented and, at times, emotional opinions. Certainly, the excessive use and unfortunate experience with dispersants on the Torrey Canyon spill serves to form the basis for most of the criticism. Additional criticism concerning the use of dispersants is grounded on the belief that even if the dispersants themselves were not toxic, the use of these agents make the oil more toxic by its increased dispersion within the environment (2). This viewpoint, however, is applicable only to the immediate vicinity of the spill. The principal question to be answered in the use of a dispersant, is, "will its use cause less environmental damage, even though there is increased toxicity in the vicinity of the spill, than the untreated spill?" Furthermore, will the environment recover more quickly when dispersants are used than the long term effects of an untreated spill such as reported by Blumer (3). These are extremely difficult questions to answer. However, one use of dispersants is based on the premise that if treated at sea, most of the damage in the inter-tidal zone and salt water marshes where there is a concentration of marine life, could be mitigated. It is well known that marine life is concentrated in three major areas: (a) the surface, (b) the benthic zone, and (c) the inter-tidal zone. It is these three major areas that the uncontained, poorly dispersed oil spill is concentrated (4), whereas, the majority of oil in the chemically treated spill is concentrated in the water column where it is more easily diluted by tidal flushes and where there is less concentration of marine life. The affect of oil on the marine environment has long been a concern to the environmentalists and oil companies alike. The severity of biological damage depends on many factors, some of the major ones are: the type of oil spilled, the dose of oil, the physiography of the area, weather conditions, type of local biota, season, previous exposure of the area to oil and other pollutants and the treatment of the spill. Three conditions are especially critical, and some researchers claim that all three must exist simultaneously for a spill to have significant environmental damage. The conditions are:

(1) The volume of oil spilled must be large with respect to the body of water being impacted.

(2) The oil should be refined.

(3) Storms or heavy surf must cause the spilled oil to be churned into bottom sediments (5).

Whether or not these conditions occur, some part of marine life is likely to be affected by an oil spill. Studies from more than one hundred major oil spills over a twelve year period indicate that birds are the type of marine life most often affected (6).

The use of dispersants to mitigate the impact of oil spills have been used almost exclusively in the United Kingdom where it appears to have had minimal impact on the environment. Caution should be exercised in transferring the United Kingdom results to the use of dispersants along the United States coastline. Britain has very high tides, especially in the Milford Haven area in Wales where dispersants have been extensively used. The tides in this area range from twenty-four to twenty-eight feet. An example of the use of dispersants to prevent oil from reaching the beach and inter-tidal zone is their use in the Christos Bitos incident (7).

The variability of sea conditions, as well as the size of a spill are two of the major factors which often inhibit the containment and recovery of spilt oil. If about 2000 barrels (84,000 gallons) of Bunker C oil were spilt on a calm sea on a windless day, and if no action is taken for about three hours, the circumference of the spill would be approximately 6300 feet. Consequently, this size of a spill would make deployment of sufficient oil booms a rather formidable task. Their use, in many cases, has not prevented oil from reaching biologically sensitive areas.

1.2 DISPERSANTS

Dispersants specifically designed for use on oil spills are relatively new and most of these have been developed since the time of the Torrey Canyon in 1969. They are found under various names - dispersants, emulsifiers, detergents and degreasers, however, those specifically designed to combat oil spills are normally referred to as dispersants. Dispersants are compounds which emulsify, disperse or solubilize oil into the water column or act to further the spreading of oil slicks to facilitate dispersal of oil into the water column. They consist of three primary components: surfactants, solvents and stabilizers. Surfactants decrease the interfacial tension between the oil and water, thus allowing the oil to more easily spread and be dispersed into small globules. Surfactant molecules are composed of hydrophilic (water compatible) and lipophilic (oil compatible) groups. They can be divided as to being either anionic, cationic or non-ionic. The anionic surfactants compose the largest group in use since the anion is quite surface active. Usually these dispersants are alkalai salts of sulphates or sulphonates. Cationic surfactants have a low surface activity as do the non-ionic ones. However, the non-ionic ones have been found to be the most effective for dispersants for salt water oil spills, being composed of fatty alcohol condensates, ethylene oxide being the most common (7).

The second primary component of a dispersant, the solvent, comprises the bulk of the product. The solvents enable the active agent (surfactant) to mix and penetrate into the oil to form an emulsion. The solvents range in base from petroleum to water, petroleum solvents being the most toxic, but the ones which dissipate most rapidly in a water environment.

A certain amount of mechanical mixing energy is generally required to get the dispersant oil mixture into the water column. Early in their use, helicopters, tugboats or other large powerful ships were used in an effort to cause dispersion. In the United Kingdom, the use of batter boards towed behind boats have proved effective. Obviously in high sea conditions, the mixing energy is no problem. Under such high sea conditions, dispersants have been found to be very effective. There are also self-mixing dispersants available. A self-mix dispersant utilizes the diffusion energy of the surfactant, acting at the oil-water interface.

1.3 PROGRAM INTRODUCTION

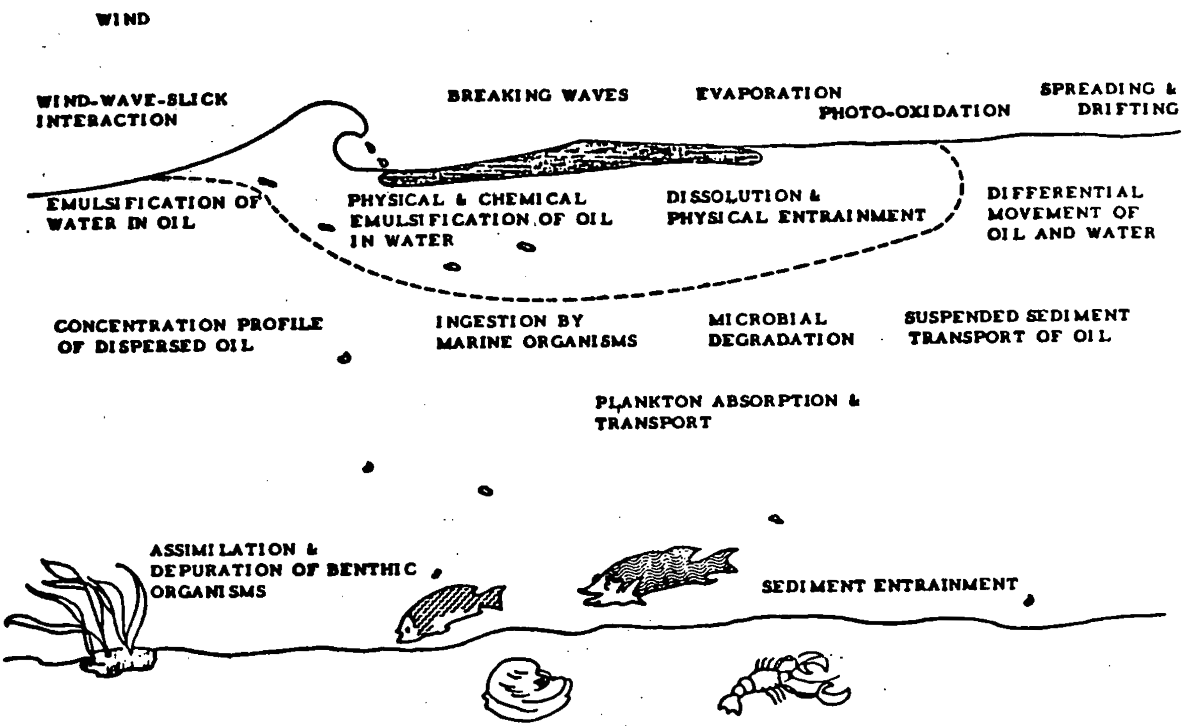
The results of this program describe an approach to estimate the environmental impact of an untreated oil spill versus a spill treated with dispersant. It is holistic, in that it combines the physical, chemical, microbial and macro-fauna responses to a spill. The results reported herein represent the findings of a four year effort that integrates mathematical, laboratory, meso-scale in-situ experiments and analyses. The in-situ analyses came as a result of responding to three spills of opportunity. These are the Argo Merchant which grounded on the Nantucket Shoals in December 1976, the Bouchard spill that occurred near the entrance of the Cape Cod Canal in ice-choked Buzzard's Bay in late January 1977 and the fire/oil spill that occurred at the Strategic Petroleum Reserve facility at West Hackberry, Louisiana on September 21, 1978. The investigation of this latter incident was supported under separate contract with the Department of Energy and a final report is being issued (8).

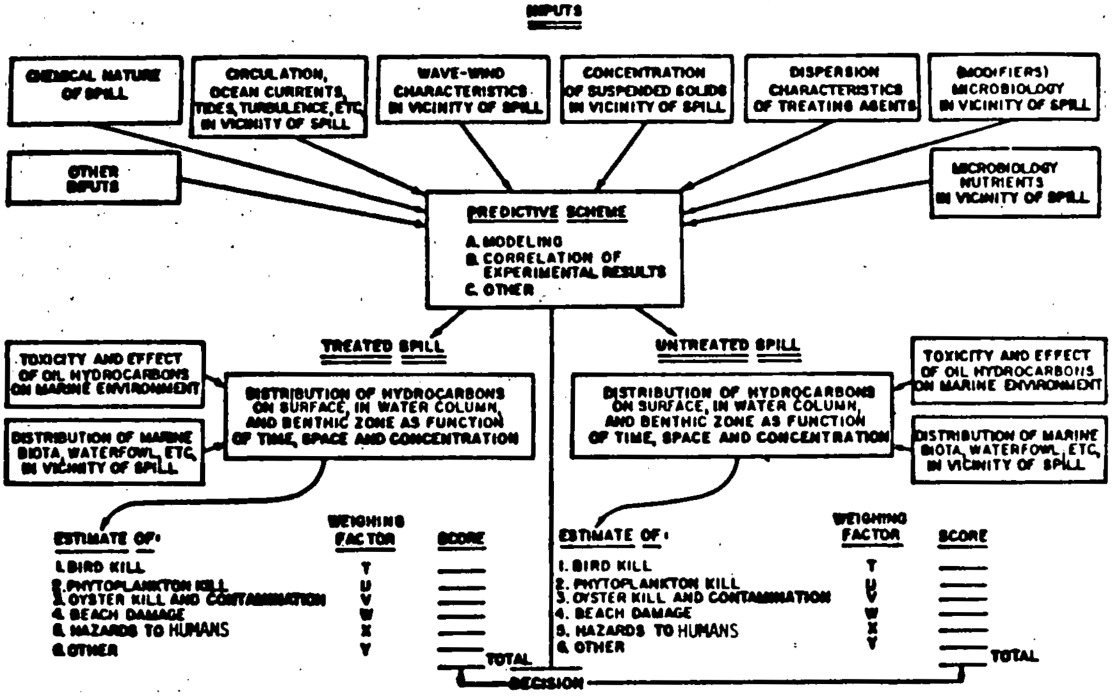
Many models and investigations have been conducted in the past concerning the environmental impact of spills, but none presently available encompasses the breadth and depth required to make a decision as to whether or not dispersants should be used. This program has been designed to provide some guidance in this direction. In spite of this, there are still many unanswered questions concerning the impact of an oil spill on the environment. The fate and effects of an oil spill, whether treated with dispersants or not, depends on many complicated factors. First, the chemical composition of any oil is extremely complicated and they are composed of many different aromatic, aliphatic and alicyclic compounds (9). Even among the crude oils, the physical properties and chemical composition can vary greatly, and consequently, any refining of these crudes produces even more diverse properties. Since there is such diversity, it is difficult if not impossible to make anything but general statements concerning the effects of oils on specific marine biota. Secondly, because of our lack of understanding of the environment, specifically cause and effect relationships, predator-prey relationships, etc., one can only make some isolated estimates of impacts on specific species. Even this is difficult because the organisms in a real spill are exposed to time-varying concentrations and varying chemical composition caused by natural weathering of the oil which includes evaporation, dissolution, etc., while available toxicity data seldom include these effects.

The approach in this program has been to attempt to mimic the natural weathering and entrainment processes and to expose the organisms to varying concentrations from lethal to minimal sublethal dosages and to study predator-prey relationships under these conditions.

1.4 PROGRAM DESCRIPTION

As mentioned in the above paragraphs, the problem of assessing the impact of an oil spill on the marine environment is a formidable task at best, especially if the objective is to assess both short and long range impacts. Damage assessment such as clean-up costs, losses to business, etc., are much easier to assess after the fact and certainly much more tangible than those associated with losses in fish catch, etc. In the latter type of assessment, a holistic and implicit approach is mandatory. This type of approach requires a determination of the temporal and spatial history of the spill, coupled with the physical, chemical and biological processes that affect the nature of the spill as shown in Figure 1.1. Some of the input that must be considered in this type approach is shown in Figure 1.2 which is a simple version of the decision making process to treat or not to treat a spill. The most important aspect of this procedure is the realization of the strong interdependency of all of the processes. Microbial utilization is both a function of the chemistry and spatial distribution of the oil and other nutrients, whereas the spatial and temporal distribution is a function of wind wave activity, currents etc., and the physical and chemical properties of the oil. The impact of a spill on marine organisms is also a function of the chemical, temporal and spatial distribution of the oil. The traditional bioassay work based on LC_{50} on 48, 72 or 96 hour tests are of limited value because the tests are static and seldom are these organisms exposed to constant concentrations in the real environment with the exception of some spills in marshes and beaches. Some knowledge of the lethal concentrations as a function of time, together with the temporal and spatial distributions of both the oil and organisms, permits a first order assessment of the number of organisms destroyed as a direct result of the spill. Of secondary importance is the cumulative effect of varying concentrations on the organisms with time as well as sub-acute effects on


WIND
WIND-WAVE-SLICK INTERACTION
BREAKING WAVES
EVAPORATION
PHOTO-OXIDATION
SPREADING & DRIFTING
EMULSIFICATION OF WATER IN OIL
PHYSICAL & CHEMICAL EMULSIFICATION OF OIL IN WATER
DISSOLUTION & PHYSICAL ENTRAINMENT
DIFFERENTIAL MOVEMENT OF OIL AND WATER
CONCENTRATION PROFILE OF DISPERSED OIL
INGESTION BY MARINE ORGANISMS
MICROBIAL DEGRADATION
SUSPENDED SEDIMENT TRANSPORT OF OIL
PLANKTON ABSORPTION & TRANSPORT
ASSIMILATION & DEPURATION OF BENTHIC ORGANISMS
SEDIMENT ENTRAINMENT


INPUTS
CHEMICAL NATURE OF SPILL
CIRCULATION, OCEAN CURRENTS, TIDES, TURBULENCE, ETC. IN VICINITY OF SPILL
WAVE-WIND CHARACTERISTICS IN VICINITY OF SPILL
CONCENTRATION OF SUSPENDED SOLIDS IN VICINITY OF SPILL
DISPERSION CHARACTERISTICS OF TREATING AGENTS
(MODIFIERS) MICROBIOLOGY IN VICINITY OF SPILL
OTHER INPUTS
MICROBIOLOGY NUTRIENTS IN VICINITY OF SPILL
PREDICTIVE SCHEME
A. MODELING
B. CORRELATION OF EXPERIMENTAL RESULTS
C. OTHER
TREATED SPILL
UNTREATED SPILL
TOXICITY AND EFFECT OF OIL HYDROCARBONS ON MARINE ENVIRONMENT
DISTRIBUTION OF MARINE BIOTA, WATERFOWL, ETC. IN VICINITY OF SPILL
DISTRIBUTION OF HYDROCARBONS ON SURFACE, IN WATER COLUMN, AND BENTHIC ZONE AS FUNCTION OF TIME, SPACE AND CONCENTRATION
TOXICITY AND EFFECT OF OIL HYDROCARBONS ON MARINE ENVIRONMENT
DISTRIBUTION OF MARINE BIOTA, WATERFOWL, ETC. IN VICINITY OF SPILL
DISTRIBUTION OF HYDROCARBONS ON SURFACE, IN WATER COLUMN, AND BENTHIC ZONE AS FUNCTION OF TIME, SPACE AND CONCENTRATION
ESTIMATE OF:
WEIGHING FACTOR
SCORE
1. BIRD KILL
2. PHYTOPLANKTON KILL
3. OYSTER KILL AND CONTAMINATION
4. BEACH DAMAGE
5. HAZARDS TO HUMANS
6. OTHER
T
U
V
W
X
Y
TOTAL
ESTIMATE OF:
WEIGHING FACTOR
SCORE
1. BIRD KILL
2. PHYTOPLANKTON KILL
3. OYSTER KILL AND CONTAMINATION
4. BEACH DAMAGE
5. HAZARDS TO HUMANS
6. OTHER
T
U
V
W
X
Y
TOTAL
DECISION

behavior and reproduction.

The program was divided into three major but integrated groups, one to study entrainment and evaporation processes, a biological group including microbiology to study the effects of treated oil versus untreated oil on selected marine organisms and oil degradation rates and a third group to provide the chemical analysis. Laboratory type tests were conducted by each group to study some of the fundamental processes, however, all groups participated in the combined tests conducted in the meso-scale facilities as described in the next section. Spills of opportunity provided experimental data to correlate with meso-tank results.

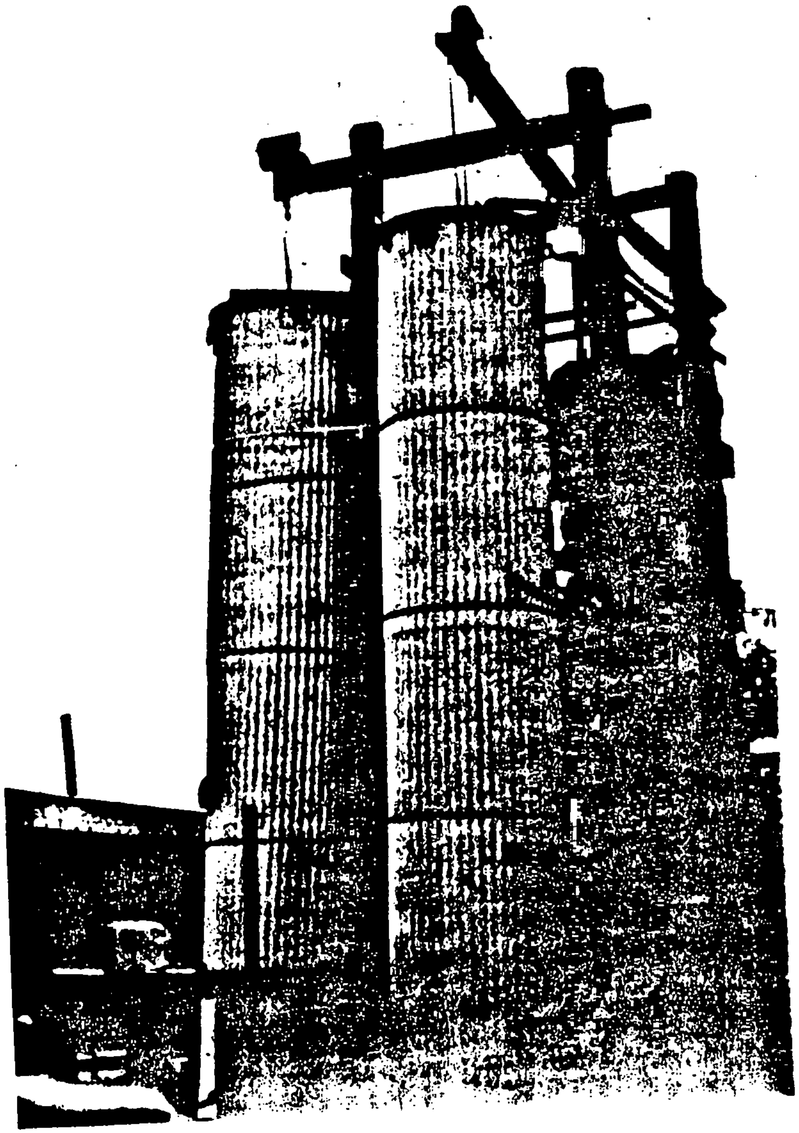
1.4.1 MESO-SCALE TEST FACILITIES

The meso-scale test facility is composed of three twenty-foot high by three feet in diameter fiber glass tanks as shown in Figure 1.3. A schematic of the tank is shown in Figure 1.4. The facility is located adjacent to Narragansett Bay. Salt water is pumped either into the top or bottom in batch operations or in a continuous flow mode. The tanks are wrapped with a coil for fresh water closed cycle cooling and insulated by three inches of polyurethane foam. This type of cooling was chosen because it was capable of providing a uniform temperature distribution of the tank, void of any cold or hot spots. The heat sink for the closed cycle cooling system is a coil submerged in Narragansett Bay. This system is capable of maintaining the water in the tanks to within 1°F of the Bay temperature. Thus, temperature stresses on marine organisms in the tank were minimized. The cooling coils were made in three sections to allow them to be operated in a series or parallel mode. Using this approach, virtually any temperature distribution could be achieved from a stratified layer to a uniform distribution.

Mixing in the tank was provided by submerged oscillating annular disks as shown in Figure 1.4. The amplitude as well as the frequency is adjustable, making it possible to obtain a wide variety of mixing conditions in the tank. Generally it was adjusted so as to provide mixing in only the upper ten feet of the tank. This roughly corresponds to the subsurface circulation caused by an ocean wave having a wavelength of thirty feet.

Bottom dwellers such as scallops were lowered in a basket to prescribed depths before the surface was oiled. To prevent contamination of the scallops when retrieving the basket, a cylindrical section of teflon approximately a foot in height was installed at the water/oil - air interface. When samples were to be retrieved, the teflon section was collapsed across the surface thereby sweeping the oil to one side of the tank, leaving a clean surface through which the samples could be collected.

Water column samples were collected from taps located every twenty-four inches along the length of the tank.



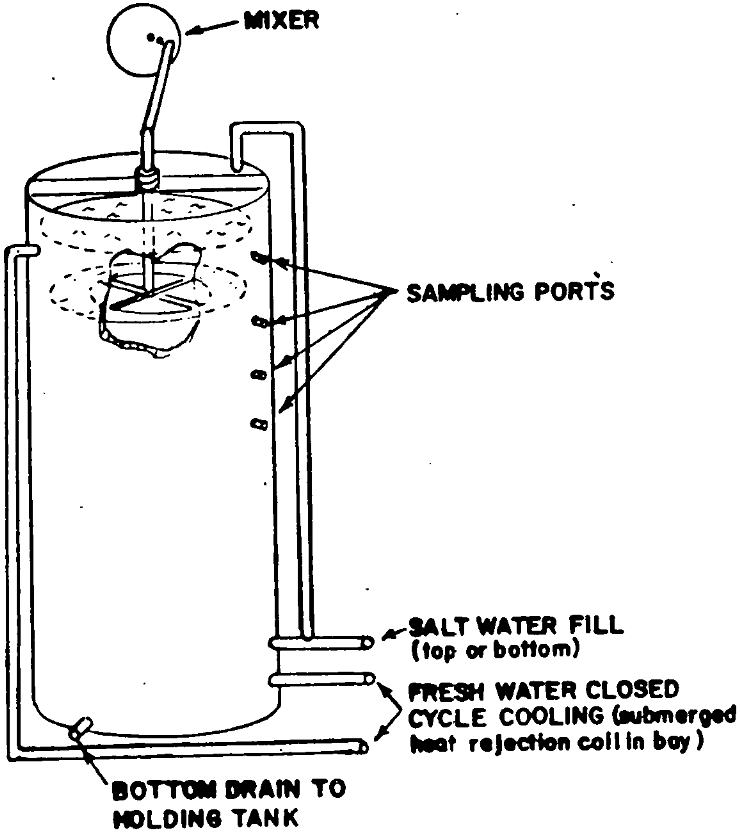


FIGURE 1.4: MESO-SCALE TANKS

1.4.2 ENTRAINMENT, DISSOLUTION AND EVAPORATION STUDIES

One of the primary goals of the program was to determine the temporal and spatial distribution of the treated and untreated oil, hence a comparison of the toxicity and impact under both sets of conditions. Much work has been done in the drifting and spreading of the oil but only limited amount of predictive information is available for entrainment of the oil into the water column and sediment.

In an attempt to gain a better understanding of the combined evaporation, dissolution and overall entrainment process, a series of experiments was designed. These ranged from basic measurements of interfacial tension to combined wind/wave experiments. These experiments and their role in the overall program are described as follows and the section of the report in which they are covered is identified.

INTERFACIAL TENSION

Since entrainment is primarily caused by work done against interfacial tension, a knowledge of the effect that the dispersant has in this property is fundamental to any of the entrainment processes. A series of different types of approaches to measure this property was considered.

The capillary-height method is probably the simplest method available. When a capillary is inserted below the interface of a two liquid system, due to the excess free energy of the interface, the liquid in the lower layer rises to a higher level within the capillary. But for the crude oil water system under study, this method could not be used as the darker upper layer of the crude prevents observations of the capillary height.

In the drop weight method, drops are allowed to form at the top of a capillary immersed in another liquid. From a knowledge of the dimensions of the drop and its weight, it is possible to calculate the interfacial tension. Since drops have to be formed at a finite site, this method is not applicable in systems where a surfactant is present.

The ring method consists of a platinum ring which is pulled up from the interface of the liquids whose interfacial tension is to be measured. The force that is necessary is measured by a torsion balance. Because of problems encountered in obtaining repeatable results in using this method as well as the reasons stated above in the drop weight method, it was decided to investigate other methods.

The bubble pressure method measures the pressure difference across a bubble or drop in another liquid which is proportional to the interfacial tension. Since this is a dynamic method and is difficult to obtain accurate results, it was decided to use the following method.

The pendant drop method is the one chosen to measure the interfacial tension. It consists of making a drop form at the tip of a capillary tube and "letting" it hang in the second fluid. If the density difference is not appropriate, the drop can be made to rise up from the tip of the capillary rather than let it hang. The shape of the drop reflects a balance between interfacial tension and the gravitational forces and can be used to measure the interfacial tension. The static nature of the method makes it suitable for use where diffusional effects are involved. This method and the results are fully described in Section 12.1.2 of this report.

DROP SIZE DISTRIBUTION, COALESCENCE AND STABILITY OF THE OIL-IN-WATER EMULSION.

Of primary concern is the effect that dispersants have on the formation of stable oil-in-water emulsions and the drop size distribution. The drop size distribution, although not a direct measure of stability, is indicative of the type of emulsion formed and can be used in interpreting the results of other experiments. To measure the mixing energy and drop size distribution, a standard impeller technique was chosen. Total concentration of hydrocarbons in the water column was taken by extracting the water samples with carbon tetrachloride and measured by infra-red spectroscopy. The drop size distribution was measured photographically. Stability and coalescence was determined by measuring the concentration of oil in the water column as a function of time following formation of the emulsion. The complete description of this process and the results are given in Section 2 of this report. Stability of the emulsion was also investigated in Sections 3 and 4 of this report by measuring its settling or creaming rate.

ENTRAINMENT PROCESSES: THE WIND/WAVE EXPERIMENT, THE RAINDROP EXPERIMENT, EVAPORATION AND STABILITY

The real world entrainment process of oil and treated-oil slicks is extremely complicated, and is probably one of the most least understood of the processes that have a major effect on the fate of an oil spill. The complex wind/wave interaction, wave dynamics and currents in the ocean will effect the rate of entrainment and stability of the oil-in-water-emulsion. The addition of a dispersant enhances entrainment processes, but also relies either on mechanical or chemical forces or a combination of both to incorporate the oil into the water column. Furthermore, addition of a dispersant increases the oil slicks spreading properties, thus making the slick thinner and more easily dispersed. For the most part, this project has been concerned with oil and water emulsions and has not concentrated efforts on the formation of water-in-oil emulsions such as "chocolate mousse."

The stability of the oil-in-water suspension (or emulsion) depends on many factors such as the degree of subsurface mixing, the concentration of the oil, the size distribution of the oil droplets, the concentration of plankton, the concentration and type of suspended sediments, etc. Mousse, on the other hand, is a water-in-oil suspension (emulsion) and is generally thought to be much more stable than oil-in-water suspensions. To understand the differences as well as the similarities of these processes, they are discussed in some detail in the following paragraphs.

The important factor that links oil-in-water and water-in-oil emulsions is the type of emulsifying agent that may be found in sea water and naturally occurring in the crude oil, as compared to manufactured oil emulsifiers. The physics of formation of oil-in-water emulsion is the same as the formation of water-in-oil emulsions. Whether one or the other is formed depends on the type of emulsifying agent present during the process. It is well known that soaps of univalent metals give rise to oil-in-water emulsions, while multivalent metals favor water-in-oil emulsions (10). Whether or not this is the case with respect to crude oil in sea water is yet to be proven. However, Kuwait crude which is well known to easily form "chocolate mousse" also has a higher concentration of organic-multivalent hydrocarbons than most other crudes. As previously stated, the water-in-oil emulsion was not studied in this program, however it was observed in some of the experiments, especially the wind/wave experiment reported in Section 3 of this report.

Suspended sediments can play a role in the emulsification process. It can be easily explained in the following manner (11,12) and involves the interfacial tension between the solid and water, the water and oil, and between the solid and oil. If the surface tension between the solid and oil is greater than the sum of the surface tensions between the water and oil and solid and water, the solid will remain suspended in the aqueous phase. If the surface tension between the solid and water is greater than the sum of the surface tension between the water and oil and solid and oil, the solid will remain in the oil. If the surface tension between the oil and water is greater than the sum of the surface tension of the solid and water and solid and oil, the solid will concentrate on the boundary.

It is known that clay sediments tend to incorporate oil into the water column. Conversely, fine grain sand is generally found in tar balls.

Physical entrainment and stability of the oil-in-water suspension was studied both from an experimental as well as an analytical viewpoint and is discussed in some detail in Section 4 of this report. The "entrainable" particles depend, for most of the systems studied, on particle size distribution and subsurface circulation. Except for the case when there exists a chemical stabilizing agent in the dispersant, the oil droplets, generally having a density less than water, and tend to rise to the surface. Hence, most oil-in-water suspensions are basically unstable and require some degree of agitation or circulation to maintain them in suspension. In the natural environment, quite often the circulation beneath waves, etc., is sufficient to maintain the fine droplets in suspension as with the case in most of the experiments conducted in this report. Subsurface circulation was studied analytically and the results of this study are presented in Section 4 of this report.

The wind/wave experiment was designed to study the effects of waves, and wind blown waves on the entrainment of oil droplets. One of the conditions for the experiment was to allow the action of waves and wind to occur over a sufficient period of time to allow the natural weathering of oil to take place. Initially, it was conceived to produce waves and an air flow in an annular type of wind tunnel. A small scale experiment was designed and conducted. The major problem encountered during the initial test was that oil collected on the inner wall due to circulation in the tank and wind activity. It was, therefore, decided to use a cylindrical tank as described in Section 3. of this report. The particular arrangement chosen allowed the surface slick to undergo wind/wave action for indefinite periods of time without contacting the walls of the container. It consisted of a tank eight feet in diameter and approximately four feet in height, having the same capacity as the meso-scale tanks previously mentioned. A doughnut shaped wave maker oscillating vertically produced the radially inward moving surface waves. Its frequency and amplitude could be varied so that different wave heights and wave lengths could be achieved. Air flow was provided by an exhaust hood placed over the tank. Subsurface water samples could be collected in similar fashion as in the meso-scale tanks. Radial traverses of oil concentration were also conducted utilizing glass rods inserted through the sampling ports. The results of these tests and a complete description of the experiment are given in Section 3 of this report.

Another entrainment process investigated was the study of entrainment caused by the penetration of an oil slick by water droplets. These droplets can be formed by breaking waves or be due to rain. A description and the results of this experiment are given in Section 4 of this report.

Evaporation from oil slicks is part of the natural weathering process. It is also a fractionation process since the lighter, more volatile components evaporate most readily. Evaporation rates as well as definition of the components are reported in two sections of this report, Section 7 and Section 12.4

1.4.3 OIL SPILL TREATMENT STRATEGY

This particular portion of the project was to use an oil spill fates model as a tool to analyze the effect of various treatment strategies on the fate of a simulated spill. The location of the spill was chosen at the center of the Cod spawning region of Georges Bank and at a time, mid-winter, to affect a maximum impact on the Cod fishery. The output of the model resulting from these simulations was used as input to a fisheries model and is discussed in detail in Section 6 of this report. The oil spill fates model and treatment strategy is presented in Section 5 of this report. The fates model was basically used as a method to show the difference between the spreading characteristics of a surface spill and the diffusional subsurface current driven treated spill, as well as to estimate the concentration distribution of each. The fate model includes most naturally occurring processes as well as the effects of clean-up, removal and dispersion actions and could be used in "real" time to aid the On-Scene-Commander (OSC) in control and clean-up of a spill.

1.4.4 FISHERY-OIL SPILL INTERACTION MODEL

An oil spill-fisheries impact model was developed to obtain an order of magnitude estimate of the impact of a treated versus untreated oil spill. To what extent oil spills at sea affect the commercial catch over the ensuing years and under what circumstances, if any, treatment with a dispersant will mitigate the effect, are addressed in this research. The model estimates first order, direct effects of an oil spill on a commercially fished population. The primary effect is assumed to occur through egg and larval mortality. The biological impacts model formulated contains as subcomponents a population model of the fishery, a model for advection and diffusion of oil and fish larvae which is coupled to the oil spill behavior and fates model described in the previous section.

The model was used to simulate nine variations of an oil spill scenario on Georges Bank, producing a rough sensitivity analysis of system response. Following an overview of the model system, the results and implications of these simulations are discussed along with limitations of the approach used. It is suggested that the most significant unknowns in the system are the parameters governing recruitment dynamics in the fishery, toxicity threshold values and oil entrainment rates being of secondary importance in open ocean conditions.

1.4.5 CHEMICAL ANALYSIS

The overall objective of the project was to address the environmental impact of chemically treated vs. untreated oil spills. The primary objective of the chemistry group was to determine the amount and compositions of petroleum chemicals in the atmosphere, surface waters, water column and sediments resulting from a treated and untreated spill. To meet with this objective it was necessary to develop sample collecting, extraction and chemical analysis methods. In addition, extensive development and testing computer software was required to collect and massage the analytical data. Laboratory experiments were designed and executed to aid in the development of these analytical techniques. Results from the laboratory studies determined the techniques which would be applied to the analysis of the meso-scale experiment and eventually to any "real world" spills of opportunity. The major portion of the chemical analysis is reported in Section 2 of this report. Other chemical analysis techniques developed for quantitatively distinguishing the dispersant from Kuwait Crude by both infra-red and gas chromatography techniques are reported in Section 8 and 12.2.

1.4.6. MICROBIAL DEGRADATION

The study of microbial degradation of hydrocarbons was deemed an important area of investigation. Since the use of dispersants greatly increases the surface area of the oil, making it more susceptible to biological degradation and hence, an important question to answer if dispersants are to be used. The hydrocarbon degradation potential of ocean environments has not been adequately defined, however, it is known to be influenced by such factors as the number and types of hydrocarbon degrading microorganisms, the degree of oil dispersion, temperature and nutrient availability. Hydrocarbon degradation rates measured in the laboratory have been misleading since they were found to be considerably higher than in situ rates. Consequently, microbial utilization of the hydrocarbons was measured in the meso-scale tanks which most closely approach the real environment. A series of other tests was conducted in the laboratory to gain a better understanding of the process. The details of the experiments and results are reported in Section 8 of this report.

1.4.7 BIOLOGICAL INVESTIGATIONS

This portion of the investigation was to study the effects of realistic concentrations of oil and oil-dispersant mixtures on marine life. The impact of a spill on marine organisms is a function of the chemical, temporal and spatial distribution of the oil. The traditional bioassay work, based on LC_{50} on 48, 72 or 96 hour tests are of limited value in estimating the impact of a spill, because they are static and seldom are these organisms exposed to a constant concentration in the real environment, with the exception of some spills in marshes and beaches. Furthermore, most of these tests are conducted with unweathered oil, thereby exposing these organisms to the more volatile and toxic components. The approach in this study was to determine lethal concentrations as a function of exposure time. Knowing the temporal and spatial distribution of both the oil and organisms allows a first order assessment of the number of organisms destroyed as a direct impact of the untreated or treated oil spill. It was also recognized that other important parameters that could affect the impact of a spill depended on predator-prey relationships that could cause mortality even when the organism survives the spill. The experiments and results are given in Section 9 of this report.

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2.0 Effect of Chemical Dispersants on the Stability of Oil Water Emulsions

Mathew Cherian

Thomas J. Kim

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Nomenclature

A - Interfacial Area

d - diameter of the drop

D - diameter of the impeller

Fr - Froude Number

g_c - acceleration due to gravity

g - gravitational constant

N - number of the revolutions of the impeller per minute

n - number of drops of diameter d

O - Order of magnitude

P - rate of power input

Po - Power number

Re - Reynolds Number

v - velocity of the drop

α and β phases α and β

ε error in measurement of any quantity

ϕ hold-up

μ Viscosity

σ Interfacial Tension

Subscripts

AM - arithmetic mean

SM - Sauter Mean

i - component i

2.1 Introduction

In recent years oil spills on the high seas and inland waterways have been given increased attention because of their adverse ecological and environmental effects. It is estimated that over sixty percent of crude oil consumed all over the world is transported over water. In view of this enormous volume of oil conveyed over the seas and inland waterways, chances of oil spills are great indeed.

Retention and cleanup of oil has met with limited success so far. Mechanical methods are cumbersome and transportation of the equipment is difficult, slow and expensive. On the other hand dispersants and surface-active agents are easier to transport and use, and have met with success in Europe. There has been considerable controversy regarding the use of dispersants to break up oil spills. It has been known that chemical dispersing agents, which are surface active agents, often do more damage than the oil which they tend to disperse (44).

The effectiveness and practicality of chemical dispersants have been seriously questioned since their initial use. In support of this, two well-known incidents are cited often - the Torrey Canyon and the Santa Barbara spills. In both cases substantial quantities of dispersants were used. In both instances there was extensive contamination of the environment.

Unlike mechanical methods which seek to isolate and remove oil from the water surface, dispersants break up the oil into tiny droplets. Oil in this condition is considered to be amenable to biodegradation (18).

Biodegradation of oil is a rate process and depends upon interfacial area and time. For biodegradation it is desirable that we have the smallest droplets possible and have them stay in the water column for the longest duration of time. It is here that the stability of the dispersion becomes important. Stability of the dispersion can be defined as a fraction of the hold-up or interfacial area. (Hold-up can be defined as the fraction of the dispersed phase in the continuous phase.) Since interfacial area is a function of hold-up, interfacial area alone can be thought to be a criteria for stability of the emulsion.

It is the intention of this investigation to evaluate the effectiveness of dispersants in distributing and stabilizing crude oil in the water column.

2.2 Literature Survey

Previous work on the dispersants to break up oil into small droplets is of relatively recent origin. In a recent investigation Jasper, Kim and Wilson (42) studied the effect of dispersants in breaking up a crude oil into fine droplets. They used two dispersants, a self-mixing type and a conventional one. The conventional dispersant is a surface active agent which merely reduces the interfacial tension. The new generation 'self-mix' dispersant on the other hand is expected to produce spontaneous emulsification. This type of surfactant is predominantly soluble in the oil-phase. When the oil comes into contact with water, that part of the surfactant that has a strong affinity for water tends to diffuse to it. During this process it carries droplets of oil into the water phase. The self-mix type and the conventional dispersant were found to perform differently, with the self-mixing type creating a better dispersion. The study revealed that the self-mix type dispersed oil more efficiently as the rate of energy input decreased. Further it was found that a finer dispersion was possible using a self-mix dispersant. The study by Jasper et al also showed that there was minimal increase in hold-up with increase in power input.

In the past, investigations in this area have been conducted with an entirely different goal in view. In liquid-liquid extraction operations two immiscible phases are brought into intimate contact, and when equilibrium has been achieved, allowed to separate in a settler. Here, instability of the dispersion and not stability is the consideration. There is yet another striking difference between traditional extraction operations and the situation encountered in an oil spill. In extraction operations the hold-up is of the order of 10 to 50 percent. In the present investigation the hold-up is of the order of parts per million. However, since coalescence and break up of droplets are basic to both situations they will be considered in this survey.

The earliest investigation on the coalescence of droplets concerned the behaviour of a single droplet resting on a plane liquid surface. This is conceivably the simplest possible situation. Reynolds (1) began the study of coalescence by observing the behaviour of a rain drop resting momentarily on the surface of a pond. The findings were rather qualitative in nature. This observation was followed by Smoluchowski (2) who analyzed the rate of coalescence of droplets in dispersions and developed an idealized model for the rate of coalescence of droplets. Apart from the above two studies there had been no significant contributions in this field until the second half of this century.

The latter half of the twentieth century saw a burst of research activity in the field of coalescence. It should be noted that the bulk of research in this area has been confined to coalescence of single drops. This is understandable because all factors involved in the coalescence of single droplets should be identified and their significance estimated before coalescence of swarms of droplets can be studied. Thus all workers found that the time interval of the arrival of a drop at the interface and its disappearance into its parent phase is not constant; but there is a distribution of times - the distribution being approximately Gaussian. Further all researchers agreed that the coalescence process includes five consecutive stages. These are

(i) the approach of the drop to the interface, resulting in the deformation of both the drop and the bulk phase
(ii) damped oscillation of the drop at the interface
(iii) the formation of a film of the continuous phase between the drop and its bulk phase
(iv) drainage of the film, its rupture and removal with the initiation of the coalescence process proper and

(v) transfer of the contents of the drops partially or wholly into its bulk phase. Most workers assumed (without much evidence) that stages (i) and (ii) took place immeasurably fast so that the time of coalescence was the time taken for stages (iii), (iv), and (v) during which the drop rested on the thinning film at the interface. Some workers called this the rest time.

As has been stated above, for drops of the same size and physical properties coalescing under identical conditions there is a spread of coalescence times. This suggests that a large number of experiments had to be carried out in order to get the distribution. Gillispie and Rideal (3) found that about 100-200 drops had to be observed to get reproducible results whereas Jeffreys and Hawksley (4) using more refined apparatus found that it was necessary to study only 70-100 drops to get reproducible results. Working with drops stabilized with surfactants, Cockbain and McRoberts (5) were able to obtain reproducible distribution curves using only 30 drops. In the study of coalescence time, researchers have defined two means, namely the arithmetic mean of the time of coalescence (of identical drops of course) and half rest time which is the time taken for half the drops to coalesce. Generally half rest time has been found to be more reproducible than the arithmetic mean and the ratio of the arithmetic mean to the half rest time has been found to be greater than one (in the range of 1.01 to 1.27.)

A drop residing at the interface may coalesce completely or it may coalesce partially, producing a smaller drop which will ultimately behave in a manner similar to the parent drop. That is, it will coalesce producing a smaller drop and the process may continue for as many as six or seven times. This phenomenon is known as stepwise coalescence. It was first observed by Wark and Cox (6) during froth floatation experiments and a little later by Mahagar (7) during experiments at the air-liquid interface.

The coalescence of a single droplet at a plane interface is accomplished through the drainage and rupture of the film of the continuous phase. Therefore the factors that most affect drainage and rupture, control the coalescence process. These factors have been tabulated by Lawson (8).

Nearly all workers studying coalescence agree that coalescence time increases with drop size. A larger drop tends to flatten into an oblate spheriod when resting on the interface so that the film between the drop and the interface is increased in size and thereby the drainage time is increased also. Moreover, interfacial area between a larger drop and the interface is larger for the large drop so that the resistance to drainage is larger and the coalescence time is greater. It should be pointed out that Lang (9) found by theoretical analysis that the thickness of the film at the instant of rupture is independent of drop size. Neilsen, Wall and Adams (10) found that for some three component systems the stability of the drop increased with increased size. This would clearly depend on the nature of the third component. A diffusing solute would increase or decrease the stability of the drop depending on the direction of mass transfer.

A number of investigators have found that the settling distance through which the drop traverses affects the coalescence time. Nielsen (10) reported that the coalescence time was independent of the distance through which the drop traverses, while Lang (9) suggested that the distance of fall (or rise) could either increase or decrease the stability of the drop depending on the mechanical disturbances produced. However Lawson (8), Hawksley (11), and Jeffreys and Hawksley (4) have shown that the stability of the drop increases with increase in the distance of fall. It is widely accepted that the coalescence time is proportional to the distance that a drop traverses raised to an exponent n. The exponent n increases with drop size but is independent of temperature. It is only the first step of coalescence that is affected by the distance that the drop traverses although many workers have reported that the distance of fall also affects the other steps to a large extent. There are several explanations to the above mentioned observations:

(i) The drop may acquire an electrostatic charge during passage through the continuous phase. The extent of this charge increases with the distance of descent, thereby offering a greater resistance to the drainage of the film. This seems to be a perfectly logical explanation. However, McDonald (12) found no pronounced effect of electrostatic charge except on very large drops.

(ii) Drops passing through the continuous phase collect small quantities of surfactants which tend to increase the stability of the drops. The greater the distance travelled, the greater the amount of surfactant collected. It should be pointed out that if this were the case, reproducible results would never have been possible by using different batches of the same chemical. As different batches, however carefully controlled in production, contain minute quantities of surfactants in varying degrees.

(iii) The variation could also be produced by the drop "bouncing" after striking the interface, with the result that rippling of the interface prevents the film between the drop and the interface from draining. However, Hawksley (11) showed that the terminal velocity of most of the drops is attained within fifteen to twenty drop diameters. Since the mean coalescence time continues to increase when the critical distance has been exceeded, this could not be a good explanation.

Curvature of the interface between the drop and the coalesced phase was found to have an effect on the stability of the drops. Nielsen (10) has shown that the stability of the drop increased when the curvature of the coalesced drop phase was concave to the drop. This could be expected because drainage of the film is thereby promoted.

Density difference between the two phases is another factor that seems to have some bearing upon the coalescence rate. Large density differences result in severe deformation of the drop. The drop tends to flatten so that the area of drainage of the film is increased, whereas the hydrostatic force causing drainage does not increase proportionately. These two opposing tendencies tend to cancel each other. In fact, many workers have claimed that the rest time increases with increase in the density difference between the phases.

Phase viscosity ratio is another parameter which influences the coalescence time. An increase in the phase viscosity would be expected to increase the coalescence time as it takes more time to drain a more viscous film. There is experimental evidence to confirm this.

A high interfacial tension results in the drop resisting deformation so that the area for the film to drain would tend to decrease with increase in interfacial tension. Thus coalescence time tends to decrease with increase in interfacial tension. However, an increase in interfacial tension also tends to inhibit the flow of the film itself so that here again there are two opposing tendencies. Generally, coalescence time tends to decrease with an increase in interfacial tension.

Temperature affects all the physical properties that affect coalescence. Generally an increase in temperature tends to reduce coalescence time unless there is a change brought about in the coalescence process. Thus, Jeffreys and Hawksley (4) found that single step coalescence changed to multi-step coalescences in some instances when temperature was raised.

There are conflicting reports on the effect of vibrations on coalescence times. Gillespie and Rideal (3) suggested that vibrations tend to stabilize the drainage film, thereby impeding coalescence. On the other hand Lang (9) proposed that vibrations introduced random variations in the coalescence reported by different workers. Lang and others investigated the effects of extraneous vibrations and found these to be negligible. Brown and Hanson (13) studied single drop coalescence in alternating current fields of different frequencies and they concluded that in the systems they investigated, coalescence time was virtually independent of frequency.

Extensive research has been done on the effect of an external electric field on the rate of coalescence. Charles and Mason (14) applied a direct current field to the drop in such a manner that the force promoting coalescence was several hundred times that of gravity. They found that the drop flattened so that the area of draining the film was greatly increased, but since the force was so large the rate of coalescence was accelerated. Furthermore, they found that when stepwise coalescence occurred, the secondary drop was much smaller.

The presence of electrical double layers affect the rate of coalescence in a significant way. It had been widely observed that the rate of coalescence of drops whose phases contain electrolytes is lower than the rate of coalescence of pure drops residing in pure solvent. This is explained in part by the formation of electrical double layers between the draining film and the drop and the coalesced phase and the draining film. These double layers tend to retard the flow of draining film through the force of attraction of the opposite charges at the interface and in the flowing liquid. This effect has been given the name "electro-viscous effect" by Elton and Picknett (14). It will be most pronounced when the thickness of the draining film is of the same order of magnitude as that of the electrical double layer, and when the apparent viscosity becomes five times that of the normal viscosity of the liquid in the draining film. Both Cockbain and McRoberts and Gillespie and Rideal (3) suggest that where double layer effect is significant, small drops should be more stable than large ones. However, the problem is more complex than suggested by this simple statement because, although the force promoting coalescence is small in the case of a smaller drop, so is the area of the drainage film. Consequently, there will be less chance of the double layer becoming significant.

The presence of a third component tends to accelerate or retard the rate of coalescence. Thus solid substances tend to promote coalescence especially if they are wetted by the drop phase because the solid particle tends to form a bridge across the draining film thereby promoting the rupture of the film. This was demonstrated by Charles and Manson (15) who contaminated a benzene-water interface with minute glass beads. They found that coalescence was instantaneous.

There is a tremendous increase in interfacial area in emulsification; and this makes it necessary to take a look at surface activity. For example dispersion of only 1 cubic centimeter of oil into water in the form of fine droplets of a radius of 0.1 micron size creates an interfacial area of 300 square meters - an increase of the order of a millionfold. Under such circumstances the properties of surfaces and especially interfaces become of great importance.

The notion that surfaces and interfaces behave in a manner different from the bulk of the matter had been known for centuries. Partington (19) cites Leonardo da Vinci in this connection. For many years explanation of surface tension depended on the assumption that the free surface behaved like a contractile skin. Although liquids behave as though such a skin exists it is not really necessary to take such a view. It is the short range attractive forces that are known as van der Wall forces that are responsible for the special behaviour of the surfaces and interfaces. Molecules in the bulk of the liquid experience a balanced force in all directions because the attractive forces fall off rapidly with distance. However, at the interface the molecules experience a net inward pull; and this accounts for the contractile skin-like behaviour of the free surface. When a surface film is increased more molecules are brought to the higher energy condition at the surface. Thus, creating new surface is analogous to the phenomena accompanying vaporization. Stefan (20) was the first to suggest that there would be a relation between surface tension and latent heat of vaporization. Partington (19) gives an extensive list of theoretical and empirical equations relating the two properties.

Surface tension of most liquids decrease with increase in temperature. This is a corollary to the molecular theory of surface tension. The increased kinetic energy acquired by the molecules at the higher temperature will overcome the net attractive force on the molecule. Moreover, at conditions approaching the critical, the cohesive forces between the molecules vanish, and therefore the surface tension will vanish also at the critical. Eotovos (21) proposed a semi-empirical equation, which would predict the surface tension of a wide variety of substances from one empirical constant, the molecular weight and the critical temperature. This equation was improved by Ramsay and Shields (22), who in effect modified the empirical constant in the Eotovos equation.

Interfacial tension is a condition identical to surface tension except that instead of the vapor space above the free surface of a liquid there is yet another liquid whose molecules will exert substantial attractive force on the molecules of the other liquid at the interface. Thus the interfacial tension between two liquids will lie between the surface tensions of the liquids at the same temperature. Dupre (23) suggested an equation for calculating interfacial tension from the surface tension values of the separate phases. But there was the limitation that the two liquids had to be immiscible in each other. Since few liquids are completely immiscible in each other, the interfacial tension values so calculated were not accurate. Antonoff (24) suggested an improvement to Dupre's equation taking into consideration the mutual solubility of the liquids. Recently Girifalco and Good (25) have suggested an equation, based on sound thermodynamic principles, which is in fair agreement with experimental data.

When considering emulsions, it is of far greater importance to look at the effect that solutes have on interfacial properties. The fact that small amounts of solute can have a violent effect on interfacial properties has been demonstrated by Hardy (26). A large lens of petroleum jelly was formed on the surface of pure water. A drop of oleic acid was placed on the lens. After a short time considerable agitation was noticed and then the lens appeared to shatter, with almost explosive violence into small fragments, which were propelled to the edges of the container.

That the presence of a small concentration of solute should have such an effect on the surface tension is not surprising; what is surprising is the tremendous variability of the effects observed. The large lowering of the interfacial tension on the addition of certain types of solutes is due to the fact that the solute concentrates at the interface. The molecules which produce this effect are known as amphiphilic molecules. They are oriented at the interface with their lipophilic portion extending into air (or into a non-aqueous phase). That there should be a higher concentration of the solute which causes the decrease in the interfacial tension at the interface has been proven by Gibbs. The assumptions involved in the derivation of the Gibbs equation have been critically reviewed by de Witte (27), and the rigor of the equation has been criticized by Guggenheim (28). Scatchard (29) reviewed the derivation by Gibbs and concurs with him.

In any mixing operation it is often necessary to know the energy input to the system. There are a number of ways to determine this. Energy input can be directly measured by a dynamometer, by measuring the amperage of the electric mixing motor or by making use of a torque meter. These methods can be expensive, inconvenient or inaccurate. However we can design a 'standard' mixing operation for which power correlation curves are available. When a standard impeller is turned in a liquid, a flow pattern is established in terms of the impeller characteristics, type of fluid and the geometry of the mixing vessel. After this circulation pattern has been set-up, the only way the input energy can be changed is by changing the rate of rotation of the impeller. In otherwords, the speed of the impeller and the environment it is in controls the input energy regardless of the power capacity of the driving mechanism.

White and co-workers (39) were the first to suggest the possibility of correlating the performance of mixing impellers by dimensional analysis. This idea was later extended by Hixon (40), Johnson and Thring (41) and Rushton and Oldshoe (42). The power correlations give Power number as a function of impeller Reynolds number and Froude number. Power number is given by

$$P_o = \frac{P\, g_c}{\rho N^3 D^5}$$

the impeller Reynolds number by

$$Re = \frac{D^2 N \rho}{\mu}$$

and the Froude number by

$$Fr = \frac{D\, N^2}{g}$$

Froude number characterizes the gravity forces and in a well baffled tank it is negligible. In this case the Power number becomes a function of the impeller Reynolds number alone.

2.3 Experimental Set-Up and Procedure

Equipment: The experimental set-up consists of a baffled tank with a turbine-type agitator system. A refrigeration system was used for temperatures below ambient. Other accessories included a temperature controller and a temperature recorder.

The experimental tank (fig. 2.1), made of 'Nalgene', a commercial polyethylene, had a height of 0.6 M and diameter of 0.42 M. The tank was filled up to 0.0757 M^3(20 U.S. Gal.) in all experiments. This corresponds to a height of 0.42 M, thereby giving a height to diameter ratio of 1:1 for the undisturbed liquid. Using the tank for the above mentioned capacity of 0.0757 M^3, gave a free-board of 0.18 M - more than adequate to prevent any splashing when operating up to speeds of 600 RPM using a 0.09 M (4 in.) turbine. The tank was fitted with four equally spaced taps made of Polyvinyl Chloride. Glass tubes were attached to the insides of the taps extending to one half the radius of the tank.

Since the experiment involved detection of small quantities of hydrocarbon in the water, the tank prior to use was tested to see if any hydrocarbon will leach out from the polyethylene material. The results

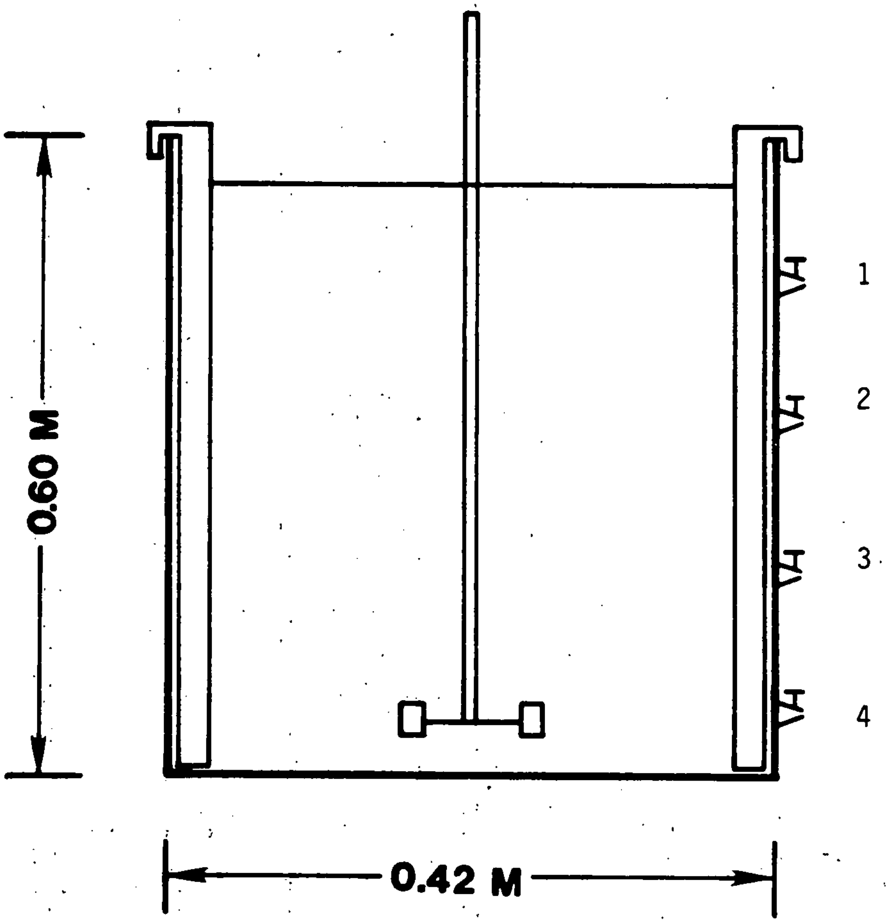

Figure 2.1 Experimental Tank - 20 gallon

were negative.

Four equally spaced rectangular baffles of 1/12 the diameter of the tank, and made of aluminium were used. The baffles were fitted to the tank through a notch and fixed using Allen screws.

The liquid was agitated using a six-blade flat turbine of 0.101 M (4 in) diameter. A d.c. current motor of 0.373 kilowatts (1/2 h.p.) was used to drive the turbine through a shaft of 0.0063 M (1/4 in). The d.c. motor permitted continuous variation of the speed over a wide range. Both the turbine and the shaft were made of stainless steel to protect against corrosion due to sea water.

Samples were collected in 500 ml graduated bottles with glass stoppers. Extractions were done in 0.0005 M (500 ml) separatory funnels, with polyethylene stop-cocks and stoppers.

To study the drops of oil in the water column, photography was used. This method was preferred over automatic electronic counting (using Coulter Counter) because of the necessity of maintaining a quiescent medium for studying the stability of the dispersion. Coulter Counter requires a flowing system. The photographic technique on the other hand requires only small samples from the system. The samples were taken on pre-cleaned glass slides using glass pipettes. Cover glasses were used to prevent evaporation of the samples. A Leitz-Wetzlar microscope (Model No: 512), to which a Nikkon camera was attached, was used. The microscope had four objectives: 5, 10, 25, 50 magnification. The ocular had a magnification of 10 thereby giving a maximum magnification of 500 for the microscope. A very slow black and white film (Kodak ASA 32) was preferred, since the static system did not call for a fast film. The slower film gives better drop definition than the high speed film. The size of the drops were estimated by comparison with a scale etched on the objective and photographed along with the drops. The photographs were mounted and projected on a screen for counting.

2.3.1 Extraction of Oil:

The oil in the water column was extracted by carbon tetrachloride. Three aliquots of 10 ml each of carbon tetrachloride was used for each sample. The quantity of oil removed by the carbon tetrachloride was determined by a Perkin Elmer infra-red spectroscope (Model no.: 451). The system was calibrated for the concentration of oil in the carbon tetrachloride. Since the range of the equipment was limited to 40 parts per million of oil, the extract had to be diluted to low concentrations. Spectral grade carbon tetrachloride was used.

A. Materials:

Sea Water: Sea water was preferred over pure water and synthetic sea water, because it was desired to simulate as closely as possible ocean conditions. Pure water devoid of all salts and zoo-plankton commonly found in actual sea water, would have drastically affected surface and interfacial properties of the dispersion. The synthetic sea water although of consistently accurate composition, differs very much from sea water. The presence of very small quantities of dispersants that are usually found in sea water was not a serious problem as the concentrations of the dispersant used in the experiment was larger by many orders of magnitude. The sea water for the experiments was brought from Narragansett Bay in polyethylene containers and stored in a large "Nalgene" tank.

Crude Oil: A light Kuwait crude was chosen for the experiment. The choice of the crude was governed by the fact that this Kuwait crude had been chosen by many different laboratories for the purpose of studying oil pollution. Also, detailed analysis of the crude had been made by Exxon Research Laboratories and had been made available for the present investigation.

The crude had an API Gravity of 31.4, which would place it in the category of light crudes. Analysis (by Exxon Labs) showed that it had a sulfur content of 2.44 percent by weight and 0.14 percent nitrogen. Nickel and vanadium were 7.7 and 28 parts per million respectively. Analysis by mass spectroscopy showed that the crude was 34 percent by weight saturates and 21.9 by weight aromatics.

A commercial dispersant known as Corexit 9527 manufactured by Exxon for dispersing oil was used. Being a commercial dispersant, detailed specifications of its composition were not available.

Procedure: Sea water from Narragansett Bay was allowed to settle in the tank for a least a day before it was used for the experiments. This allowed any suspended particles to settle out. Ten ml of Kuwait crude was added to the sea water in the tank. In experiments in which dispersant was used, 2 ml of the dispersant was added to the system.

The duration of the agitation was decided from considerations of power input. To have a common basis for comparison, equal power was used in all the experiments, except in the case where there was to be no agitation.

For the calculation of power requirements, recourse was made to the power correlations for six-bladed flat turbines. In the present investigation, we had a two phase system. But power correlatons for two phase systems are very sparse. However, Laity and Treybal (31) have suggested the use of weighted property values. Since in the present case the hold-up of the dispersed phase is extremely small, the properties were essentially that of the continuous phase. The power correlations give power number as a function of the impeller Reynolds number. Power number is defined as

$$\frac{P\, g_c}{\rho N^3 D^5}$$

and the impeller Reynolds number as

$$Re = \frac{D^2 N\rho}{\mu}$$

The power required to turn an impeller at a given speed is a function of not only the fluid properties but also the geometry of the impeller and the vessel. For calculation of power for the six-bladed flat turbine reference was made to Fig. 10.10, 'Liquid Extraction' by R.E. Treybal (32).

Samples were taken in 500 ml graduated glass bottles as soon as the motor was stopped; for the purposes of studying stability a timer was started at the same instant. Four sets of samples were taken, one from each tap, at 0 hrs, 1 hr, 2 hrs, and 24 hrs, and placed in graduated bottles.

Simultaneously, three drops were taken from each tap and placed on pre-cleaned slides and covered. These samples were photographed, 9 shots for each tap at each time.

The samples in the graduated bottles were extracted using carbon tetrachloride. First the 200 ml sample was transferred to a 500 ml separatory funnel. Then the first aliquot of 10 ml carbon tetrachloride was poured into the separatory funnel. To maintain consistency for each extraction the separatory funnel was shaken 20 times by hand. The extract was collected in pre-cleaned dram bottles and labelled. The procedure was repeated with a second and third 10 ml aliquot of carbon tetrachloride.

Since the concentrations usually encountered in the above extractions were beyond the range of the Infrared Sepctrometer, 1 ml of the extract was taken and then diluted with 30 ml of carbon tetrachloride.

The photographs were developed and mounted. They were then projected on a screen and the size of the drops estimated by comparison with the scale which was photographed along with the drops.

Interfacial tension between the oil phase and aqueous phase was measured by the pendant drop method. Dynamic methods like the ring method are unsatisfactory because of the presence of surface active agents. When a new surface is formed in a medium in which a surface active agent is present, it will not be in equilibrium as the surface active agent has to diffuse to the newly created surface from the bulk of the medium. This is a consequence of the fact that there is a higher concentration of the surface active agent at the interface than in the bulk of the phase. This makes it necessary to use a method which is static or semi-static.

The pendant drop method consists of forming drops of one liquid in another liquid at the tip of a capillary. The drops are allowed to form at a slow rate so that the new surface will be in equilibrium - or close to being so. These drops were then photographed and their shapes determined by a shape factor by measuring two of their characteristic dimensions. Interfacial tension is a function of their shape.

Since the oil phase is lighter than the aqueous phase, the drop was allowed to form at the tip of a capillary which was oriented upwards. The capillary was connected to a reservoir which could be moved up or down at will. The capillary was kept in a water bath which was cooled by a refrigeration system.

The shape of the drop was determined by a photographic technique. As the drops formed at the tip of the capillary at the rate of about one drop per minute, its photograph was taken using a Mamiya Sekor camera. The camera had an extension tube attached to its lens to provide a magnification of approximately 10. A scale was photographed along with the drops. This helped in determining the size of the drop and its shape factor by comparison with the scale rather than making use of the magnification of the extension tube-lens system. The photographs were developed and mounted, and projected on a screen, and the size and shape measured.

The differential equation governing the shape of the drop has been solved as a function of the interfacial tension by a number of investigators (33). The numerical solution of the differential equation is available in the form of a table. Reference was made to these tables for the calculation of the interfacial tension (33).

To study the effect of temperature on the oil-water dispersion, a smaller tank was used. A smaller tank was used in preference to the larger 20 gal. tank because the requirements for refrigeration will be within the range of a 0.37 kw (1/2 hp) Haake refrigeration system. The tank of 0.3 M diameter, was made of glass and fitted with four baffles made of aluminum of 1/12 the diameter. Water was filled in the tank up to a depth of 0.3 M, thus giving a depth to diameter ratio of 1:1 for the undisturbed liquid. A free-board of 0.08 M was provided above the free surface of the liquid surface to make allowance for any splashing. The tank was agitated using a six-bladed flat turbine of 0.08 M (3 in) diameter. The impeller was driven by a variable speed motor of 0.06 kw (1/12 hp). The sampling and extraction procedures were identical to that used for the larger tank. The sample was taken from a depth of 0.15 M, using polyethylene tubing and placed into graduated bottles.

2.4. Results and Discussion

2.4.1 Drop-Size Distribution

When two liquids are agitated in a tank impeller system, which of the two liquids become the dispersed phase and which becomes the continuous phase depends on a variety of factors. If the two liquids are in comparable ratio, i.e., 45:55 percent by volume, the liquid that wets the impeller will be the continuous phase. However, when the volume fraction (hold-up) of one liquid is much smaller than the other, i.e., less than 25 percent, it is very difficult to disperse the liquid having the larger volume fraction. From solid geometry we know that when spheres of equal size are packed together under conditions of closest packing, the volume fraction occupied by the spheres is only 74.02 percent. But when we have spheres of varying sizes, it is very obvious that we can pack much more in a given volume. In fact, emulsions of 99 percent dispersed phase have been prepared (32). However, in the present investigation the question as to which would be the dispersed phase and which would be the continuous phase could hardly arise. The crude oil phase was of the order of 1/10000 by volume of the aqueous phase. Thus the most probable dispersion that may be observed is the oil-in-water type. The hold-up was deliberately kept low so that the system would have about the same hold-up that could be expected in an oil-spill situation on the high seas.

In this investigation, low impeller speeds were used. This was done so that the turbulence generated would be as small as possible. Power correlations of Laity and Treybal (32) give power number for the impeller as a function of impeller Reynolds number. Since it was desired to use as small a turbulence as possible, the impeller Reynolds number just beyond the transition from laminar to turbulent was used. For the tank impeller system, this speed worked out to be 58 rpm (32). Thus the lowest speed that was used was 60 rpm.

It has not yet been established how the phase that is dispersed comes to be broken up into tiny droplets. It has been presumed by many workers that the phase that wets the impeller is the continuous phase (32). If this is the case, then the break-up action of the dispersed phase is due to the shearing action by the continuous phase.

A number of investigators have set an upper limit and a lower limit on the size of the droplets that can be observed in an emulsion. The lower limit is about 0.1 microns - a size approaching molecular dimensions. The upper limit is about 30 microns (30). Drops of larger than 30 microns are difficult to observe in an emulsion because they tend to rise fast and tend to coalesce with the parent phase. In this study attention was focused on drops whose sizes varied between 1 micron and 12 microns. There are a number of theoretical and empirical models available for the calculation of the rate of rise of a drop in a quiescent medium. The Stokes model (36) assumes that the drop behaves like a solid sphere while it moves in another medium. This is an approximation as there are circulations within the droplet. A more realistic model like the Ryczynski and Hadamard model (37) takes into consideration the movement of the fluid within the droplet. This model was used to calculate the rate of rise of a drop of Kuwait crude in sea water. This data shows that for droplets of size less than 12 microns the time taken to rise to the top of the tank would be of the order of less than 10 hours (fig. 2.2). Since an emulsion of oil in water has to be stable for a time of the order of days, it was thought unnecessary to observe droplets of size larger than 12 microns.

Jasper, Kim and Wilson (42), in their investigations on drop-size distribution in oil-water systems had found that drops larger than 6-7 microns are difficult to observe in an emulsion. Further they had concluded that the larger drops are insignificant for determining arithmetic means of the drop-size distribution (43). An extremely large drop would have little effect on the arithmetic mean if the small drops outnumber

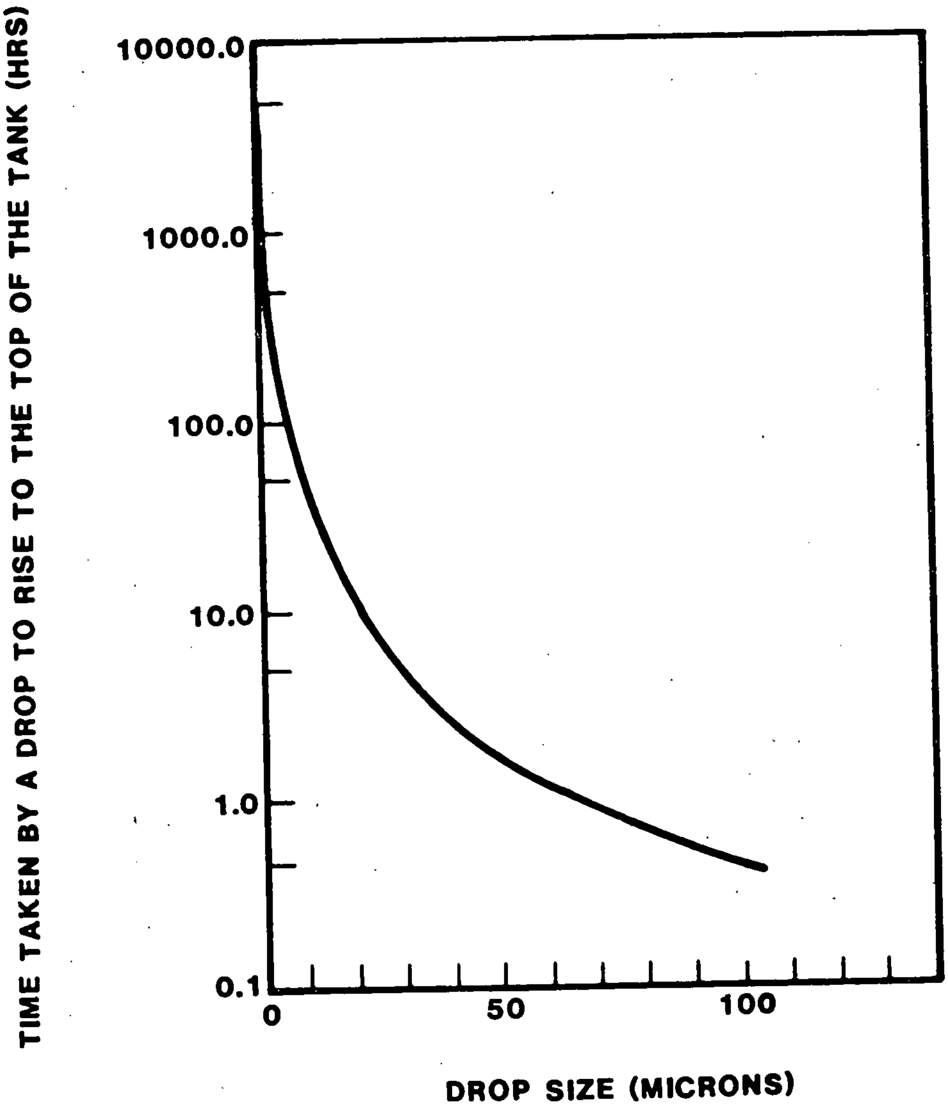

Figure 2.2 Time Taken by a Drop to Rise to the Top of the Tank (hrs).

the larger drops by a large factor. The experimental data (see distribution data in Appendix D) shows that invariably there were much larger number of smaller droplets than there were larger ones.

If the drop size distribution was normal (it is not a normal distribution, but is 'leptokurtic' or left leaning - see the plots of the distribution in Appendix C) then over 95 percent of the drops would be within two standard deviations of the arithmetic mean. For drops of average size, 2-3 microns, this would have meant that over 90 percent of the drops would be less than 7-8 microns. Therefore, taking an upper limit of 12 microns for studying emulsions is considered satisfactory, especially in view of the fact that the distributions usually found in emulsions are left leaning.

The number of drops that are counted for studying the drop-size distribution depends to a large extent upon getting the accuracy to which the distribution is desired. To arrive at a reasonable number, investigations in this area in the past by various workers were relied upon. Gillespie and Rideal (3) had found that it was necessary to observe 100-200 drops to get reproducible results, while Jeffreys and Hawksley (4) and Cockbain and McRoberts (5) using more refined techniques needed only half as many drops. Since all the samples that were counted had more than 100 drops the drop-size distribution is accurate. (See tables la thru 6d in Appendix D).

Drop-size distrubition for samples taken (figs. 2.3 through 2.7) (see Appendix A for Error Analysis) at 0 hours show an unmistakable trend that there is a larger proportion of smaller drops than larger drops. In other words, there is a maxima for the drop size distribution at the lower end of the spectrum. When the emulsion is allowed to stand over a period of time the drops tend to coalesce and the maxima tends to move towards the right.

The drop-size distribution when dispersant is used changes markedly from what it is when dispersant is not used. Figs. 2.3 through 2.7 show the distributions for different shear rates with and without dispersant. When dispersant is present, the distribution does not appear to change significantly with power input. However, when dispersant is not used there is a discernable difference in the distribution. It can be seen that the maxima for the distribution when dispersant is present is less than the maxima when dispersant is not used. This could be attributed to the lower interfacial tension between the oil and water when a surface active agent is used (see table in Appendix B).

If we consider the arithmetic mean of the drop sizes at 0 hours (figs. 2.8 thru 2.13) it can be seen that for a given rpm there was little or no difference between drop sizes at various positions in the tank. This is a corollary to the fact that while the impeller is rotating the forces induced on the drops by the forced circulation is far greater than gravity and the buoyant forces that otherwise would be dominant, when there is no such forced circulation.

In studying the drop size distribution, various averages are used. The number average mean is an obvious choice as it gives appropriate weight for drops of a given size. The weighted mean is given by,

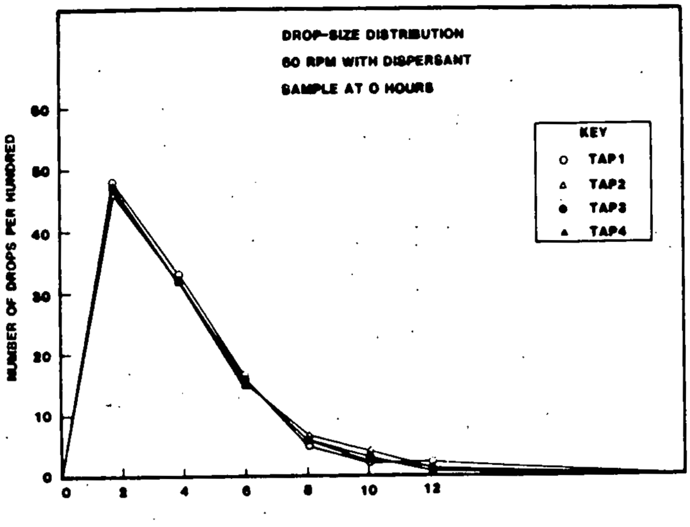

Figure 2.3 Drop-Size Distribution - 60 RPM With Dispersant

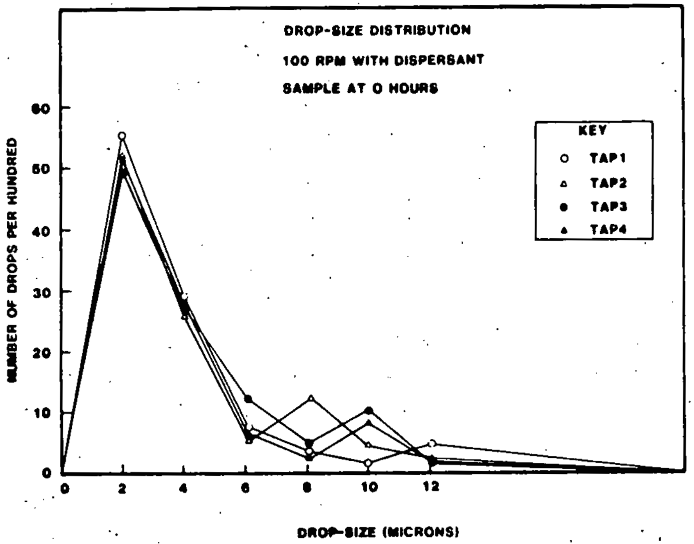

Figure 2.4 Drop-Size Distribution - 100 RPM With Dispersant

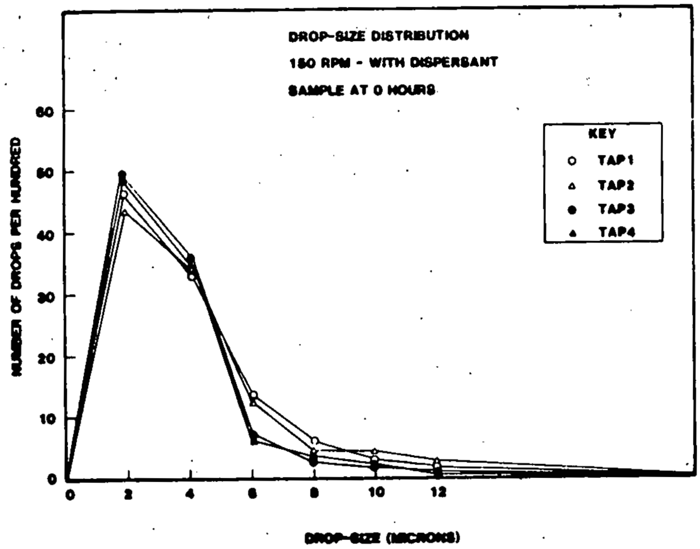

Figure 2.5 Drop-Size Distribution - 150 RPM With Dispersant

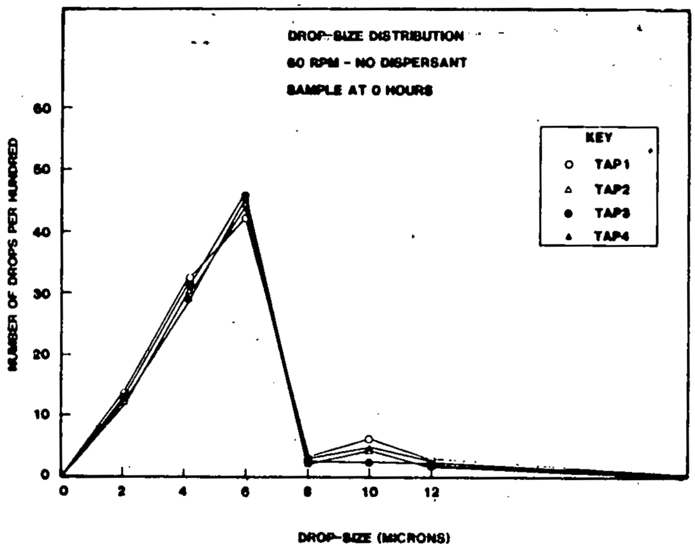

Figure 2.6 Drop Size Distribution - 60 RPM - No Dispersant

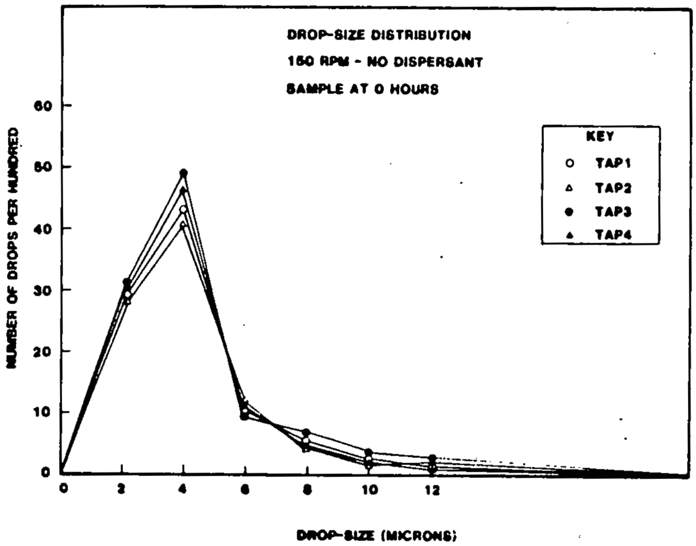

Figure 2.7 Drop Size Distribution - 150 RPM - No Dispersant

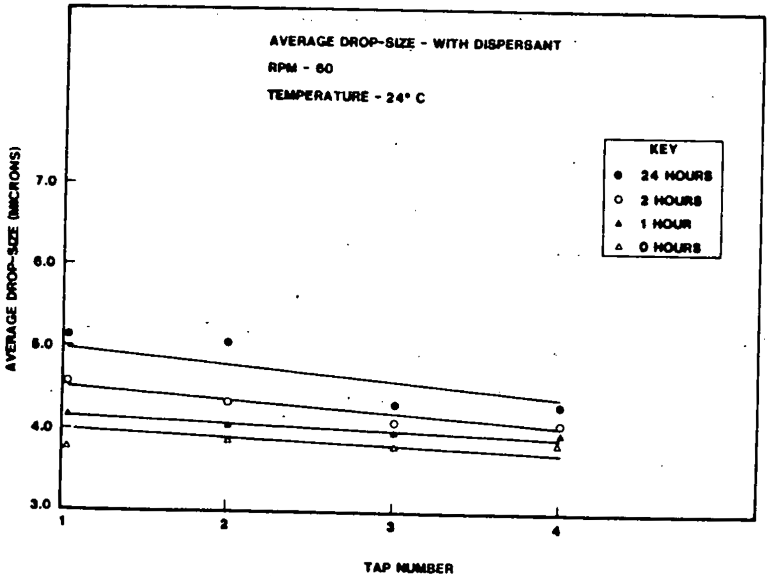

Figure 2.8 Average Drop-Size - With Dispersant RPM -60 - Temperature - 24°C

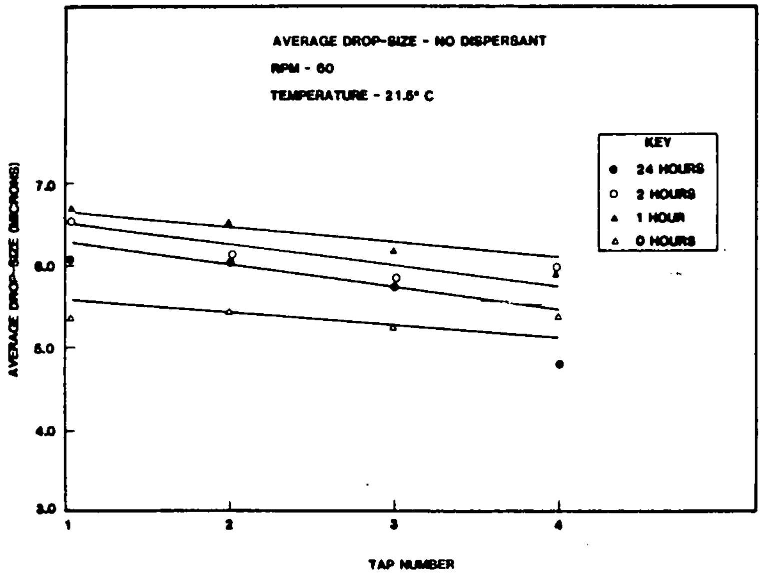

Figure 2.9 Average Drop-Size - No Dispersant RPM - 60 Temperature - 21.5°C

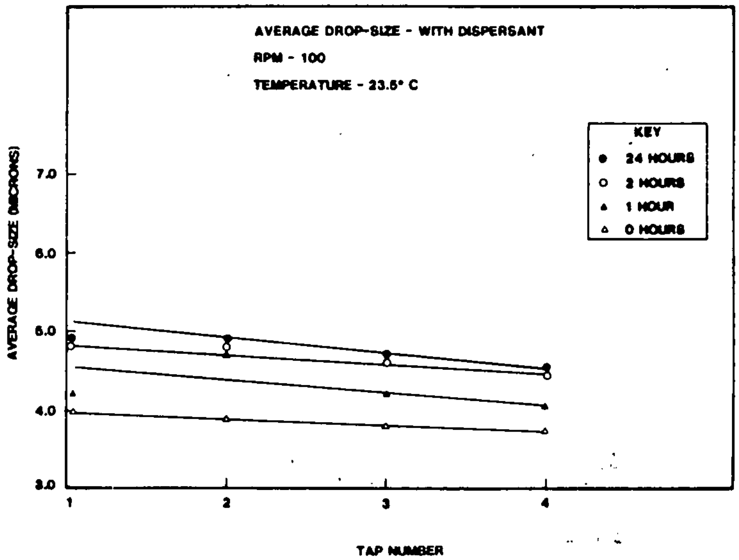

Figure 2.10 Average Drop Size - With Dispersant RPM - 100 Temperature - 23.5°C

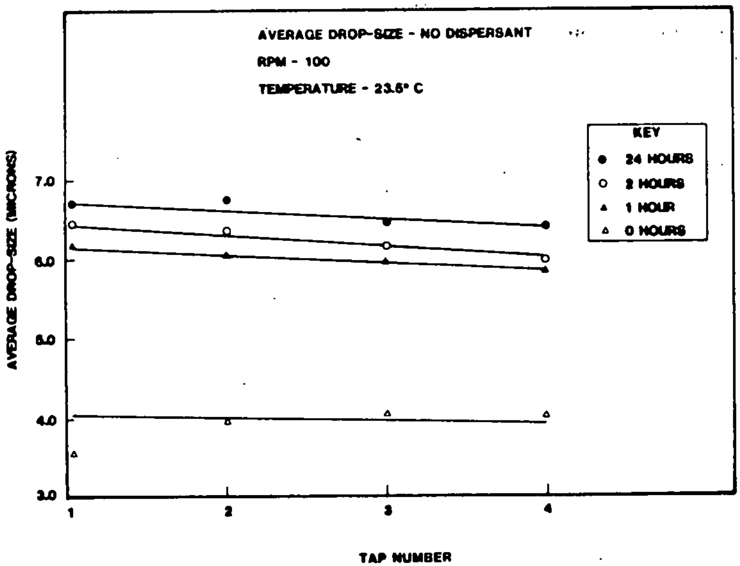

Figure 2.11 Average Drop Size - No Dispersant RPM - 100 Temperature - 23.5°C

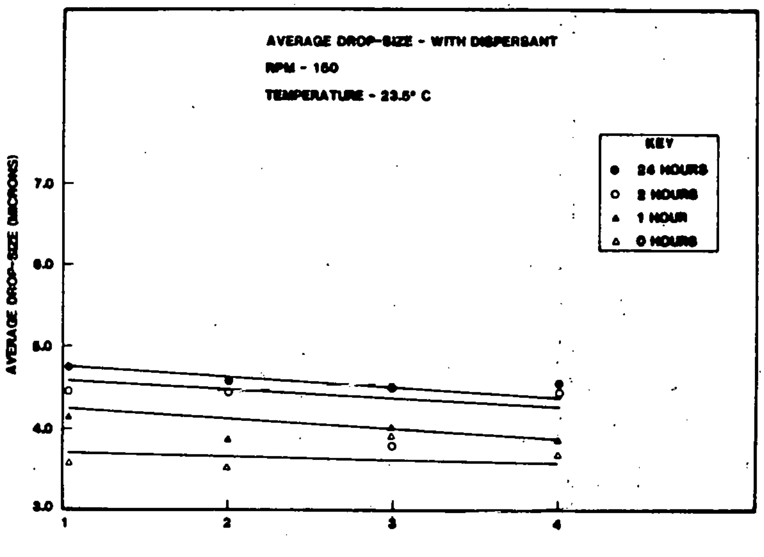

Figure 2.12 Average Drop-Size - With Dispersant RPM - 150 Temperature - 23.5^{o}C

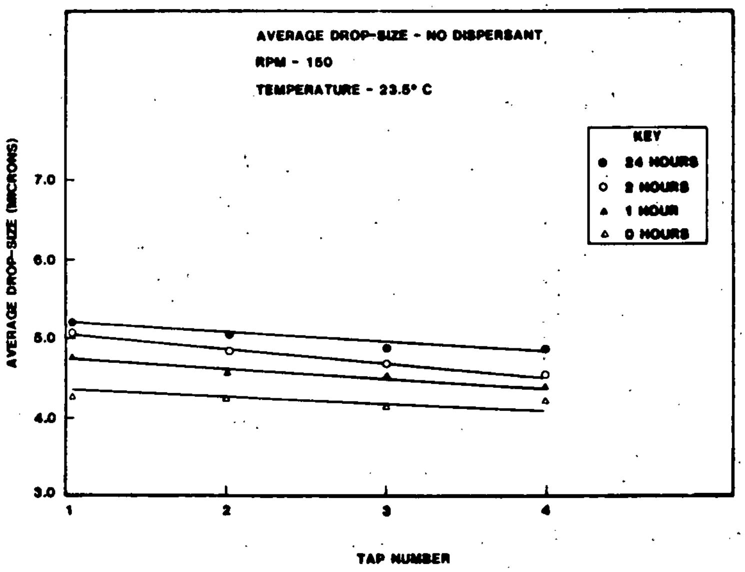

Figure 2.13 Average Drop Size - No Dispersant, RPM - 150, Temperature - 23.5^{o}C

$$AM = \frac{\Sigma N_i d_i}{\Sigma N_i}$$

While studying interfacial area Sauter Mean is the best choice. Sauter mean is given by

$$SM = \frac{\Sigma N_i d_i^3}{\Sigma N_i d_i^2}$$

The drop size distributions show that the average drop size is a function of the rate of shear and interfacial tension. It is seen that we get a finer dispersion when a dispersant is added.

The average drop size at 0 hours is approximately 20 percent smaller when the speed of the impeller was increased from 60 to 150 rpm when no dispersant was present, as shown in figs. 2.9 and 2.13. If the rate of shear is taken to be proportional to the tip speed of the impeller then this represents a decrease in drop size of 20 percent for an increase in shear rate by a factor of 2. In the presence of the dispersant the average drop size for the above two cases was smaller and the difference in drop size was only approximately 3 percent (figs. 2.8 to 2.13).

It was seen that the average drop size (except at 0 hours) increases with time as well as position in the tank as measured from the bottom of the tank. Since in the present investigation the droplets are made up of an incompressible fluid, different vertical positions (and hence the hydrostatic pressure) does not have any effect on their size. Thus the increase in size with time and position are due to coalescence processes taking place. However, coalescence in a system of as small a hold-up as this is bound to be small.

Consider two drops of equal diameters. Whey they collide and coalesce their combined volumes will be twice the volume of the original drop and the diameter will be 26 percent larger. If the average drop size at the top and bottom levels in the tank are considered at 0 hours and 24 hours (figs. 2.7 to 2.14) it can be seen that the drop size has increased from bottom to top by less than 20 percent only. This shows that coalescence was not a major factor in the instability of the system. This is as should be expected in view of the extremely small hold-up. For the hold-up used in the experiments, and for an average drop size of 4 microns, the mean free path is about 63.3 microns. This means that if the movement of the drops is completely random, the drop will have to travel 15 drop diameters before colliding with another drop. Since Brownian movement which contributes to considerable random lateral movement (in contrast with straight upward movement due to buoyancy) is negligible at drop diameters greater than 0.1 microns (30). The only possible way in which drops could collide is when they rise upwards. This type of collision is bound to be small in systems of small hold-up. This accounts for the fact that the drop-size distribution itself does not vary appreciably with time.

2.4.2 Hold-up and Interfacial Area

Hold-up is defined as the fraction of the dispersed phase in the continuous phase. When dealing with a small hold-up as in the present case, alternate units are used. In this investigation milligrams per liter was found to be a convenient unit.

There was little variation in the hold-up (with respect to different positions in the tank) at the instant the impeller was stopped (figs. 2.14 thru 19). Thereafter, the hold-up decreased continuously with time as well as position, as measured from the bottom of the tank upward. As coalescence in systems of small hold-up are small, the decrease in hold-up is a function of the terminal velocity of the droplet (Brownian movement of droplets of size larger than 1 micron being negligible). At 24 hours, the hold-up was the same for all taps and all rpms with dispersant. This was found to be the case when no dispersant was used also.

Thus the stability of a dispersion of small hold-up will depend to a large extent upon the rate of rise of a drop. If we equate the forces acting on a droplet we get (36)

$$F = \frac{4}{3}\pi R^3 \rho_c g + 2\pi\mu R v_\infty + 4\pi\mu R v_\infty$$

where the first term on the right is the buoyancy force, the second term is the form drag and the third term is the friction drag. When these forces are balanced by the gravitational forces, the drop will rise at a uniform velocity. Thus we have:

$$\frac{4}{3}\pi R^3 \rho_d g = \frac{4}{3}\pi R^3 \rho_c g + 2\pi\mu R v_\infty + 4\pi v_\infty$$

Solving for the velocity gives,

$$v_\infty = \frac{2}{9}\frac{R^2 g}{\mu}(\rho_D - \rho_c)$$

Thus a smaller drop tends to have a smaller terminal velocity.

If the shearing action of the continuous phase on the dispersed phase accounts for the break up of the dispersed phase, then the shear rate as given by the tip speed of the impeller should have a functional relation to the drop size and thereby to the hold-up. Moreover, a system of lower interfacial tension is inherently more stable thermodynamically, as the work done in creating interfacial area is smaller and hence the potential energy of the system is smaller.

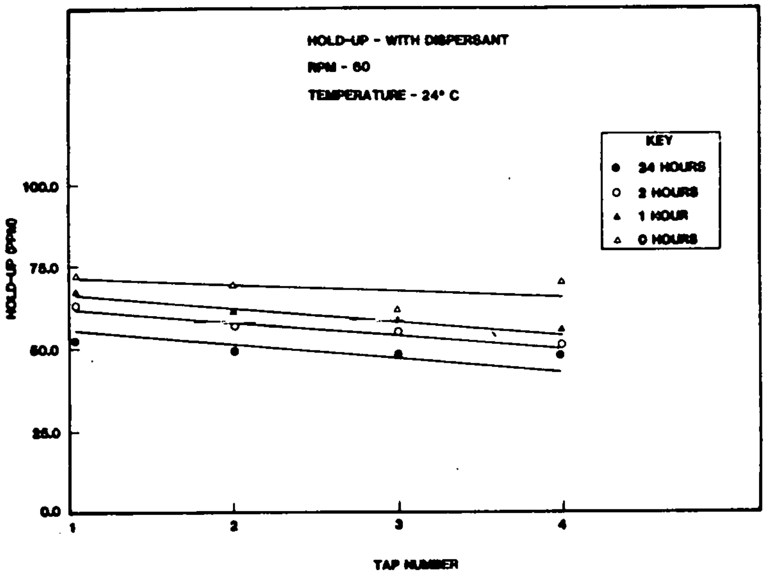

Figure 2.14 Hold-Up - With Dispersant, RPM 60, Temperature - 24^{o}C

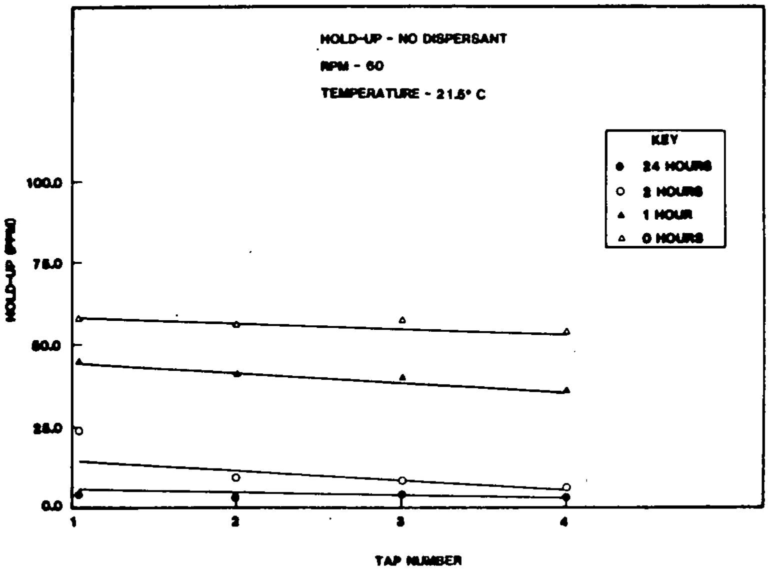

Figure 2.15 Hold-Up - No Dispersant, RPM - 60, Temperature - 21.5^{o}C

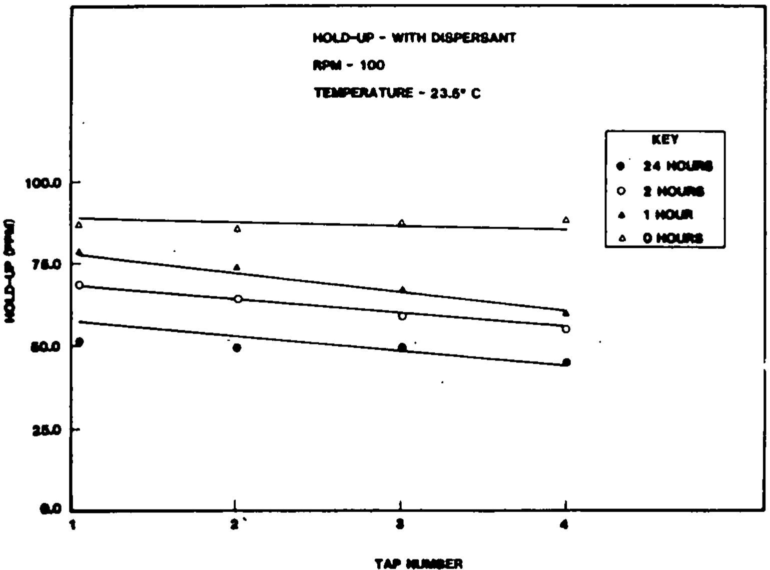

Figure 2.16 Hold-Up - With Dispersant, RPM - 100, Temperature 23.5^{o}C

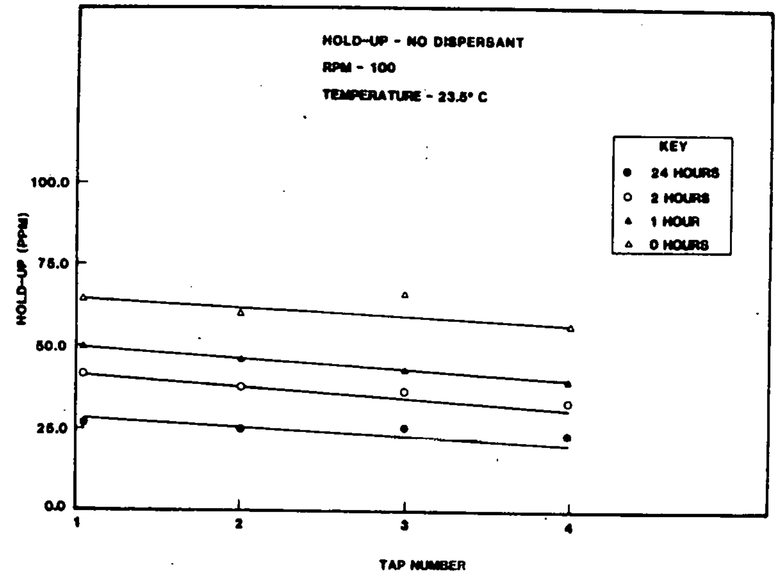

Figure 2.17 Hold-Up - No Dispersant, RPM - 100, Temperature - 23.5°C

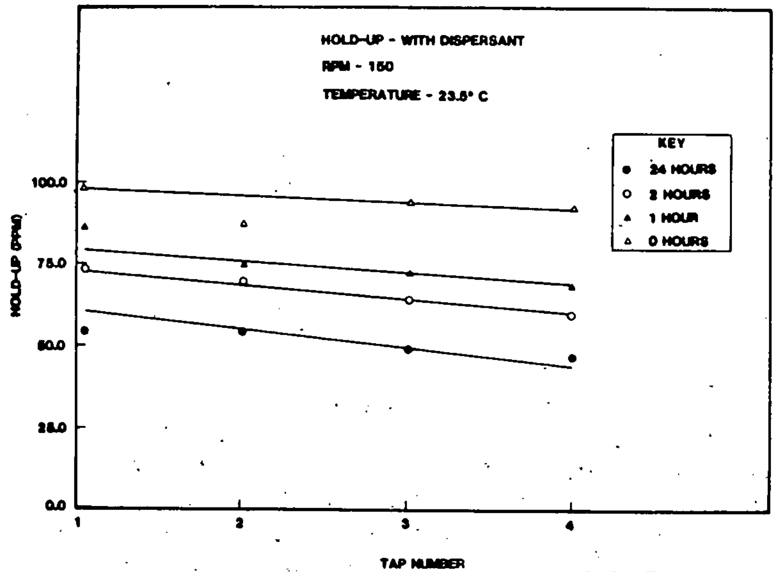

Figure 2.18 Hold-Up - With Dispersant, RPM - 150, Temperature - 23.5°C

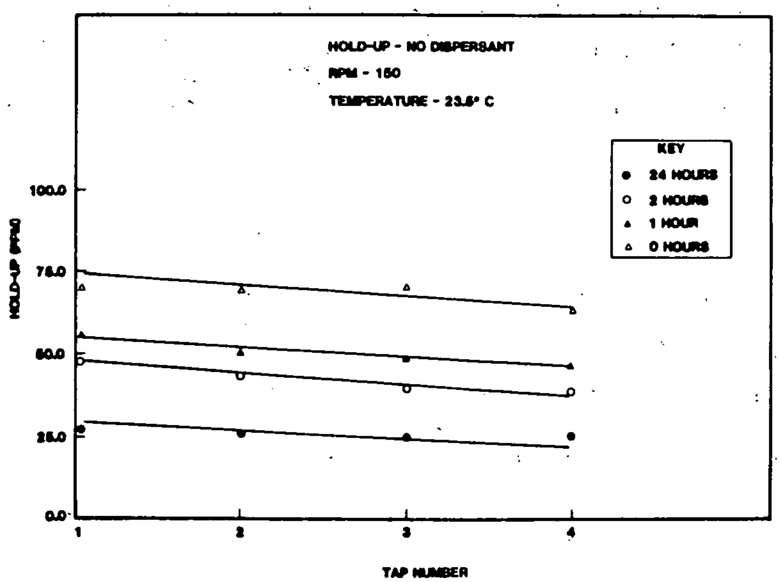

Figure 2.19 Hold-Up - No Dispersant, RPM - 150, Temperature 23.5°C

An analysis of the hold-up data shows that the hold-up when no dispersant was used, for samples taken at 24 hours was approximately constant and was very close to the solubility limit of crude oils usually observed (figs. 2.14 thru 19). When the dispersant was used, the hold-up at 24 hours was approximately constant but was higher (by a factor of approximately two) than the hold-up at 24 hours. This makes a good case for the use of dispersants in dispersing oil spills, if hold-up is the only criteria. As the dispersed phase was of lower density than the continuous phase, it naturally rises upward, and therefore the variation of the hold-up with time showed that the hold-up increased with height as measured from the bottom of the tank.

Specific interfacial area is a function of the hold-up as well as the Sauter Mean diameter of the drops. The interfacial area is given by,

$$A = \frac{6 \times \phi}{SM}$$

As had been mentioned earlier, in systems of small hold-up like the one used in these investigations, coalescence is negligible and therefore the variation in the Sauter Mean diameter with height as well as time was not great. Therefore, the interfacial area showed (figs. 2.20-25) a variation which was similar to that shown by the hold-up. As the hold-up in the case where dispersant was used was higher, so was the interfacial area.

The fraction of the oil which was initially added to the system that goes into the water column is a function of the interfacial tension, and the rate of shear (or rpm). In the series of experiments, the largest fraction of oil that went into the water column when no dispersant was used was only 61 percent at 150 rpm, as against 86 percent at the same rpm when dispersant was used. The higher intake of hydrocarbons with the application of dispersant could be due to increased stability of the dispersion and the formation of sub-micron droplets (this appears to be valid apart from the effects of the lower interfacial tension and variations of other physical properties). The hold-up of the oil at 24 hours is possibly the best indication of this increased 'solubility', which was higher by almost a factor of 2 when the dispersant was used. Since there is no sharp dividing line between 'true solubility' and sub-micron dispersibility, it is hard to say which of the two was predominant at the conditions cited above (17).

In the experiments in which a temperature of 10° C was used (see table 2.9-12), the interfacial tension between the oil phase and the aqueous phase was 3.91 dynes/cm, in the presence of the dispersant. The interfacial tension at the same temperature and when no dispersant was used was found to be 25.1 dynes/cm (see table in Appendix B). The variation in hold-up and average drop size followed a trend that was very similar to that which was observed for the runs at the higher temperature. The hold-up, and consequently the interfacial area (after having been normalized to make allowance for the smaller tank), was found to be lower than that for the runs at higher temperature. Thus the effect of the lower temperature was to give a dispersion that was less stable

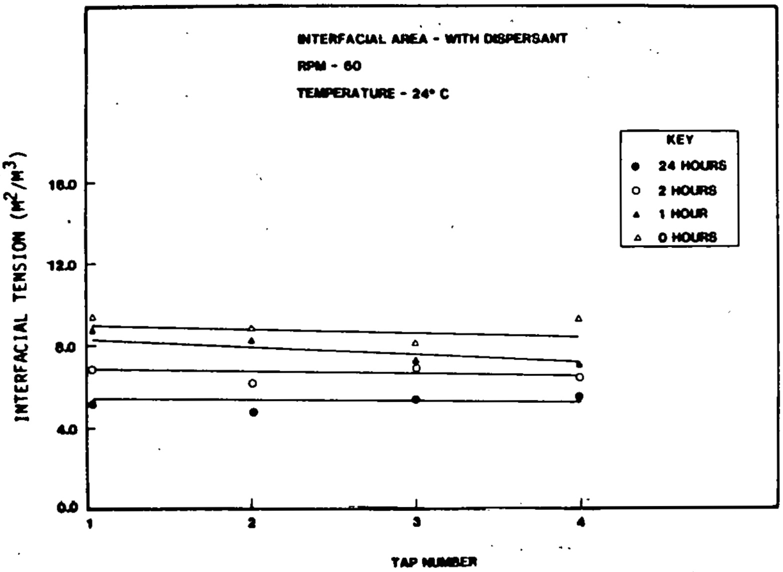

Figure 2.20 Interfacial Area - With Dispersant, RPM - 60, Temperature - 24°C

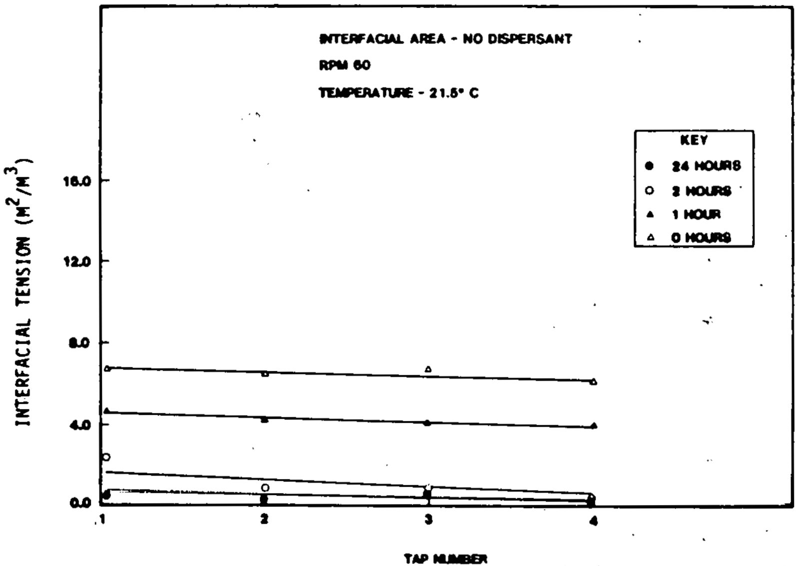

Figure 2.21 Interfacial Area - No Dispersant, RPM - 60, Temperature - 21.5°C

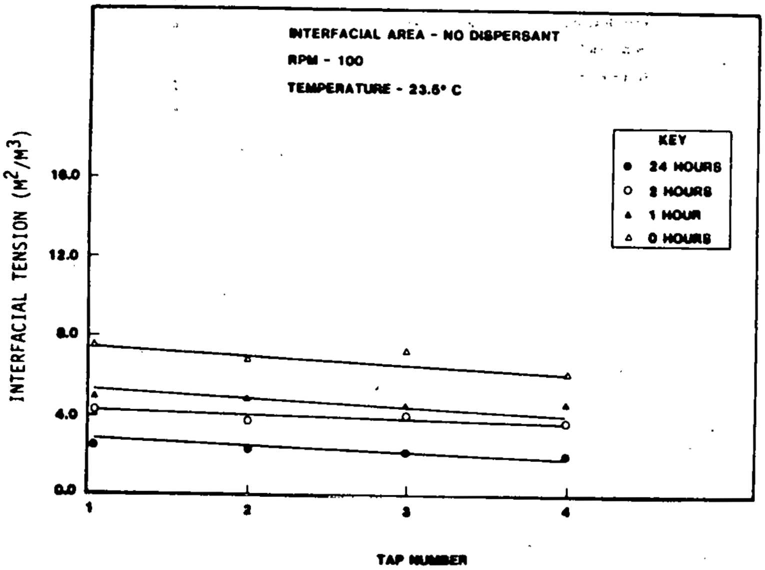

Figure 2.22 Interfacial Area - No Dispersant, RPM - 100, Temperature - 23.5°C

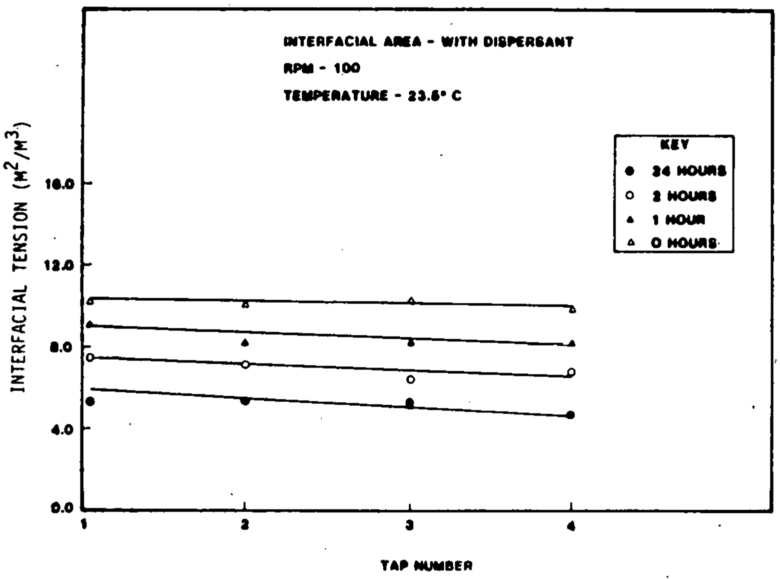

Figure 2.23 Interfacial Area - With Dispersant, RPM - 100, Temperature 23.5°C

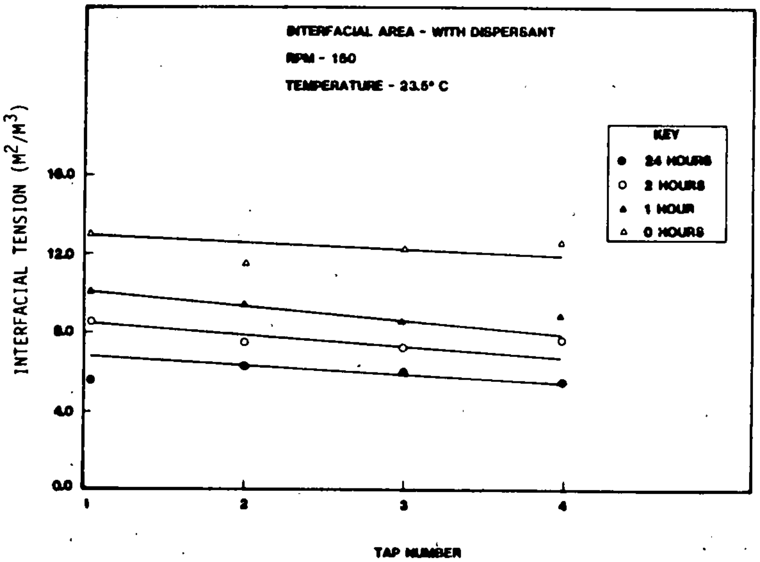

Figure 2.24 Interfacial Area - With Dispersant, RPM - 150, Temperature 23.5°C

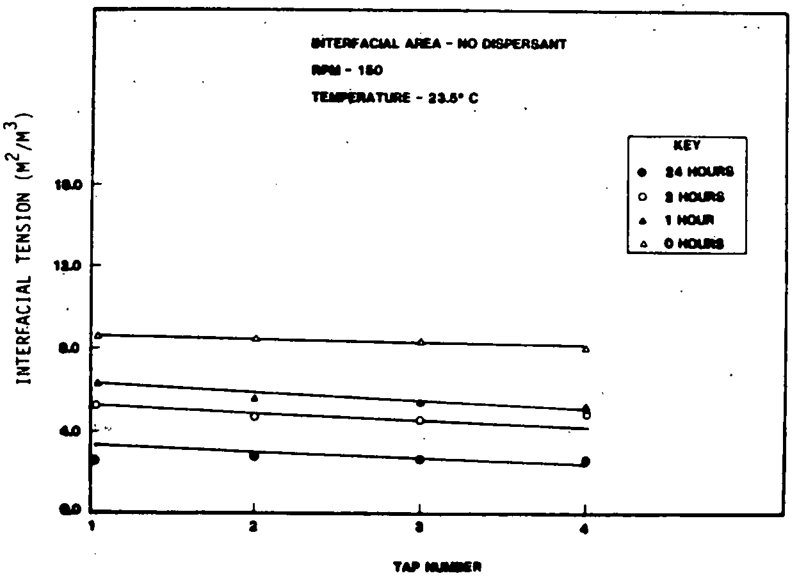

Figure 2.25 Interfacial Area - No Dispersant, RPM - 150, Temperature 23.5°C

because of the higher interfacial tension.

In contrast to the runs at 10 °C, the runs at room temperature varied over a range of 2.5 °C. Over the range of 5° C to 22 °C, the interfacial tension varied by approximately 8.0 dynes/cm. Assuming that the interfacial tension is a linear function of temperature over this temperature range, it can be seen that the variation of the interfacial tension over a range of 2.5 C is only about 1 dyne/cm. The effect of this variation of the interfacial tension over such factors as work done and power input is only about 10.0 percent. Since the drop-size is proportional to a fractional power of the interfacial tension (32), the variation of the drop-sizes due to variation in the ambient temperature is bound to be only less than 10.0 percent.

It had been observed that hydrocarbons could enter the water column without any power input. This is indicated by the runs at 0 rpm - i.e., no power input. Though the hold-up was not as large as was the case when the impeller was used, it was considerable in view of the fact that there was no power input involved.

When two phases are brought into contact with each other, initially the chemical potentials of the various components in each phase are not equal and therefore this sets up a potential difference for the components between the phases. Thermodynamically, when there is a potential difference, the tendency is to equalize them. This is achieved by the diffusion of the components from the phase in which they have higher potentials to the phase in which they have lower potentials. The diffusion continues to take place until all chemical potentials have been equalized. Once the different components are in the second phase, they may tend to agglomerate and form droplets or micelles.

Thermodynamic potential is defined as:

$$\mu_i = \left(\frac{\partial G}{\partial n_i}\right)_{T,\, P,\, n_j}$$

where G is the Gibbs free energy, n the number of moles of the constituent j, T and P temperature and pressure respectively (39). For phase A and B the Gibbs criteria for equilibrium is:

$$\mu_i^A = \mu_i^B$$

The chemical potentials are very difficult to use for studies involving crude oil in view of the large number of components involved. Phase equilibria involving more than three or four components are seldom solved by using thermodynamic potentials.

In this context it could be asked, what is the role played by power input in dispersing the crude in the water column? The thermodynamic potential, as it provides the driving force should have been sufficient to do the dispersion. But dispersion of one component into another takes place through the interface between the phases, and the rotating impeller by breaking up the dispersed phase provides a larger interfacial area, thereby speeding up the equilibrium process. The rates at which equilibrium could be achieved when no power input is involved also depends on the interfacial resistances involved. It is difficult to compare the two methods (with power input and without power input) as little is known of the interfacial resistances. However, power input has one beneficial effect. The mass transfer rate between an oil slick and the water column is proportional to the concentration difference. The forced convection currents due to power input helps keep this concentration difference high thereby increasing the rate of mass transfer.

The mechanical work that is done in creating new surface area is given by the product of the interfacial tension and the new surface area created. It can be seen that the fraction of the total energy input that goes into making new surface area is of the order of 10 percent (Appendix C). Apart from the fact that the impeller action for creating new surface area (or small droplets) is therefore very inefficient, it also shows that one should treat with great caution the use of power input as a basis for determining the creation of new surface area and hold-up.

2.5 Conclusions and Recommendations

The basic question posed in this investigation was whether it was desirable to use a dispersant for emulsifying crude oil for later biodegradation.

The series of experiments conducted show that crude oil can be effectively dispersed using a commercial dispersant, Corexit 9527 without excessive power input. (Large power input was considered impractical in an oil-spill situation on the high seas.) The interfacial area and the hold-up, which are the important parameters when considering biodegradation was found to be 2-3 times that when no dispersant was used. In this context it is important to remember that not all dispersants are useful for the purpose of biodegradation.

It was found that oil could enter the water column even when there was no power input. This is significant in that given sufficient amount of time, the oil could be effectively made to enter the water column without any power input - a desirable situation in a million gallon oil-spill.

The drop size distribution found for the 1-12 micron range can be considered to be truly representative of the emulsion. Further, this range of droplets is all that is necessary to study the emulsification process and the stability of oil-in-water emulsions.

It was observed that coalescence in a system of such a small hold-up as parts per million is very small. Therefore the instability of the system is due to the upward movement of the droplets in the continuous phase. This movement becomes ever smaller as the drop diameters become smaller.

It is hoped that it will be possible to translate the experimental data at the higher temperatures to actual field conditions at much lower temperatures. Interfacial tension is the most dominant factor that is affected by the temperature. A decrease in the temperature from 22 C to 5 C increases the interfacial tension approximately by a factor of 2 to 3. Since the work done and consequently the power input is a linear function of temperature, it is expected that an increase in interfacial tension by a factor of 1.1 would call for an increase in the power input by the same factor.

The following recommendations are made:

i) To establish a base line for studying dispersibility of crude oils in water, pure hydrocarbons should be used.

The experiments conducted with Kuwait crude will not give much information where another crude is involved. This is primarily because the crudes themselves contain many surface active agents in the form of hydrocarbons with hydroxyl and carbonyl groups. The proportion of these vary widely from crude to crude.

ii) More efforts should be made to study the effect of dispersants in dispersing oil spills without input of power.

iii) Since the stability of the dispersion is desirable the idea of stabilizing the dispersion with finely divided solids should be investigated. Use of solids would mitigate the toxic effects of most common dispersants.

The temperature on the high seas in an actual oil spill situation could very well be close to the freezing point on a winter day. Therefore, the problem of correlating the experimental data at the higher temperatures to lower temperatures in the ocean naturally arises. On the basis of the effect of temperature on viscosity and interfacial tension, it can be estimated that the interfacial area will be smaller by approximately 10-15 percent.

3.0 The Effect of Wind and Wave Motion on Oil Entrainment

Rodger B. Dowdell

Steven G. Parks

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3.1. Introduction

The wind-wave tank experiment is part of a larger study conducted at the University of Rhode Island to assess the environmental impact of treated an untreated oil spills. To develop a comprehensive model for oil slick impacts, this study required information about the amount of oil that would be dispersed under the ocean surface in a given sea state. It is believed that the largest oil concentrations result from dispersed oil droplets and that wave motion and the turbulence from breaking waves are an important dispersive mechanism. In addition, it has been shown that the oil properties can have an important effect on the amount of oil dispersed, and that these properties can change significantly over time. The experiments that have been done to date have provided valuable observations of the processes involved as well as some data. However, it has been difficult to establish even simple correlations between sea state and sub-surface oil concentrations for a number of reasons. The data from accidental spills is incomplete and it is not usually obtained under well documented conditions. Also, it is difficult to simulate sea-like conditions in the laboratory, and there is no simple accurate method available for measuring oil concentrations in water.

The wave tank experiment was proposed to address these problems and to add to the existing data. From the beginning, three design constraints were imposed: i) the experiment must be able to subject a small oil slick to various sea-like conditions, ii) it must be able to operate for an extended period of time, and iii) it must keep the effects of artificial barriers such as tank walls or containment booms to a minimum. This latter constraint is particularly difficult because water waves tend to push floating material in the direction of propagation. To solve these problems, a circular tank was designed and built with a variable speed wave generator around its perimeter, Figures 3.1 and 3.2. Water waves created at the edge of the tank travel toward the center where they interfere and sometimes break. Thus, the floating oil is contained in the region of maximum agitation solely by the wave drift currents, and no barriers are needed. The oil slick can be kept in a field of waves for as long as desired.

Of course this model has limitations. The energy in wind generated ocean waves is distributed over a band of frequencies where the energy concentration and bandwidth is dependent on wind fetch, duration, and water depth. The energy in the mechanically generated waves will be concentrated in a few distinct frequencies depending on the wave generator and tank geometries and the generator frequency. Also, the constructive interference of the waves at the center of the tank causes the waves to become steeper than they appear in the ocean. Currents are induced in the tank by the waves propagating toward the center, and in time these establish a circulation throughout the tank. All these differences are a result of the finite geometry of the experiment combined with a deterministic rather than a random forcing function for the waves. This has to result in a somewhat unsea-like environment. Nevertheless, the waves in the center of the tank have many apparent similarities to wind generated ocean waves.

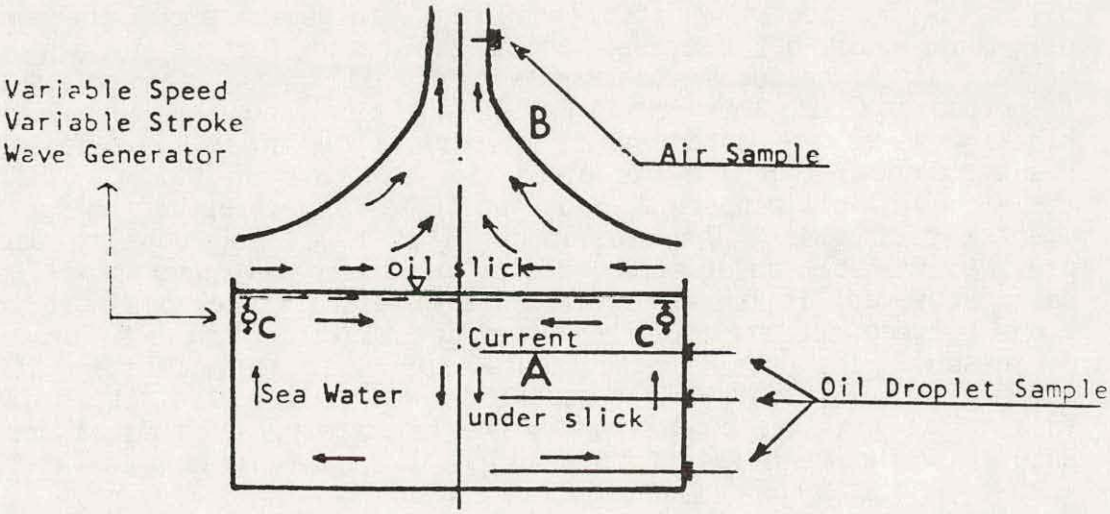


Figure 3.1. The Wind Wave Experiment

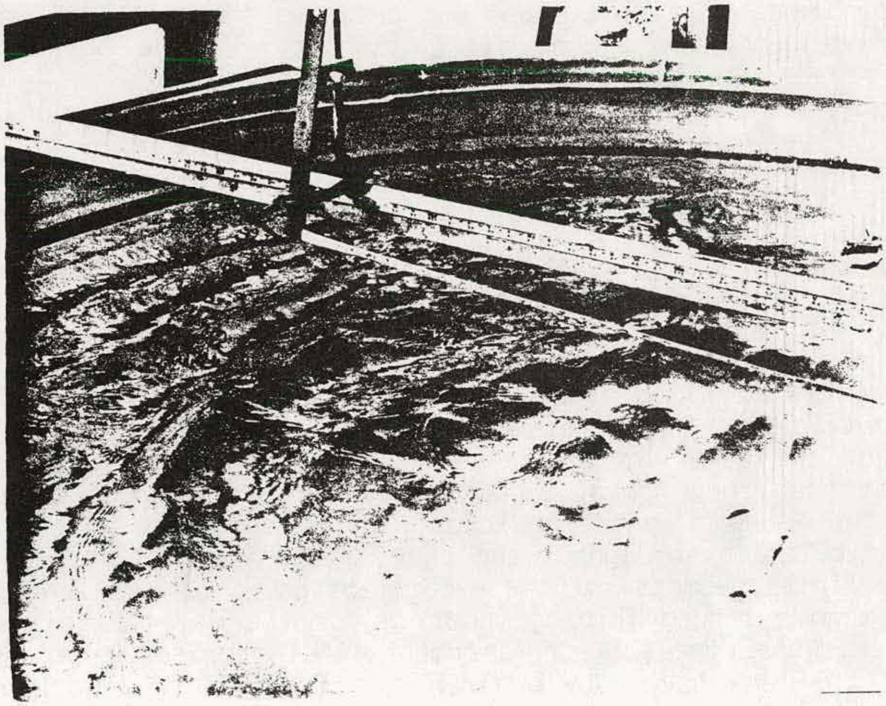


Figure 3.2. Circular Wave Tank

The intent of the experimental test program was to investigate the relationship between the amount of any given oil dispersed into the water column from a slick on the surface, and the macroscopic physical properties of the waves causing the dispersion. Of particular interest were the effects of any oil property changes on the oil in water concentrations as the oil weathers. Consequently, the experiment was designed toward this end. No attempt was made, for example, to perform detailed investigations of the turbulent structure in the breaking waves, or to test for chemical changes in the oil. Rather, a simple function between sea-state and oil concentration was assumed to exist. The major effort was devoted to measuring the important parameters that would be included in this function such as the oil concentrations in the tank, and the wave parameters including an estimate of the frequency and extent of wave breaking. Other parameters that were deemed peculiar to the experiment, such as the induced water currents, that might affect any generalizations from the data were also measured. Oil properties and water properties were only measured to establish baselines and were not investigated for changes. The presumed function is certainly an approximation which ignores many components of the problem. However, the observations and data suggest that this assumption may be valid.

3.2. Experimental Apparatus

All of the oil dispersion experiments for this investigation were conducted in the circular wave tank shown in Figures 3.1 and 3.2. This tank is 3 feet high, 8.1 feet in diameter, and has a nominal capacity of 1000 gallons. A 24 by 36 inch plexiglass window was installed in the side of the tank to permit observation of subsurface phenomona. The waves were created by an 8 foot diameter circular hoop mounted concentrically inside the tank. The hoop, shown in Figures 3.1. and 3.2., is constructed of 1 inch diameter aluminum rod and fastened to the tank with 4 aluminum connecting arms. The wave generator is driven by a slider crank mechanism attached to a Dayton variable speed 1/2 HP gear motor (model No. 3n259) which can be adjusted to operate at any frequency between 18 and 130 cycles per second.

A hood is placed over the surface of the tank and connected to the suction side of two 5 HP, two speed blowers. The air flow over the surface is in a radial direction and has an approximately constant velocity, which can be varied from about 10 knots to 25 knots. The wave motion can be created by the wind alone, the wave maker alone, or both in combination. A wide variety of wind-wave conditions can be created.

When the wave generating hoop is adjusted to pierce the water surface during an oscillation, waves are created that travel towards the center of the tank, interfere, and may break. These waves induce surface currents directed radially inward which confine any floating oil to the region in the center of the tank where it is constantly exposed to the waves and dispersed under the surface. Preliminary experiments and analysis of the wave motion in the tank showed that there are many resonant modes of the water in the tank in the frequency range of the wavemaker. If the wave generator was at or near a resonant frequency, large waves develop in the tank and sometimes a large seiching motion (Wavelength 2 D) was established. Thus, it was necessary to experiment by trial and error with different combinations of generator frequencies, generator amplitudes, and water depths until satisfactory wave patterns were found that did not change significantly over time. Eventually, it was decided to operate the wavemaker at 1.33 and 2.13 cycles per second with a water depth of 27.75 inches. With this depth restriction, the capacity of the tank is 890 gallons (3470 liters). The vertical location of the wave generating hoop was adjusted so that at the top of its stroke 1/4 of the diameter of the bar was below the still water level. The amplitude of the oscillations was kept constant at 1.5 inches throughout all the tests.

Because this dispersion experiment requires the measurement of very low concentrations of oil in water, extreme care was taken throughout the design and construction of the test apparatus to use materials that were chemically inert and easy to clean. The wave tank was constructed from wood and coated on the inside with 4 layers of a polyester resin which had been shown not to leach any detectable levels of contaminants into the water. The wave generating apparatus was made completely out of teflon and aluminum.

The measurement apparatus that was used included equipment for determining wave heights, water current velocities, water and oil properties, and oil concentrations. The wave measurements were performed with two Coastal Data Service model WS 100 capacitive wave staffs. These instruments were specially modified to increase their sensitivity by replacing the coated metal probes that were supplied with the instrument with 16 gauge teflon coated wire. The voltage time series produced by the probes were recorded on magnetic tape with a Hewlett Packard 3960 FM tape recorder and later digitized using a Nova 1200 mini-computer.

Rhodamine B dye was used to determine the water current velocities. Samples taken from various tank locations at uniform time intervals were analyzed for flourescence (dye concentraton) with a Turner model 111 fluorometer. The water and oil interfacial and surface tensions were determined with a Cenco-Dunuoy 7045 Tensiomat. This instrument measures the interfacial tension by balancing the force required to pull a platinum ring through the fluid interface against torsion in a fine calibrated wire. The tension values are recorded directly from the instrument and corrected for force imbalances in the system as instructed in the manual.

Specific gravities were calculated by weighing an accurate volume of fluid in a sphinctometer on an analytic balance. Water and air temperatures were measured with standard laboratory mercury thermometers. Photographs of each experiment were taken with a Mamiya 35 mm SLR camera. In addition overhead still photos were taken at 5 to 10 second intervals with a Sanyo Super 8 mm movie camera. A complete description of the apparatus used to determine the oil in water concentrations will be given in the description of the sample analysis procedure.

The entire experimental set-up was located in a shed adjacent to Narragansett Bay. The experiments were performed at ambient temperatures using both bay water and fresh water. The water used in the latter experiments was passed through three filters to remove all particles larger than 5 microns. Care was taken to fill the tanks with sea water close to high tide to minimize any contaminants coming from Narragansett Bay.

3.3. Experimental Procedure.

The test procedures that were followed throughout the experimental program are described in the following sections. Ten experiments to measure the oil in water concentrations resulting from the wave action in the tank were performed using the standard experimental and sample analysis procedures listed. Three input conditions; wave generator frequency, oil volume, and water type (fresh or sea water) were varied. Most of the sea water tests were duplicated. Care was taken to insure that the experimental and chemical analysis procedures were exactly the same for all the tests with one exception: the water sampling times were changed when it became apparent that the sample variability and oil dispersion time scales were not what was originally expected. This is described completely in the sampling procedure description below. A complete list of the test conditions for each experiment is given in Table 3.1.

The input conditions (wave height, length, frequency and water current velocities and directions) caused by the wave generator were measured independently of the oil dispersion experiments. Ideally, a complete experiment would measure the oil concentrations and the wave and current conditions in the tank simultaneously. Unfortunately, oil on the water surface complicates things considerably. There are presently no readily available instruments for measuring wave heights and current velocities that will work in the presence of oil. In addition, any instrument placed in the wave field at the center of the tank would have an unknown effect on the dispersion process. Rather than develop special instrumentation it was decided to perform the wave and current measurements separately. This cannot be accomplished without some error. Oil has a visible effect on water waves. It tends to damp out high frequency capillary waves and inhibit the breaking process so that the waves become slightly steeper before collapsing. However, because the size of the experimental slick is small, and the wave action at the center of the tank was intense, it was felt that any change in the wave field due to the presence of an oil slick would be minimal, or at least that it would not be detectable within the accuracy of the experiment. This was later confirmed, in part, through observatons and comparisons of photographs.

3.3.1. Wave Measurements

Wave data time series were obtained for both the 1.33 and 2.13 cycle per second wave generator frequencies. Data were obtained from the capacitive wave probe locations shown in Figures 3.3 and 3.4. (Note: the radii listed in the figures are referenced to the centerline of the generating hoop.) These locations were chosen to measure the wave parameters at the point of maximum observed wave activity, (tank center) and at the locations where turbulent breakdown of the regular wavefronts was just perceptible. Locations at equal radii were chosen to check for symmetric conditions in the tank.

Two capacitive wave staffs were available and consequently the data were recorded in pairs. Before and after each recording, a calibration record was established by measuring simulated water level changes in the tank. Each instrument was raised and lowered 12 cm relative to the water surface along a vertical carriage. Their output was recorded at 2 cm

TABLE 3.1 -SUMMARY OF EXPERIMENTAL CONDITIONS AND PROPERTY MEASUREMENTS

Experiment	1	2	3	4	5	6	7	8	9	10
Date	2-21-79	3-3-79	6-13-79	6-26-79	6-28-79	7-10-79	7-12-79	7-15-79	7-31-79	8-3-7
Water type	Fresh	Fresh	Salt	Salt	Fresh	Salt	Salt	Salt	Salt	Salt
Water Specific Gravity	1.00	1.00	NA	1.021	1.00	1.023	1.024	1.024	1.023	1.022
Water Temperature Range:										
Minimum Temp °C	5	5.5	15	18	18	22	20	20	25	24
Maximum Temp °C	8	6	16	20	20	23	22	22	27	26
Water Salinity °/oo	NA	NA	NA	NA	NA	29.8	29.8	30.2	NA	NA
Ambient Air Temperature Range										
Minimum Temp °C	5	6	15	17	18	20	22	21	27	27
Maximum Temp °C	9	8	16	26	22	24	24	23	31	29
Amount of Kuwait Crude Oil Added (ml)	60	60	60	60	60	60	120	120	60	60
Interfacial Tension Measurements (dynes/cm)										
water-air	75.5	75.5	NA	69.7	71.4	71.6	69.3	68.8	NA	NA
oil-air	50.9	50.9	NA	26.9	26.5	26.3	26.3	26.1	NA	NA
oil-water	26.6	26.6	NA	20.1	26.2	20.0	20.3	20.4	NA	NA
Measurement Ambient Temperature °C	est 8	est 8	NA	22	22	26	26	26	NA	NA
Wave Generator Frequency (cycles/sec)	1.33	2.13	1.33	2.13	2.13	1.33	2.13	2.13	1.33	1.33

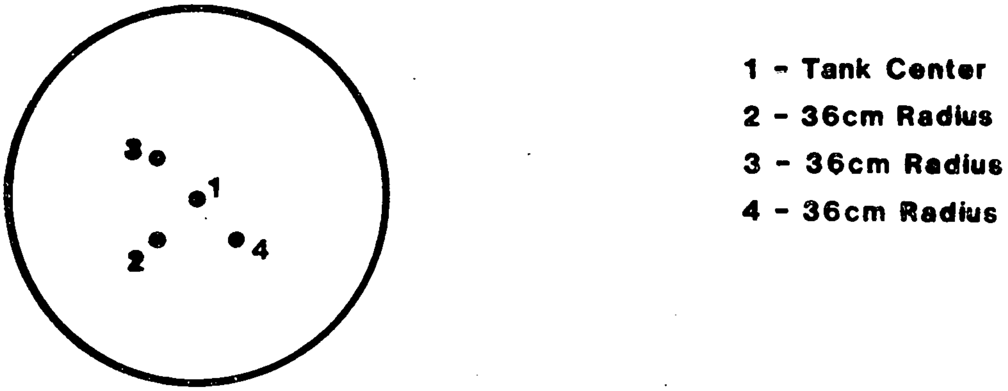


FIGURE 3.3

WAVE PROBE LOCATIONS GENERATOR FREQUENCY 1.33

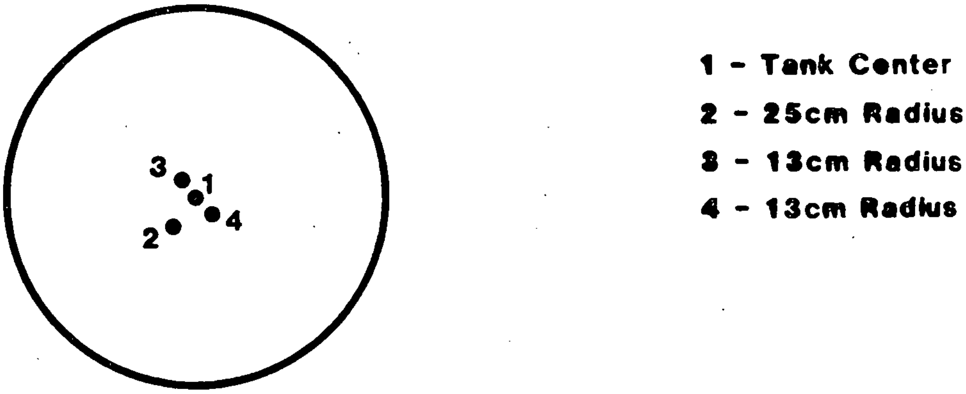


FIGURE 3.4

WAVE PROBE LOCATIONS GENERATOR FREQUENCY 2.13

intervals. A slight amount of drift was evident in the instrument outputs due to rundown of the power supply batteries. To obtain the conversion factor from volts to cm the best linear fits obtained from the two sets of data were averaged. Using this technique, output data values are accurate to within 2 percent of reading over a range of plus or minus 12 cm. The wave probe response time was found to be instantaneous if the probe remained clean. However, any water contaminants would increase the response time dramatically, up to a few seconds in some cases. This is a result of water adhering to the probe wires and draining off slowly. To ensure adequate response, the probes were oscillated at known amplitudes while their output was checked on an oscilloscope. These tests were performed before each experiment to insure that the probe readings were not affected by any surface contaminants.

Overhead still photographs and slow motion movies were taken to supplement the data and to further document the wave field. Before the tests the tank was allowed to settle for 1 hour. Any visible debris was either skimmed off the water surface or extracted from the tank. The wave generator was run for 15 minutes to allow conditions in the tank to reach steady-state before any measurements were taken.

To analyze the data for frequency components using fast fourier transforms, the necessary sampling frequencies and recording times were chosen by following the procedure outlined in Bendat and Piersol* (1). A sampling interval $\Delta h = T$ was chosen so that

$$\Delta h = 1\ (2fc) \leq 1/\ (2fd) \text{ sec.}$$

where f_c is the Nyquist folding frequency, and f_d is the highest possible frequency expected in the data. If $f_d = 20$ hz (an extremely conservative estimate):

$$\Delta h = 1/2\ (20) = 0.25 \text{ sec.}$$

To achieve an effective resolution bandwidth B_e of 0.1 hz requires that each sample record be T_r seconds long where

$$T = 1/f = 10 \text{ sec.}$$

Choosing a 512 point record sampled at $\Delta h = 0.025$ seconds gives $T_r = 12.6$ seconds.

The random error is minimized by segment averaging. If the original data is assumed to be Gaussian, the normalized standard random error ε_r is given by

$$\varepsilon_r = \sqrt{1/q}$$

where q equals the number of ensembles of length T_r. Therefore, if

$$\varepsilon_r = .1,\ q = (1/\varepsilon_r)^2 = 100$$

---

*References denoted by numbers in brackets.

and the total record length T required is:

$$T = qT_r = 100\ (12.6)\ \text{sec.} = 21\ \text{min.}$$

As a result of the foregoing analysis, 25 minute records sampled at 40 hz were obtained for each probe location.

3.3.2. Current Measurements

The surface drift currents created by the water waves propagating toward the tank center induce a subsurface return flow directed radially outward. This circulation could be easily observed by watching the motion of neutrally buoyant particles of debris. Unfortunately, the extremely low flow velocities present precluded the use of conventional instruments to obtain velocity profiles.

Measurement of the average convective circulation velocities were made using Rhodamine dye. Four experiments were performed to measure radial and circumferential water velocities as well as to estimate the time necessary to uniformly mix contaminants throughout the tank. The experimental procedure was as follows: the wave generator was run for one hour to ensure that steady-state conditions had been achieved. Then, 30 ml of Rhodamine B dye which had been diluted to be within 1 percent of the specific gravity of the tank water was applied to the center of the tank. Thirty ml water samples were then taken from the sampling valves located at the edge of the tank. The samples were taken at equally spaced time intervals, the time intervals were varied from experiment to experiment. Dye concentrations were later determined by flourescence measurements with a Turner model 111 fluorometer. Average current velocities could then be found by computing the time differences between measured concentration peaks.

In addition to these tests, numerous visualization experiments were performed with the dye to further establish the magnitude and direction of the water velocity throughout the tank and to locate any eddies. Also, surface current velocities were measured by timing the travel of 5 cm square paper drifters over the 3 paths shown in Figure 3.33.

3.3.3. OIL CONCENTRATION MEASUREMENTS

The amount of oil dispersed into the water column at any given time was determined by chemically analyzing 0.5 liter water samples taken from three depths under the slick (see Fig. 3.34). To minimize any disturbances to the experiment while tests were underway, the water samples were obtained through 4 foot lengths of 7 mm outside diameter glass tubing fixed to the valves at the edge of the tank. Visualization experiments were conducted to estimate the effect that the tubes would have on the sampled oil-water dispersion. It was found that in all cases the predominant oil droplet diameter was significantly less than the 5 mm inside diameter of the tube.. Almost all of the oil droplets ducted through the tube were collected intact. Consequently, the effect of the glass tubes on the oil concentration in the samples was thought to be minimal.

A. Sampling and Analysis

The number of water samples taken and the sampling times were determined by the time scales of the physical processes to be investigated, and by the amount of available equipment. The ten experiments conducted can be divided into three groups. The first two experiments were preliminary tests to check equipment and procedures. For these tests, one water sample was taken from each of the three tank locations 120, 240, and 480 minutes after the oil was added. When visible changes in the oil slick were observed to take place within the first hour after the oil was added, a new sampling scheme was devised. In the next three experiments water samples were taken 10, 20, 40, 80, 160, 320, 480 and approximately 1440 minutes after the oil was added. The final sampling scheme, used in the last five experiments, was devised to document changes in oil dispersion with weathering and to obtain some estimate of the data scatter. At each sampling time, three 0.5 liter samples were taken from each of the three tank locations shown in Figure 3.34 for a total of nine samples per time. The sample times were 10, (only three samples were taken), 20, 160, 480, and approximately 1440 minutes after the oil was added. In all the experiments, three water samples to be used as background measurements were obtained before any oil was added to the tank. These samples were taken from the same three tank locations after the wave generator had run for one hour. In addition, samples were obtained one half hour after the wave generator was shut down.

B. Extraction Procedure

All the water samples obtained in these tests were analysed using a well known but tedious chemical extraction procedure. Briefly, the procedure involves washing the oil-water mixture a number of times with a solvent that dissolves the oil but is unsoluble in water. In this case, CCl_4 was used. The oil concentration in the solvent was then determined by measuring the light absorbance at the fundamental resonant frequency of the carbon-hydrogen bond (k-2930 cm^{-1}) on an infrared spectrophotometer. The absorbance is a linear function of the concentration of hydrocarbons present in the solvent. Thus the total amount of extractable hydrocarbons are measured. The concentration of hydrocarbons in the water sample due solely to the oil can be determined by subtracting out the background hydrocarbon concentration measure in the samples without oil. This entire analysis procedure has several disadvantages: it is expensive, time consuming, and extremely sensitive to contaminants. Unfortunately, there appears to be no better alternative.

Before any experiments were performed, the extraction procedure was extensively tested to document its efficiency and accuracy. It was found that violent agitation of the oil-water-solvent mixture increased the efficiency of the procedure dramatically. Calibration curves of absorbance verses concentration were created by mixing known quantities of Kuwait crude oil with CCl_4 and measuring the absorbance. A complete discussion of the extraction procedure tests can be found in section 12.5.

The complete water sample analysis procedure that was used for all the oil dispersion experiments was as follows:

i) All glassware was cleaned with laboratory cleaner (Alconox). Separatory funnels and dram bottles were rinsed with CCl_4 immediately before use.

ii) Water samples were obtained by draining 0.5 liters of the tank water directly into 0.5 liter capacity separatory funnels fitted with teflon stopcocks and valves. A 30 ml aliquot of CCl_4 was then added immediately. The funnel was then shaken lightly and set aside for later extraction.

iii) The oil was extracted by violently shaking the oil-water-CCl_4 mixture in the separatory funnel on a modified paint shaker for 20 seconds. The mixture was allowed to settle and separate for 15 minutes. The oil laden solvent was then slowly drained off into a dram bottle.

iv) An additional 30 ml of CCl_4 was then added to the water remaining in the separatory funnel and step iii was repeated. The dram bottle was then tightly capped and stored in a dark place until the IR analysis was performed.

v) The oil concentration was measured using a Perkin-Elmer Model no. 457 grating infrared spectrophotometer with 5 cm pathlength quartz cuvettes. The relative light transmittence z between k 3200 cm^{-1} and k 2930 cm^{-1} was determined by zeroing the machine at k 3200 cm^{-1} and letting it scan down to k 2800 cm^{-1}. The absorbance was then computed from a $\log_{10}(100/z)$, and the organic concentration in the CCl_4 was read off the calibration curve. Water sample organic concentration was then computed using the following equation:

$$[\text{Total Organic Concentration In Water } (\text{mg}/\ell)] = [CCl_4 \text{ Analyzed (ml)}] \times$$

$$\text{Total Organic Concentration In The } CCl_4 \ (\text{mg}/\ell)] \times \left[\frac{1\,\ell}{1000\text{ ml}}\right] \times \left[\frac{1}{\text{Water Sample Size } (\ell)}\right]$$

The estimated oil in water concentrations were established by subtracting out the background organic concentrations determined from the first three tank samples.

As a result of the preliminary experiments to test the extraction procedure, the overall extraction efficiency i.e., the percentage of the organic material extracted out of the water sample during each aliquot, was found to be about 90 percent. Because this is a relatively high value, in the interest of economy the second aliquot was not taken for some of the experiments. Consequently, all the concentration data presented in Table 3.2 are computed from the results of one aliquot.

3.3.4. Oil Dispersion Experiment Test Procedure

The following standard experimental test procedure was used in the ten oil dispersion experiments:

i) The tank and wave generating apparatus were cleaned thoroughly by scrubbing with a wire brush and solvent (National Chemsearch ND 150) and then rinsed completely.

ii) The tank was filled to a depth of 71 cm (3470 liters) with either fresh or filtered salt water.

iii) The wave generating hoop was installed and adjusted so that at the top of its stroke 1/4 of the hoop diameter was submerged. The hoop was adjusted to be parallel to the water surface. The desired generator speed, either 1.33 or 2.13 cycles per second was selected. The generator amplitude for all the experiments was fixed at 7.6 cm.

iv) The wave generator was run for one hour at the desired speed. At the end of the hour, background water samples were taken from the three sampling locations shown in Figure 3.34. In addition, one liter surface samples to be used for water property measurements were also taken at this time.

v) An 8 mm movie camera (Sankyo Super 8) was installed over the tank and adjusted to shoot either one frame every five seconds or every ten seconds. The camera was activated one minute before oil was added to the tank.

vi) Standard Kuwait crude oil was added to the tank (60 or 120 ml.) by pouring down a glass plate to inhibit any initial dispersion.

vii) Three 1/2 liter water samples were taken at the locations and times described in the sample analysis procedure. Samples were immediately preserved with the first aliquot of CCl_4. 35 mm photographs were taken of the water surface and the water column directly after the sampling. Water temperature, air temperature, and any observations were also recorded.

viii) The samples were processed as outlined in the sample analysis procedure.

ix) The first three tests operated for a duration of eight hours while the last seven tests lasted for 24 hours. Additional water samples were taken 1/2 hour after the wave generator was shut down.

Table 3.2 Concentration Data, First Aliquot Only

CONCENTRATION DATA
MG HYDROCARBONS/LITER H_2O — 1st ALIQUOT ONLY — Not Corrected for Extraction Efficiency

TIME (MIN.) After oil Added	location	EXPERIMENT NO. 1	2	3	4	5	6	7	8	9	10
0-											
	1	.47	.08	.03	.03	.00	.00	.11	.03	.00	.00
	2	.16	.04	.00	.03	.00	.08	.00	.03	.181	.00
	3		.00	.02	.00	.00	.05	.00	.03	.116	.00
		oil added at time 0+ (immediately after 3 samples above obtained)									
10											
	1			4.21	6.70	8.49	5.52	1.26	12.00	2.38	5.44
	2			2.71	2.29	6.42	3.73	1.25	5.51	1.88	.84
	3			0.28	10.32	5.06	1.19	.49	6.28	1.63	1.15
20											
	1a				1.62	10.29	4.36	1.41	9.15	3.35	4.98
	1b						8.66	4.33	16.9	2.54	6.22
	1c						7.82	3.87	8.02	3.60	3.14
	2a			1.65	.862	8.39	3.05	6.64	11.5	2.13	2.74
	2b						3.03	4.37	3.64	3.26	2.10
	2c						3.23	3.28	4.60	2.12	3.58
	3a			.62	2.75	3.92	2.06	2.28	1.09	2.09	2.50
	3b						2.63	1.80	2.07	1.43	2.19
	3c						2.36	1.41	1.06	2.07	2.65
40											
	1			9.27	21.97	6.42					
	2			5.36	3.92	7.56					
	3			2.75	5.20	5.08					
80											
	1			8.64	28.18	3.76					
	2			3.64	12.39	9.33					
	3			1.73	7.55	4.48					
120											
	1	.88	1.90								
	2	.91	.32								
	3	2.41	.40								
160											
	1a				15.16	5.78	11.1	12.43	12.5	3.07	7.99
	1b						6.30	5.01	10.2	2.50	7.61
	1c						11.5	27.57	15.0	3.04	6.22
	2a			4.14	9.77	6.85	9.45	10.93	5.86	2.38	6.21
	2b						4.67	17.56	5.44	1.80	5.39
	2c						4.65	5.76	7.74	1.76	4.76
	3a			4.47	3.95	4.90	5.25	5.17	2.40 .028	3.82	6.57
	3b						2.83	4.16	1.45 .029	2.15	4.98
	3c						3.15	4.05	1.29 .028	1.89	6.29
240											
	1	1.01	* .54								
		.99	.30								
		.56	.39								

Table 3.2 Concentration Data, First Aliquot Only (Cont'd)

TIME	EXPERIMENT NO.									
(MIN.)	1	2	3	4	5	6	7	8	9	10
320										
1			6.53	26.26	4.14					
2			7.92	11.10	2.54					
3			4.99	14.84	3.71					
480										
1a	.85	.60	7.77	18.77	3.93	19.5	33.3	*8.73	3.32	8.17
1b						10.0	16.5	4.97	3.95	6.91
1c						8.58	25.0	37.8	2.82	10.39
2a	.84	.40	4.28	10.63	3.32	11.7	9.88	2.57	2.99	8.02
2b						6.93	5.62	2.27	2.67	7.71
2c						8.29	4.64	5.46	3.16	6.83
3a	.54	.58	4.97	5.21	3.85	11.4	4.34	.77	2.92	15.22
3b						7.42		2.74	1.80	6.03
3c						5.58	3.82	1.92	.86	7.64
1440*										
TIMES				1340	1440	1430	1495	1495	1595	1760
1a				*2.72	3.03	*20.7	*9.47	**19.7	*31.41	*8.38
1b						17.6	3.26	2.89	31.13	7.15
1c						15.1	1.58	3.42	83.31	
2a				24.75	2.43	19.2	5.05	3.29	88.91	7.77
2b						19.4	1.10	1.20	10.38	8.86
2c						12.7	2.21	.53	8.79	7.78
3a				1.53	2.73	37.4	4.56	.92	15.64	13.08
3b						10.2	1.44	.44	4.32	12.12
3c						11.2	2.38	2.84	4.29	5.89
Wave Generator Shut Down Time	490	490	490	1360	1450	1440	1510	1500	1605	1780

*NOTE: 1440 minutes is the nominal time for the last water samples. The actual sampling times are listed in each column.

3.4. CHARACTERISTICS OF EXPERIMENT

3.4.1. WAVE MEASUREMENTS

Sample water surface elevation records for four of the wave staff locations shown in Figures 3.3 and 3.4 are presented in Figures 3.5 through 3.8. The data for these plots was extracted from much longer samples used for a spectrum analysis. Note the difference in amplitude scales from figure to figure.

A. Observations

The wave patterns produced by the wave generator operating at 1.33 cycles per second are shown in Figures 3.9 through 3.13. These figures are all photographs taken of experiment 6. Figure 3.9 shows the regular concentric wavefronts spaced approximately 9 inches apart. Here they continue all the way to the tank center and concentrate the oil in a small area. By contrast, Figure 3.10 shows a more random pattern of waves with a much larger region of oil submergence. Generally, the oil was dispersed by either breaking or collasping waves within a 36 inch diameter region at the center of the tank, and the random pattern of Figure 3.10 was more prevalent. However, the most intense breaking and the highest waves usually occurred at the center.

The waves created at the 1.33 cycle per second generator frequency ranged in height from one to six inches at the tank center. They were generally steeper than waves normally seen in the ocean. Figures 3.11 through 3.13 show some of the different wave shapes produced. Most waves resembled plunging breakers often seen at beaches (Fig. 3.11). Other waves were shaped like small pyramids and would collapse straight back on themselves (Fig. 3.12). In the most extreme cases, the disturbance resembled small jets of water that would shoot straight up about six inches and then fall straight back into the water column (Fig. 3.13). The frequency of occurrence of any of these wave shapes appeared to depend on the radial symmetry of the wavefronts created, with the most symmetric wavefronts producing the most extreme and localized disturbances. Although it was possible to affect the location of the most intense wave action by tilting the generating hoop, it was not possible to create a given type of wave simply by changing adjustments. The wave pattern existing at any give time depended on the interaction between the generated waves, the waves reflected off the tank walls, and the waves that had previously interfered and collapsed.

The actual water surface area covered by each individual breaking wave ranged up to 1 inch by 3 inches. The median area can be estimated by observation to be about 1 by 2 inches. While the waves in the tank clearly collapse as do breaking waves in the ocean, much less air is entrained by the water. Consequently, the waves do not have the characteristic appearance of "whitecaps". Each collapsing wave injected a plume of water into the water column which could be visualized by following the motion of oil droplets or entrained air bubbles. The observed plume depth was directly related to the height of the collapsing surface

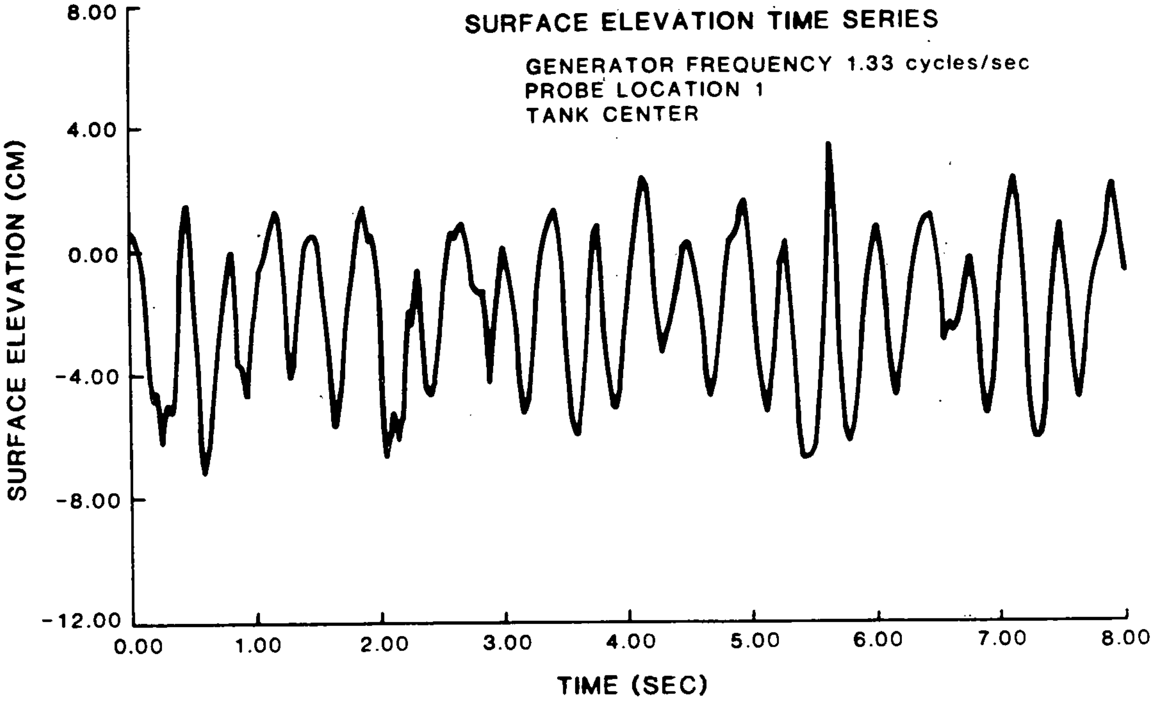


Figure 3.5. Surface Elevation Time Series Probe Location 1

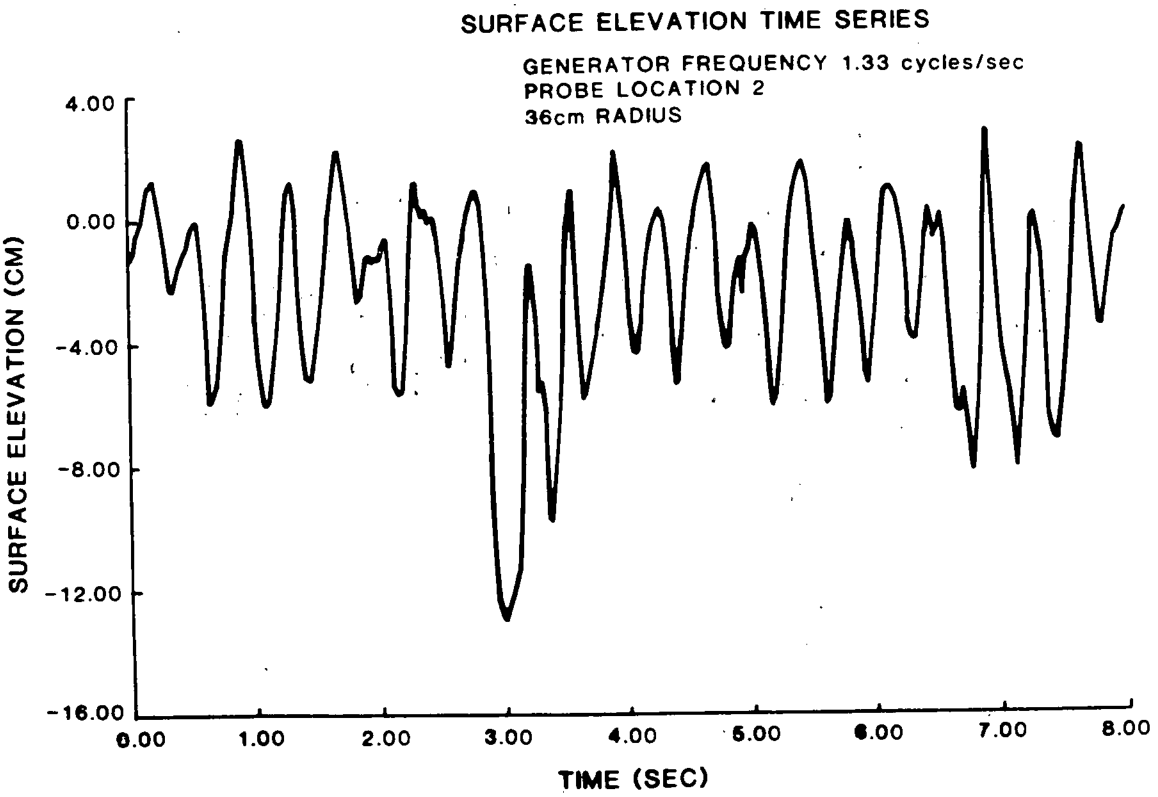


Figure 3.6. Surface Elevation Time Series Probe Location 2

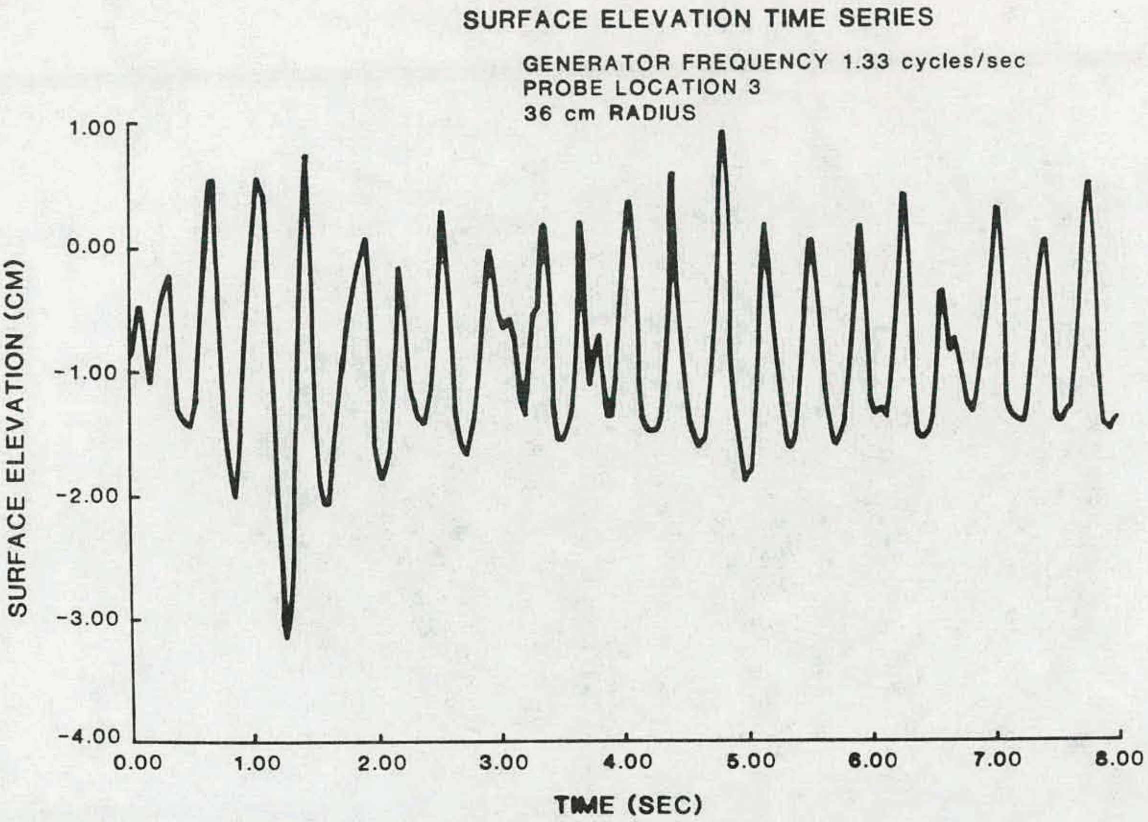


Figure 3.7. Surface Elevation Time Series Probe Location 4

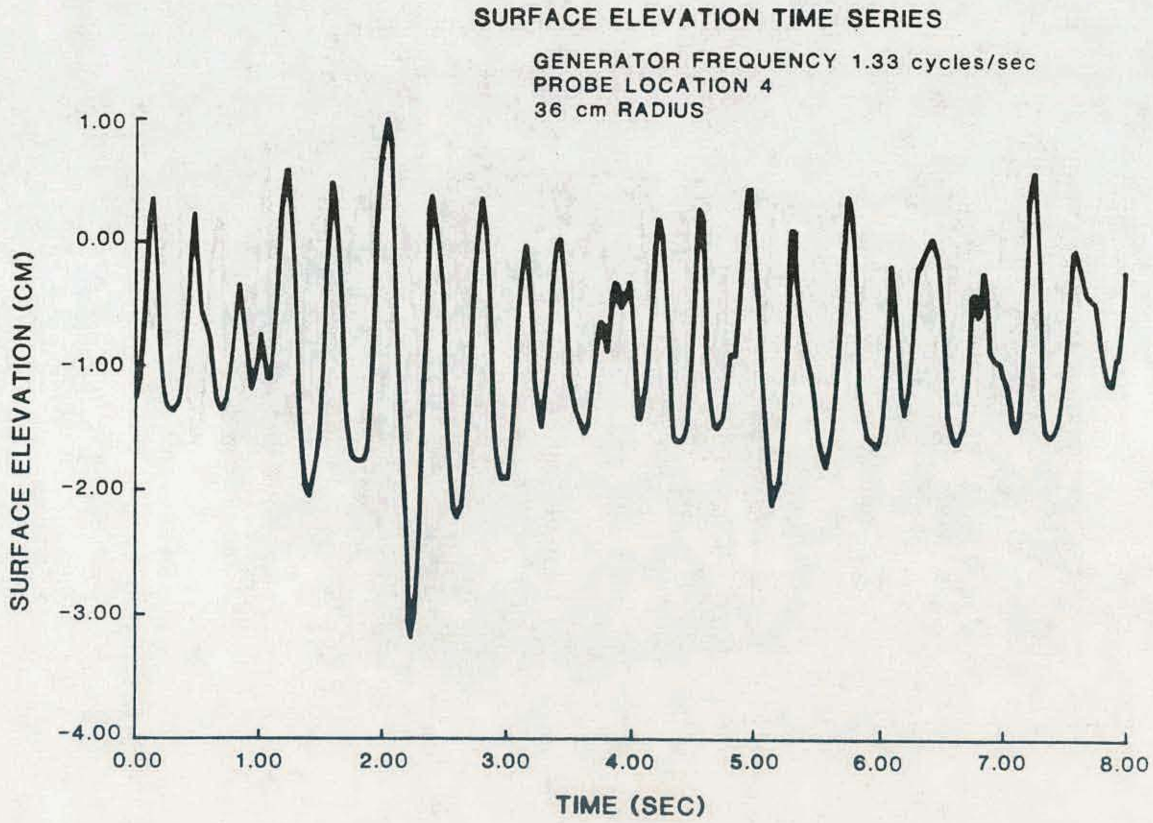


Figure 3.8. Surface Elevation Time Series Probe Location 4

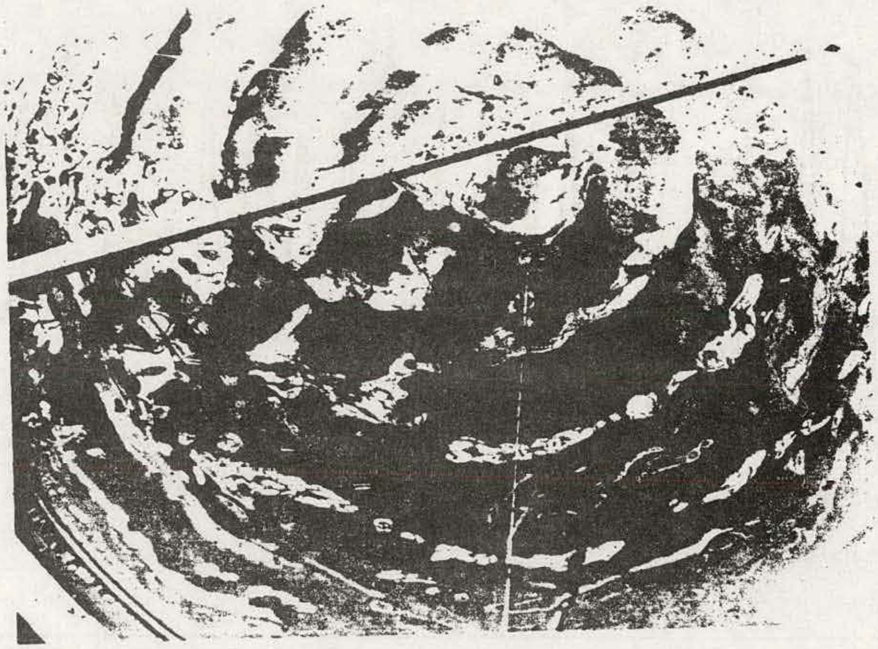


Figure 3.9. Wave Fronts 1.33 CPS

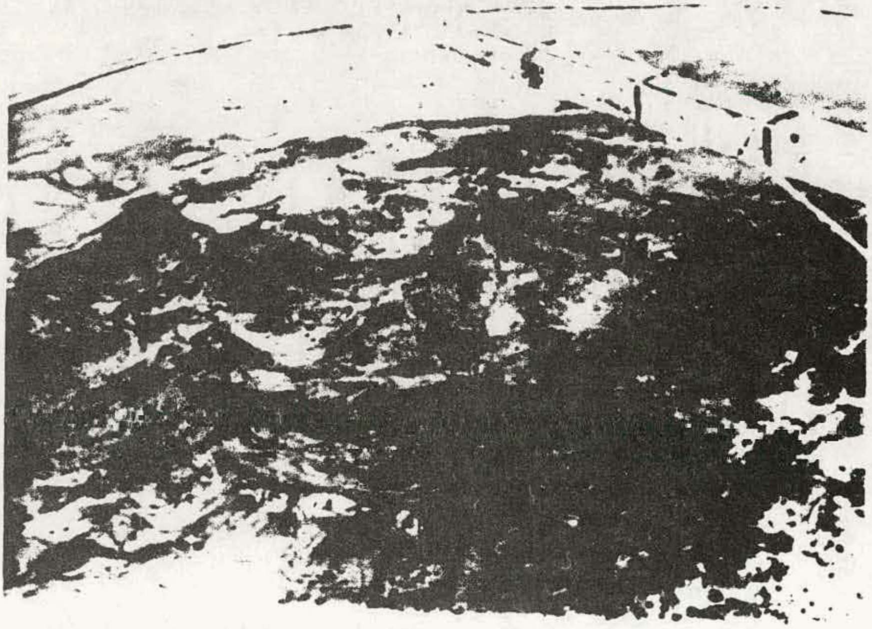


Figure 3.10. Random Waves at Center

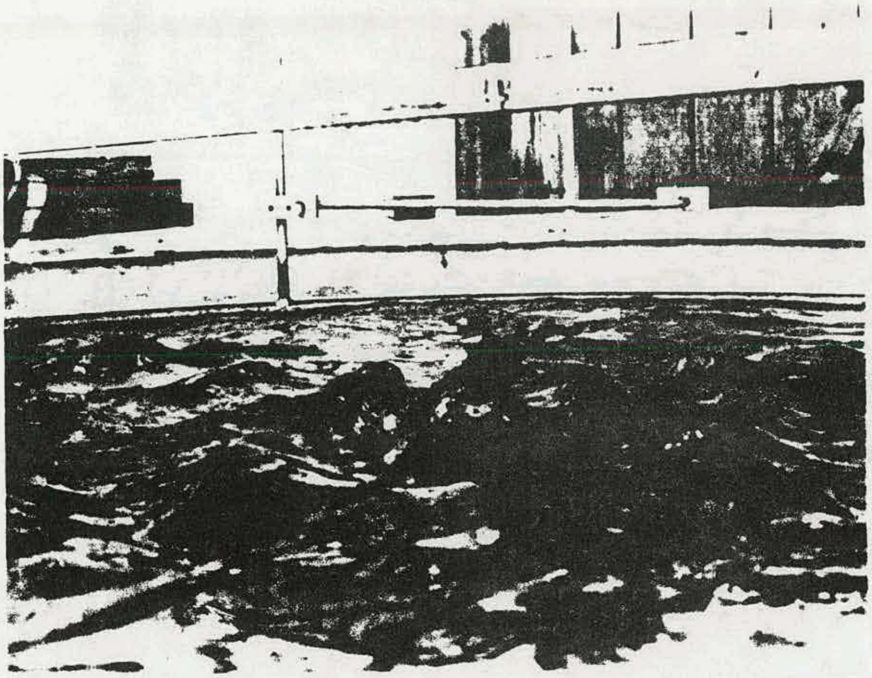


Figure 3.11. Wave Shapes

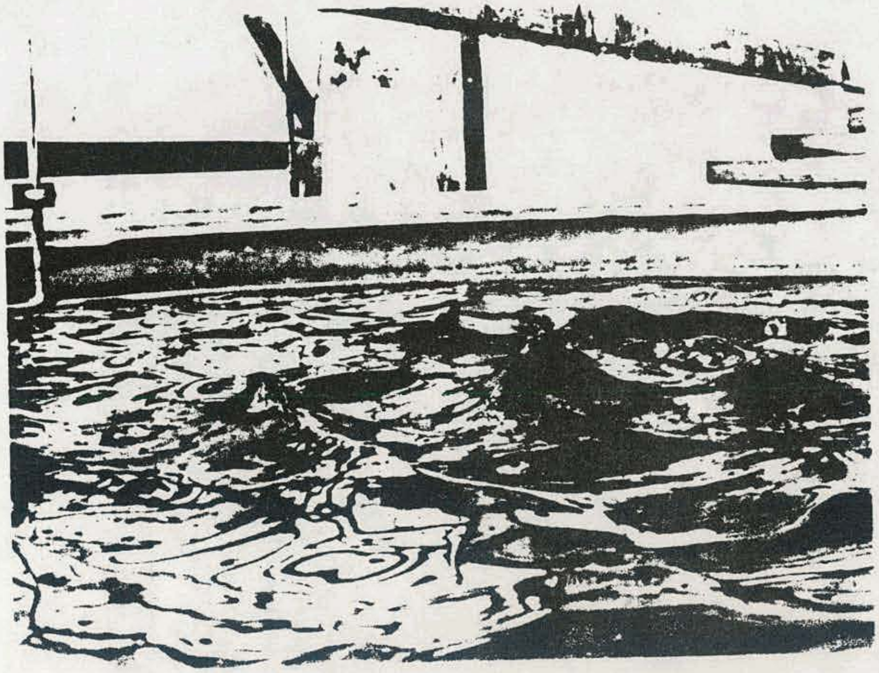


Figure 3.12. Wave Shapes

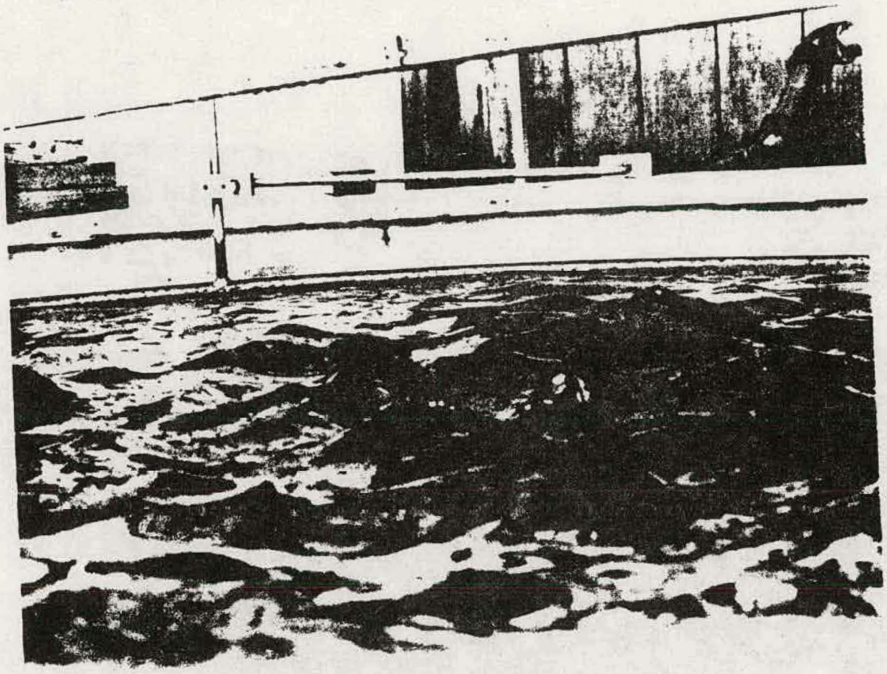


Figure 3.13. Wave Shapes

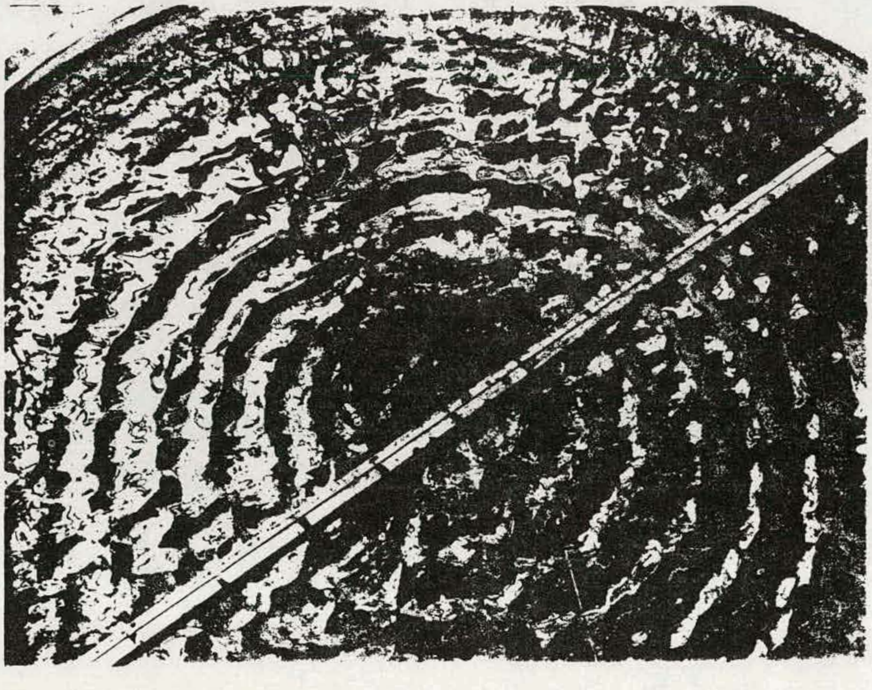


Figure 3.14. Wave Pattern 2.13 CPS

Figure 3.15. Wave Pattern 2.14 CPS

wave, and in all cases the depth appeared to be roughly equal to the wave height.

Waves created at the faster (2.13 cycle per second) wave generator frequency are more closely spaced, smaller, and caused less intense individual disturbances in the tank. Figure 3.14 through 3.15, taken of tests 5 and 7, show the wave characteristics. From Figure 3.14 the crest to crest distance can be estimated at about 4 inches. It can also be seen that the oil is contained in a much smaller region (approximately 18 inches in diameter). The smaller waves did not display the variety of shapes evident at the lower generator frequency. Most of the waves near the tank center were pyramid shaped and tended to collapse back upon themselves. (See Fig. 3.15).

B. Results and Discussion

Applying fourier transforms to the recorded wave data results in the power spectral density plots shown in Figures 3.16 to 3.23. The transformations confirm that the dominant frequency of the waves produced by the generator operating at 1.33 cycles per second is 2.67 cycles per second, or twice the generator frequency. The waves produced by the 2.13 cycle per second generator frequency have important components at 2.1 and 4.2 cycles per second.

The total ENERGY, potential and kinetic, per unit area of the water surface contained in a simple harmonic progressive wave train equals (Ref. 3.2):

$$1/2\ \rho\ g\ a^2 \text{ or } 1/8\ \rho\ g\ H^2$$

where

ρ = water density
g = gravitational acceleration
and H = 2a = wave height.

The ordinate in the graphs of the wave spectral distribution is in units of the square of the fourier coefficients or the square of the amplitudes of the frequency components. Thus the ordinates are in units of wave energy. The root mean square wave height may be obtained by integrating under the spectral peaks and taking the square root:

$$H_{RMS} = 2\sqrt{\int_0^\infty \left[a\ (f)\right]^2 df}$$

and

$$H \text{ peak} = \sqrt{2}\ H_{RMS}$$

a numerical integration of the fourier transformed wave data was performed using a trapazoidal approximation. The results are presented below:

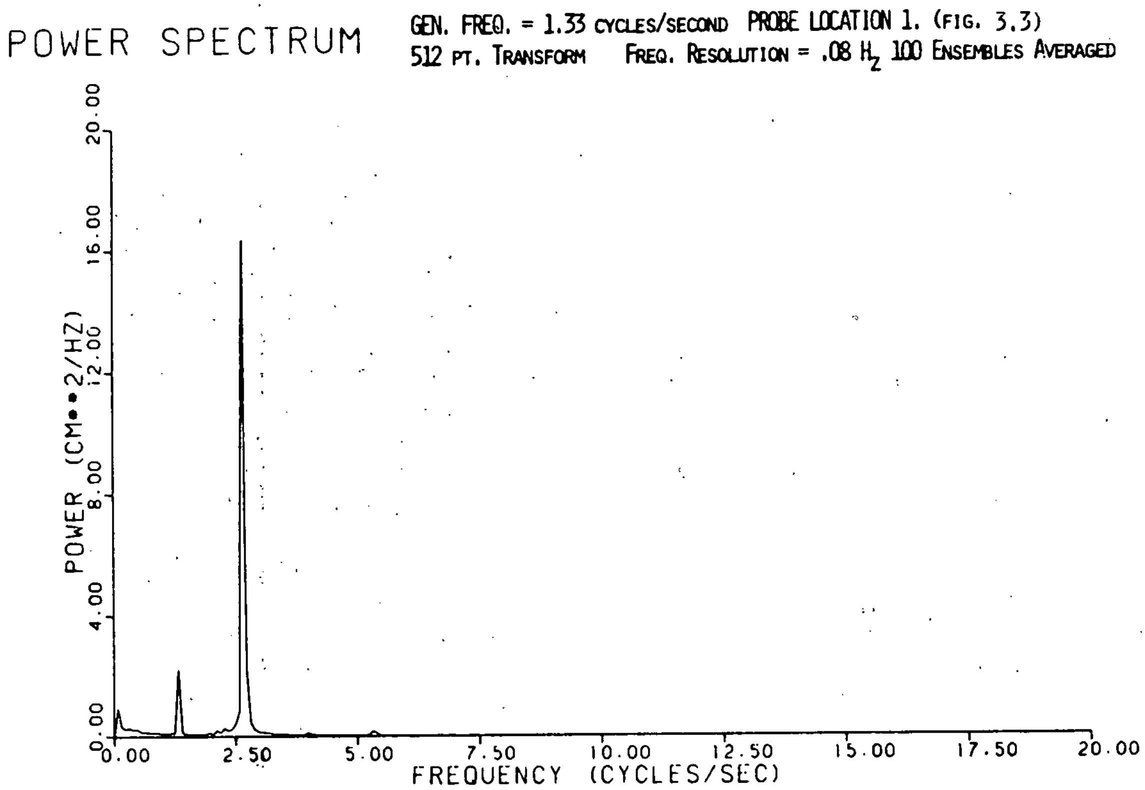


Figure 3.16. Power Spectrum Probe Location 1 512 Pt. Transform

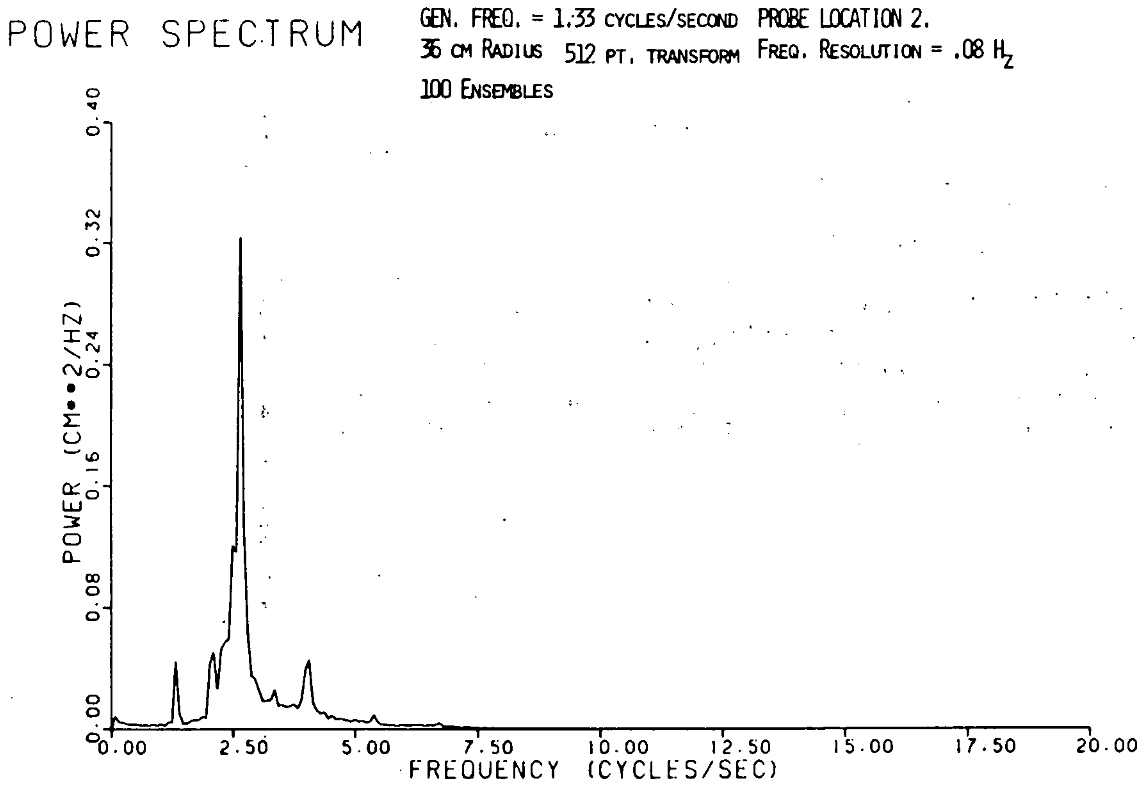


Figure 3.17. Power Spectrum Probe Location 2 36 cm Radius

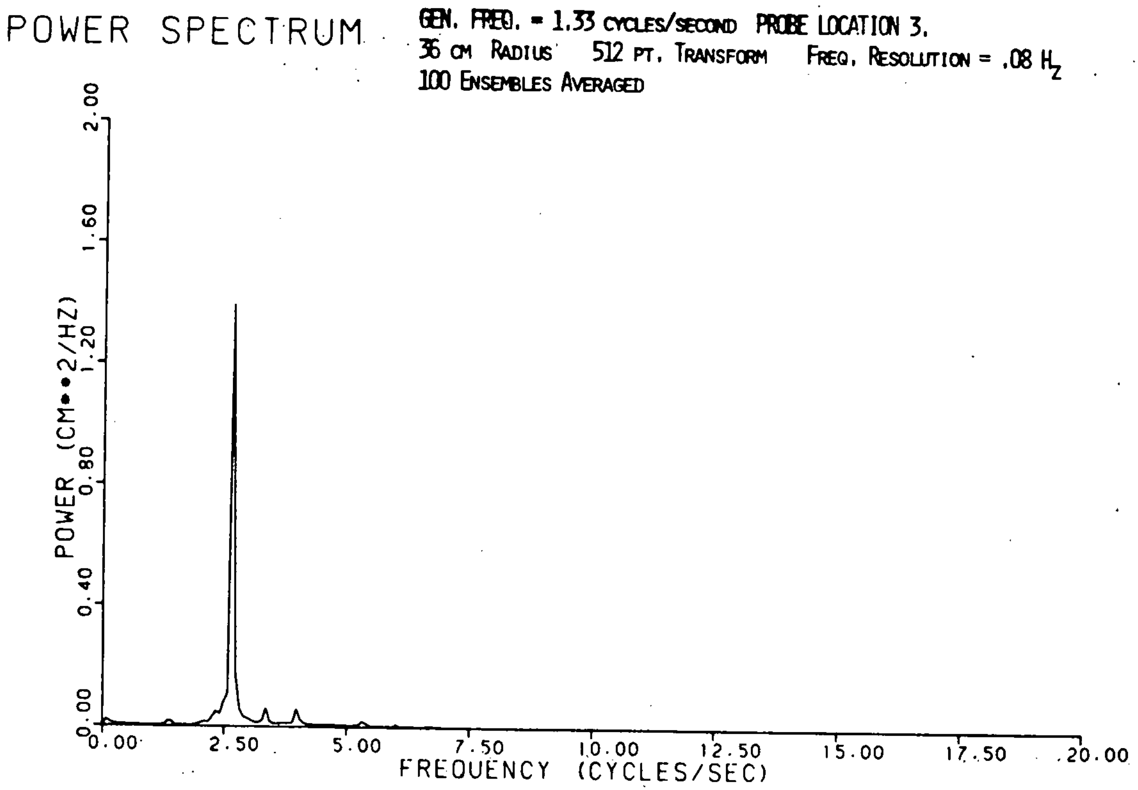


Figure 3.18. Power Spectrum Probe Location 3 36 cm Radius

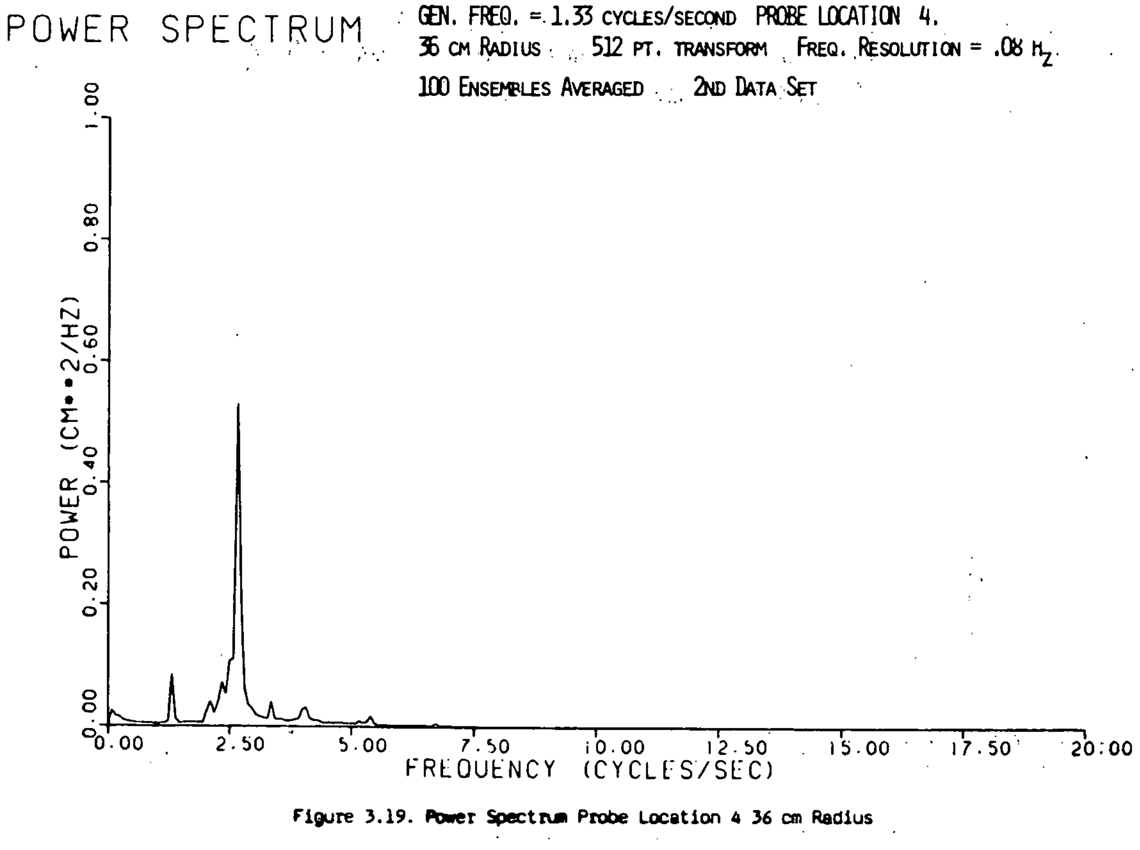


Figure 3.19. Power Spectrum Probe Location 4 36 cm Radius

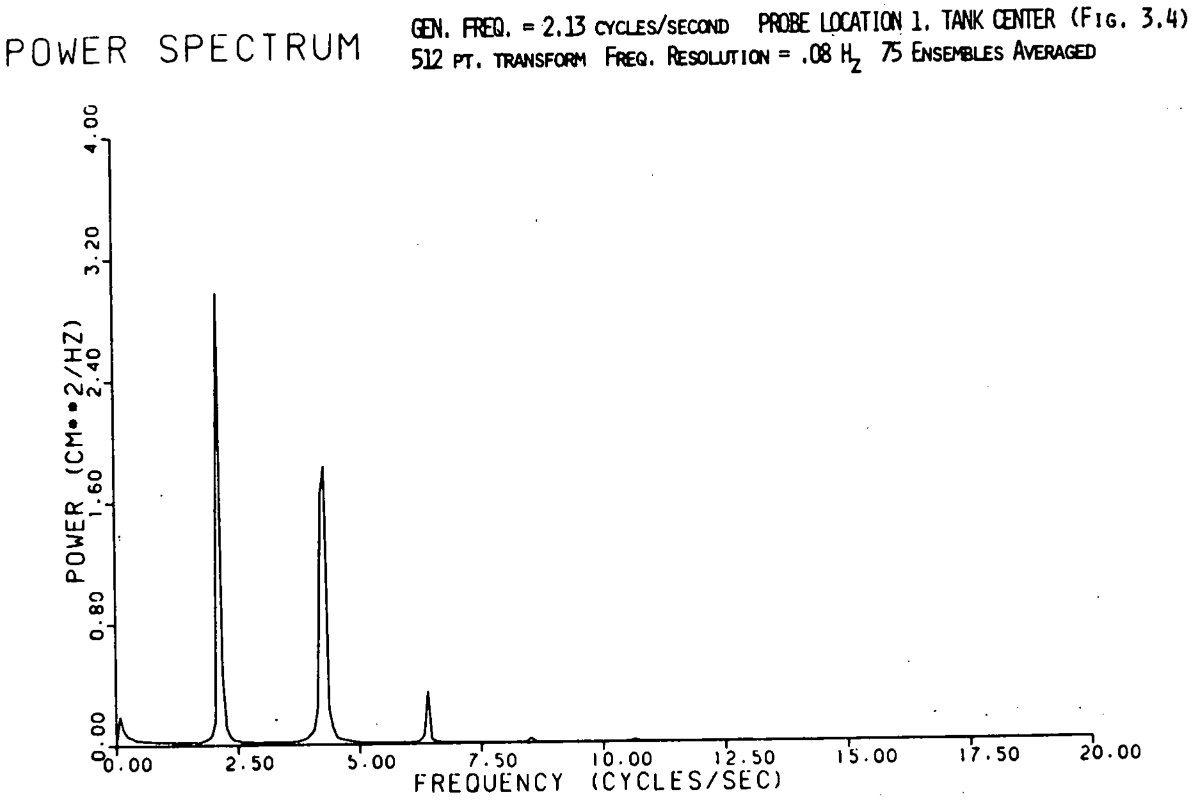


Figure 3.20. Power Spectrum Probe Location 1 512 Pt. Transform

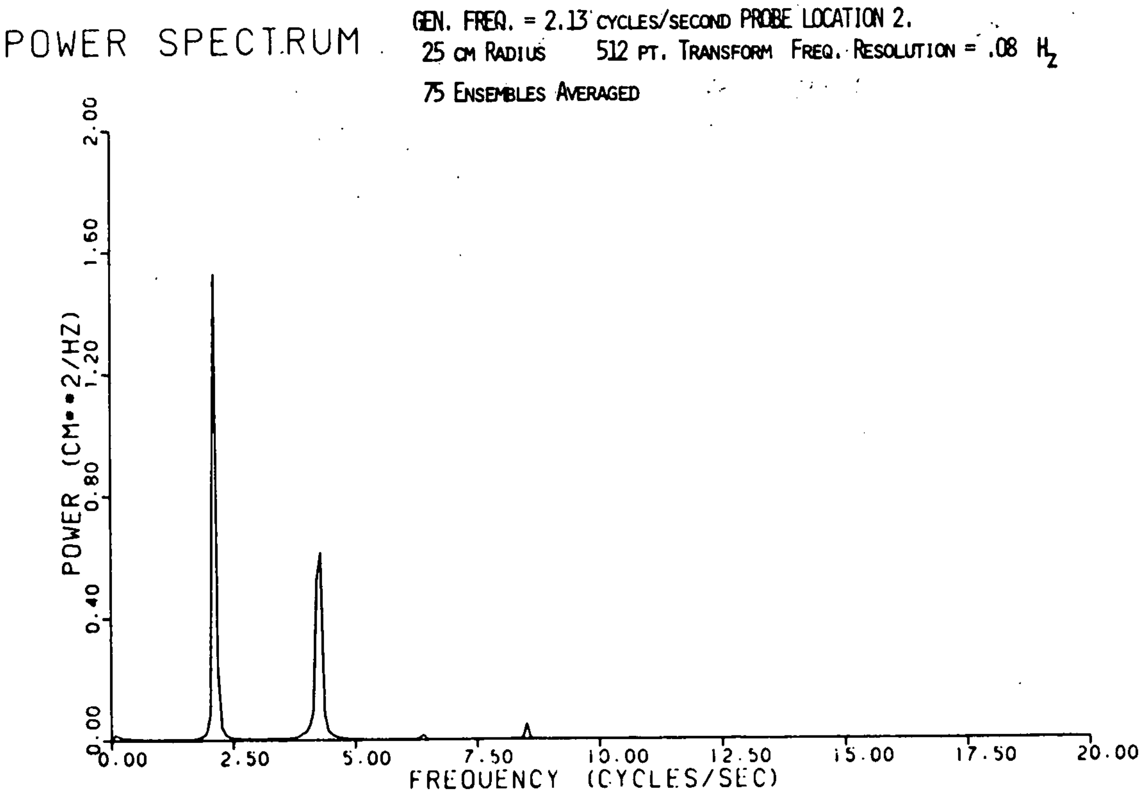


Figure 3.21. Power Spectrum Probe Location 2 25 cm Radius

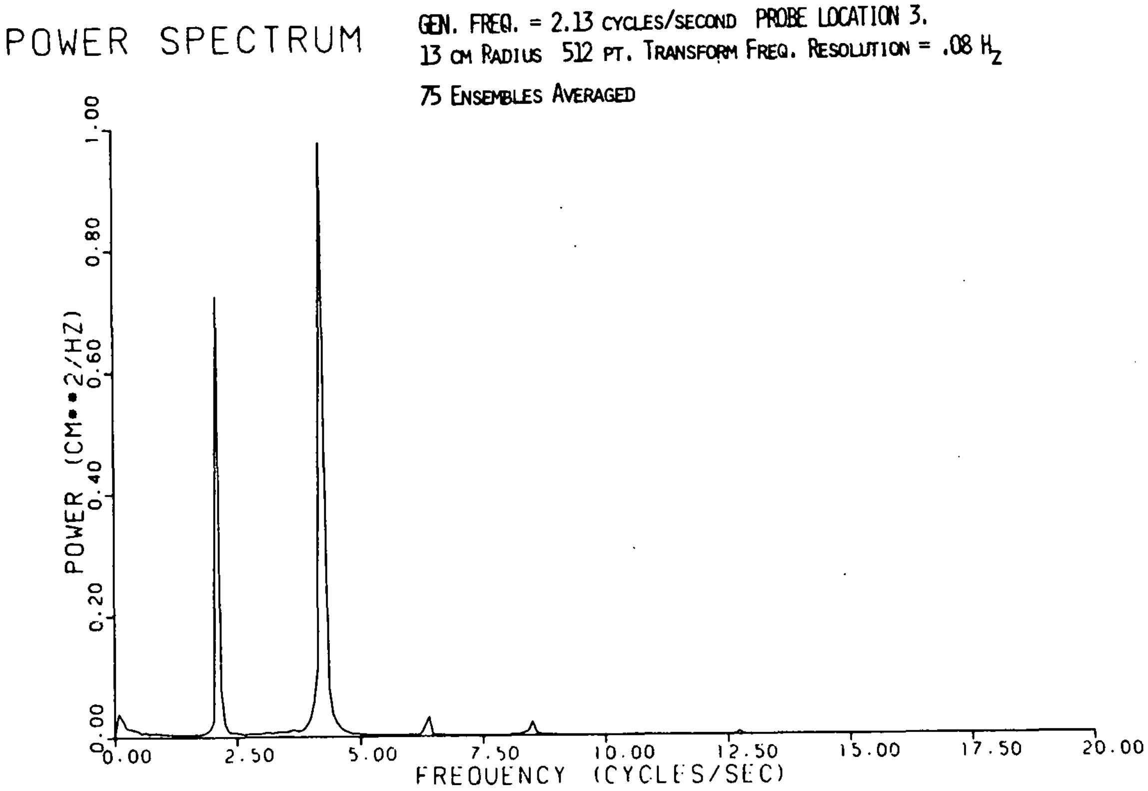


Figure 3.22. Power Spectrum Probe Location 3 13 cm Radius 512 Pt. Transform

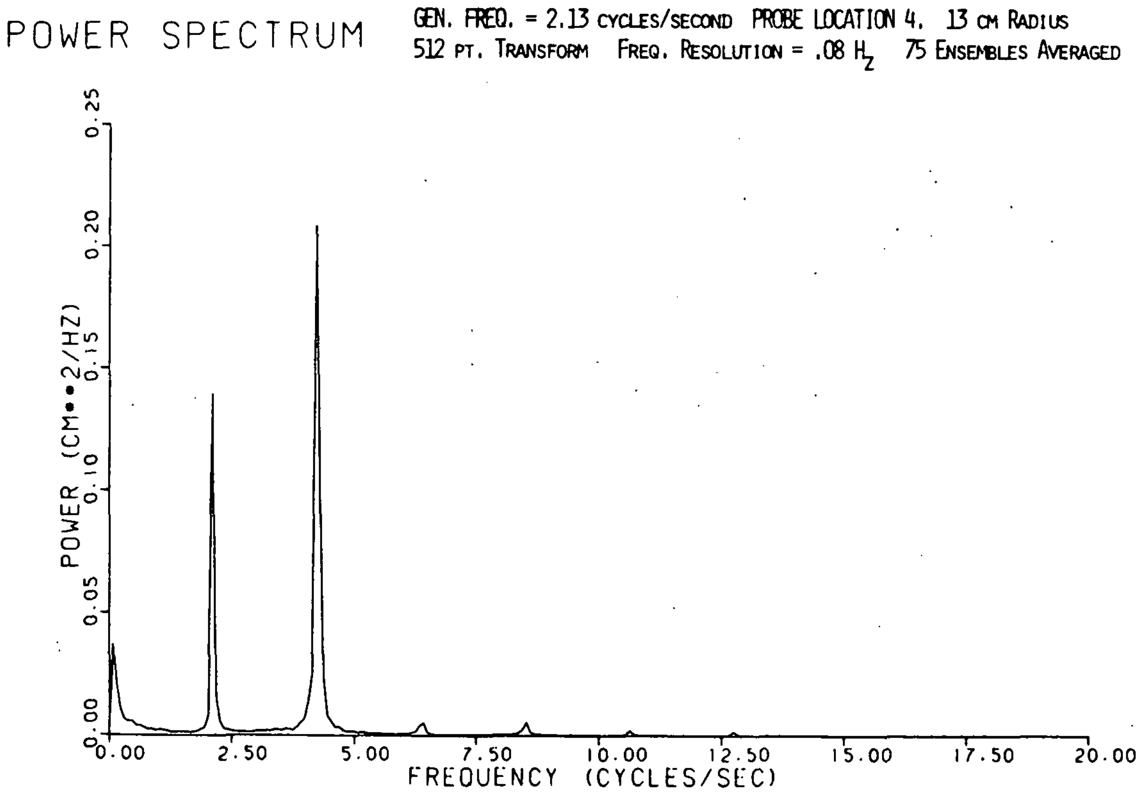


Figure 3.23. Power Spectrum Probe Location 4 13 cm Radius 512 Pt. Transform

Expt. 1 Wave Generator Frequency = 1.33 cycle/second

1. Measurement Location: (see Fig. 3.3)	1	2	3	4
2. Wave Frequency: (cycles/second)	2.67	2.67	2.67	2.67
3. Peak to Peak Wave Height: (cm)	6.2	1.8	1.4	1.6

Expt. 2 Wave Generator Frequency = 2.13 cycles/second

Measurements Location: (see Figure 3.4)	1	2	3	4
Wave Frequency (cycles/second)	2.1	2.1	2.1	2.1
Peak to Peak Wave Height: (cm)	2.4	1.6	1.2	0.4
Wave Frequency: (cycles/second)	4.2	4.2	4.2	4.2
Peak to Peak Wave Height: (cm)	2.4	1.4	1.6	0.8

The results show that except for Location 4 of the second experiment, the waves are approximately the same average height at equal tank radii, and that the wave height grows as the waves approach the center, which is expected from energy conservation principles. As the wave fronts travel toward the center of the tank, the energy per unit area must remain the same (not counting frictional losses). This is accomplished by an increase in wave height until a limiting value is reached at which point the wave collapses. Examination of the wave data from location 4 of the second experiment show that after about ten minutes, the recorded wave amplitudes are significantly lower. It is believed that the wave probe was fouled by debris in the tank making the data from this probe suspect.

A theory for water waves of finite heights was developed by Stokes in the nineteenth century. The theory solves the wave equation with the wave parameters input in the form of a truncated infinite series. Results are also in series form. A discussion of the second and third order results can be found in Ref. (3.2) and (3.3). The second order theory gives the following equation for the wavelength and celerity.

$$L = \frac{gT^2}{2} \tanh \left(\frac{2\Pi h}{L}\right)$$

$$C = \frac{gT}{2} \tanh \left(\frac{2\Pi H}{L}\right)$$

If the quantity in parentheses is large (> 3), the value of the hyperbolic tangent is approximately 1, and the equation may be simplified to:

$$L = \frac{gT^2}{2\Pi}$$

$$C = \frac{gT}{2\Pi}$$

Generally, this simplification is valid if h/L > 4. Since the observed wavelengths of the waves in the tank are about 4 inches (10.2 cm) and 9 inches (22.9) (see the photographs in Figures 3.14 and 3.9) for the 2.13 cycle/second and 1.33 cycle/second wave frequencies respectively the above criteria are satisfied. The results from substituting the appropriate wave periods identified from the spectral plots into these simplified equations are presented in the following table:

Table 3.3.

Wave Frequency	Wave Period (sec)	Wavelength (cm)	Wave Celerity (cm/sec)
2.67	.375	21.9	58.5
2.1	.476	35.3	74.2
4.2	.238	8.8	37.1

It can be seen that the wavelength computed for the 2.67 and 4.2 cycle per second wave frequencies are in reasonable agreement with observed lengths. The Stoke's wave theory also predicts that the steepest water waves will have a crest angle of 120 degrees, or alternatively that the wave height divided by the length will be less than 0.142: i.e.,

$$H/L \leq .142 \approx 1/7$$

for stable waves. Steeper waves will collapse and break.

Using the data computed above, height to length ratios have been computed for the 2.67 and 4.2 cycle per second water waves:

Wave frequency = 2.67 cycle per second

Probe location (see Fig. 3.3 and 3.4)

	1	2	3	4
H/L	.28	.08	.06	.07
Wave Frequency = 4.2 cycles per second				
H/L	.27	.16	.18	.09

The results show that for both the 2.67 and 4.2 cycle per second surface waves, the breaking criteria is exceeded at the center position.

3.4.2. CURRENT MEASUREMENTS

A. Observations

The directions and relative magnitudes of the currents and eddies in the tank were found by observing the motions of dye plumes and neutrally buoyant particles from numerous tank locations. A sketch of a tank section showing an estimated current profile derived from these observations is given in Figure 3.24. It can be seen that the influx of water toward the tank center occurs in a shallow path with relatively high water velocities. This path is 5-8 cm deep at the 1.33 cycles per second generator frequency and 4-5 cm deep at the 2.1 cycles per second frequency. The return flow travels out and down from the center of the tank in the shape of a shallow cone. The interface between these two flows is not well defined. Just beneath the surface flow is a layer of slow moving water with no preferred direction. Also, at the corner between the tank wall and floor, and in the small space behind the wave generator, back eddies were observed.

The currents and eddies near the center of the tank depended on the surface wave action, and hence varied significantly at any given location over time. Individual plunging waves might superimpose a rapidly moving plume of water on the general downward flow at the center. Or, the rapid inflow of water could be interrupted by a wave tumbling against the current. A roughly circular region at the center of the tank was defined by a ring of surface water with no average radial velocity. This ring was formed when the radial inflow induced by the water waves met water tumbling away from the center from collapsing or breaking waves. This ring forms a convenient boundary. Inside the ring is the region of intense breaking wave action and outside the ring waves are regular and the wave fronts are circular. When small pieces of paper were scattered over the entire surface of the tank and allowed to migrate toward the center, the maximum distance the paper would reside from the center of the tank would be the radius of this ring. Indeed, this was also the maximum radius of the experimental oil slicks. The approximate maximum radius of the center region was 55 cm at the slow generator frequencies and 40 cm at the fast frequency. However, the dimensions would expand and contract depending on the wave intensity in the tank.

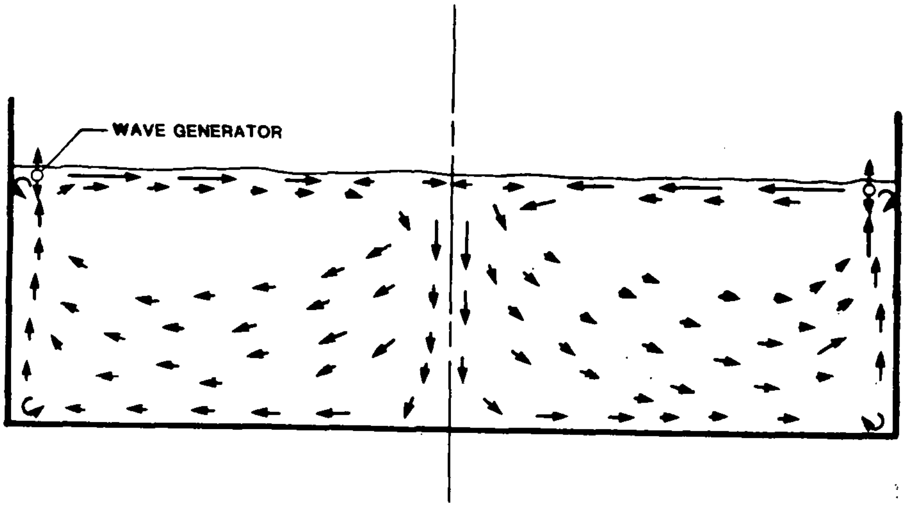


FIGURE 3.24
CURRENT PATTERN

The water at the center region of the tank would rotate as a whole with smaller eddies contained inside. The maximum rotational velocity was estimated to be .05 to .3 radius per second. However, the rotation was not steady or consistent. No preferred direction of rotation was observed, nor was any regular frequency of direction change apparent.

The average velocity of the water travelling the entire convective path from the tank center down and out to the edge, and back to the center again, was found by determining the time difference between successive dye concentration peaks resulting from a plume of dye injected into the flow and sampled at the tank wall. Data from four experiments with 30 ml of dye applied to the center of the tank are shown in Figures 3.25 to 3.31. Input conditions, generator frequencies and sampling locations are listed on the figures. The ordinate in all the figures has been normalized by the uniform tank concentration resulting from 30 ml of dye mixed with 3470 liters of tank water. Dye sampling locations are shown in Fig. 3.32. The dye was then added at the center and water samples for the first two experiments were taken from locations 1 and 3 shown in Figure 3.32. Samples for the third experiment were taken from locations 1 and 2 and samples for the last experiment were taken only from location 1. First the tank was filled with fresh water and the wave maker run for one hour. Additional measurements of the surface currents were performed by timing the motion of .5 cm square paper drifters migrating toward the center of the tank. The tracks over which the drifters were observed are shown in Figure 3.33. The data is listed in Table 3.4.

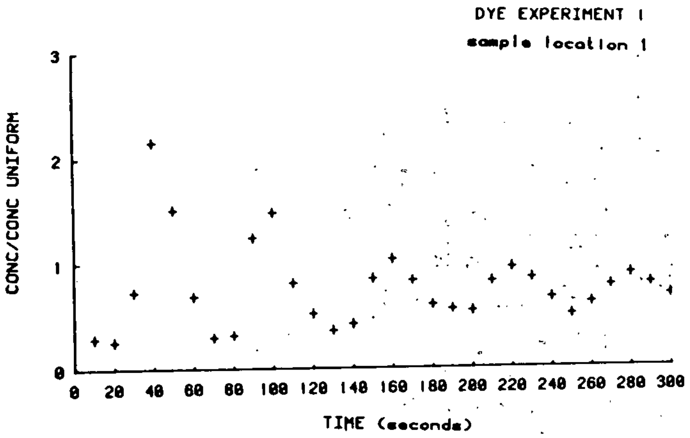


Figure 3.25. Dye Experiment 1 Sample Location 1

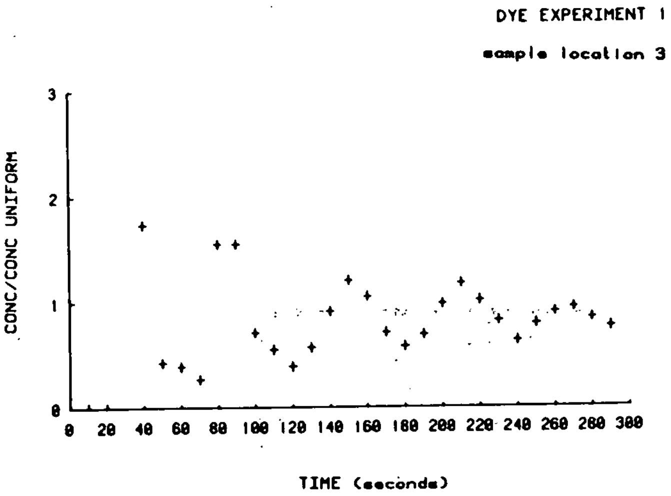


Figure 3.26. Dye Experiment 1 Sample Location 3

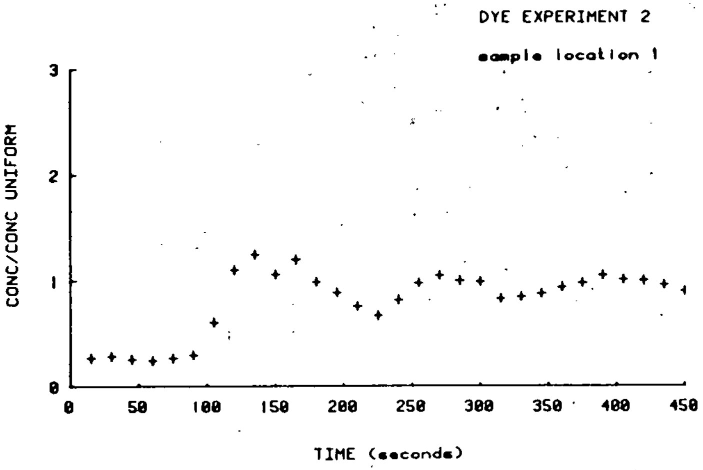


Figure 3.27. Dye Experiment 2 Sample Location 1

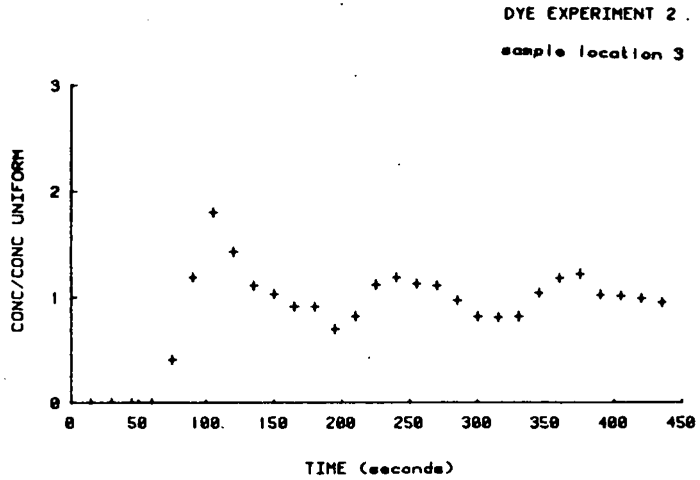


Figure 3.28. Dye Experiment 2 Sample Location 3

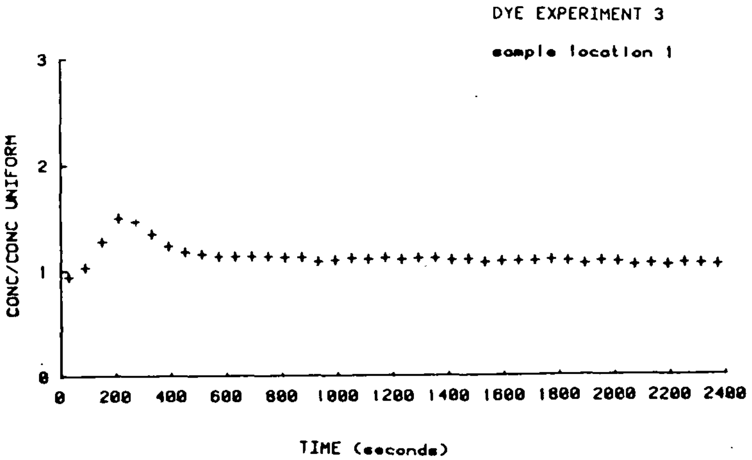


Figure 3.29. Dye Experiment 3 Sample Location 1

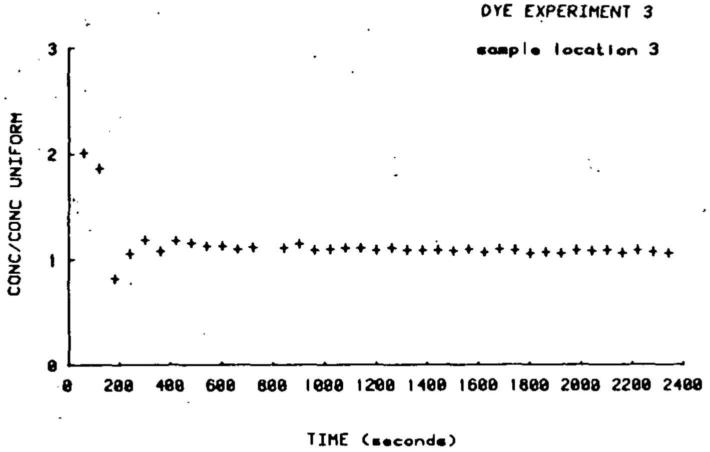


Figure 3.30. Dye Experiment 3 Sample Location 3

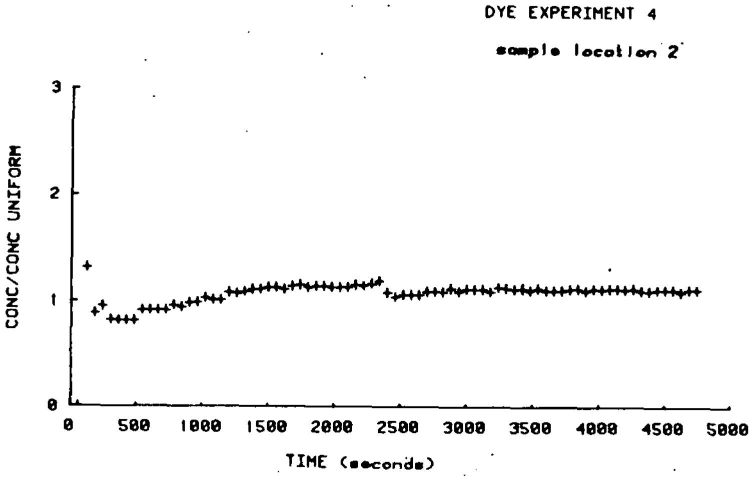


Figure 3.31. Dye Experiment 4 Sample Location 2

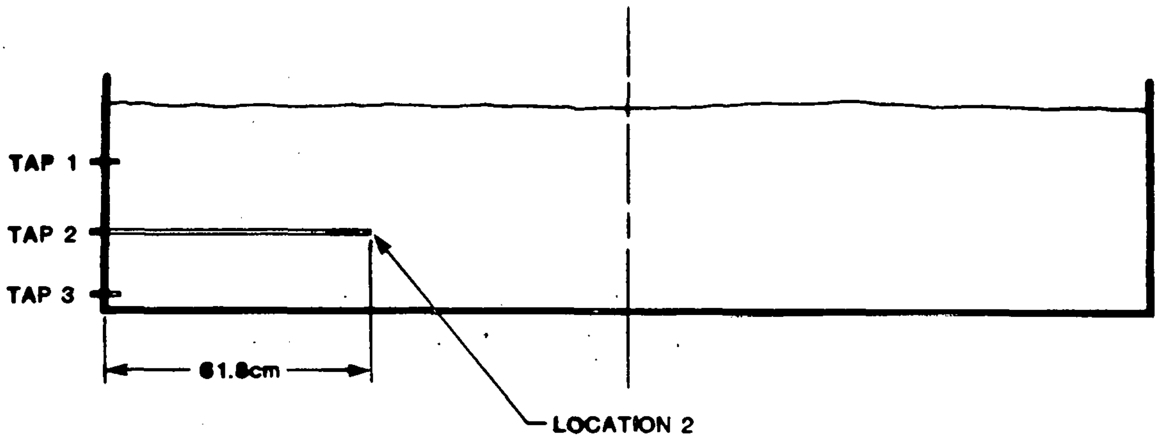
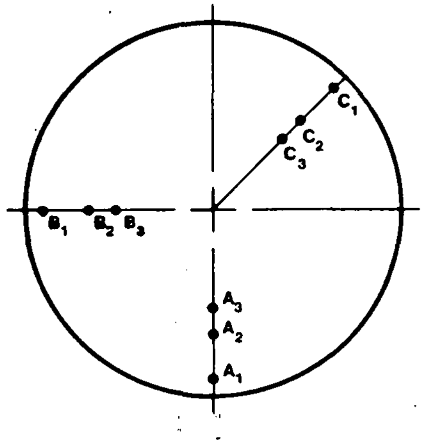


FIGURE 3.32
DYE SAMPLING LOCATIONS



RADII $A_1 = B_1 = C_1 = 112.4\text{cm}$
$A_2 = B_2 = C_2 = 79.4\text{cm}$
$A_3 = B_3 = C_3 = 64.1\text{cm}$

NOTE 1 :

All the radii measurements are referenced to the centerline of the wave generating hoop.

NOTE 2 :

$A_3 = 48.9\text{cm}$ for the 2.13 Hz tests.

FIGURE 3.33

PATHS OVER WHICH DRIFTERS WERE TIMED

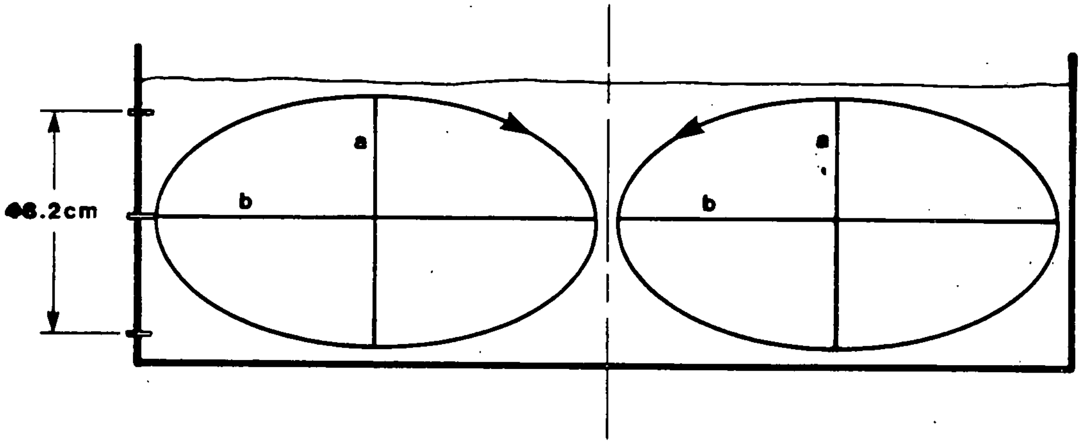
TABLE 3.4. TRAVEL TIMES FOR PAPER DRIFTERS (seconds)

Wave Generator Frequency: 1.33 cycles/second						2.13 cycles/second	
Location: (see figure)							
A_1A_2	A_1A_3	B_1B_2	B_1B_3	C_1C_2	C_1C_3	A_1A_2	A_1A_3
3.1	9.5	3.5	6.0	4.2	7.8	2.5	6.0
4.8	10.5	3.2	4.5	2.9	7.4	2.9	8.1
4.0	7.1	3.8	5.5	4.6	6.9	2.5	8.1
4.7	6.6	3.6	5.5	3.5	6.6	2.2	6.9
3.6	12.9	3.6	5.0	3.3	6.1	2.4	6.9
4.8	13.0	3.6	6.6	5.0	7.4	2.8	8.5
3.3	9.6	3.5	6.5	4.1	8.2	2.5	7.3
3.2	6.1	4.2	5.0	2.4	6.2	2.5	7.3
4.0	12.9	3.0	4.9	2.9	5.1	2.6	7.4
4.6	8.5	3.4	8.2	3.3	7.0	2.5	8.8
4.1	9.6	2.4	7.2	3.9	6.9	3.0	7.0
4.0	7.2	3.1	4.6	3.5	6.4	2.8	5.7
4.7	8.4	3.6	5.4	4.4	6.8	2.4	7.1
4.3	8.8	3.8	6.4	3.4	8.4	2.7	8.9
3.9	6.5	2.9	5.0	2.7	6.1	2.7	5.7
4.1	8.4	2.6	7.3	3.6	8.2	3.0	7.1
4.9	10.5	3.3	5.6	3.3	6.8	2.6	7.5
3.2	9.8	3.1	6.6	2.9	6.7	2.1	7.5
4.0	7.5	2.6	4.7	4.6	5.8	2.4	5.9
5.4	7.4	4.4	5.4	3.7	8.4	2.9	7.3
4.3	10.4	3.2	6.4	3.8	6.2	2.3	7.3
4.3	6.0	3.3	6.8	3.7	6.0	2.7	7.2
4.0	10.9	3.5	5.0	3.9	6.2	2.5	6.1
4.2	6.3	3.0	5.9	4.0	6.9	2.6	7.4
4.5	5.9	3.6	4.6	3.6	7.3	2.5	7.5
3.1	9.8	3.3	4.4	2.7	6.6	2.0	7.8
4.0	9.4	2.9	4.5	3.4	5.8	2.7	6.5
5.3	7.8	3.0	5.8	2.8	7.1	2.8	5.9
4.5	7.2	2.9	5.1	3.2	8.8	2.3	7.4
4.3	11.5	3.3	4.8	3.4	6.8	2.7	6.0
			5.7				5.6
			6.0				

B. Results and Discussion

The dye concentration verses time graphs from the first two tests clearly show the series of dye concentration peaks resulting from the dye plumes in the recirculating flow crossing the sampling locations. The concentration peaks become lower and broader with each successive cycle as the dye diffuses forward and backward into the flow stream. The concentrations also tend toward the uniform value representing complete mixing in the tank.

If each plotted concentration peak is assumed to represent the center of the dye plume, and the water is assumed to follow the elliptical path shown in the figure below, the average circulation velocity can be determined by dividing the path length by the mean time difference between concentration peaks. From the figure, the perimeter of the ellipse is 312.3 cm; the distance between the lower and upper sample locations is 48.2 cm.



Ellipse Perimeter, $P = \pi(a + b)k$
when $a = 36.0$ cm
$b = 61.8$ cm
$k = (1 + 1/4\, m^2 + \ldots)$, $m = \left(\frac{a - b}{a + b}\right)$
$= 312.3$ cm

The semi-major and semi-minor axes are taken to be half the tank radius and tank depth respectively. Since this is the longest direct path that the water particles might follow, the computed velocities should represent the highest average velocities.

The data read from the concentration verses time graphs is summarized in Table 3.5. The average times for one complete circuit of the tank are found to be 131 seconds for the 1.33 cycle per second generator frequency. The respective average travel times for the dye plumes from the lower to upper sampling location are 2.5 and 7.5 seconds. Using these values, the average water velocities for the assumed circuit can be computed:

Table 3.5 Dye Concentrations Versus Time

GENERATOR FREQUENCY (cycles/sec)	SAMPLING LOCATION NUMBER	TIME OF DYE CONCENTRATION PEAK (second after dye added)	TIME DIFFERENCE BETWEEN CONSECUTIVE CONCENTRATION PEAKS (seconds) AT EACH LOCATION	TIME DIFFERENCE BETWEEN CONCENTRATION PEAK ARRIVAL STATION 3 AND 1 (seconds)
1.33	1	135		
(Expt. 2)		270	135	
		390	120	
	3	105		30
		240	135	30
		375	135	15
			Average = 131	Average = 25
2.13	1	40		
(Expt. 1)		100	60	
		160	60	
		220	60	
		280	60	
	3	35	55	5
		90	65	10
		155	55	5
		210	65	10
		275	Average = 60	Average = 7.5

Wave Generator Frequency (cycles/sec)	Average Velocity (cm/sec) Total Circuit	Lower to Upper Sample Location
1.33	2.4	3.4
2.13	5.2	6.4

The third dye experiment was performed to test for longer term variations of dye concentrations, possibly due to circumferential flow components in the tank. The experiment was done at the faster generator frequency. One set of water samples was taken at location 2 (Figure 3.32) at half the tank depth and half the radius. The other set was taken from location 1 near the water surface at the tank wall. The results show that after 600 seconds, there is almost no variation in dye concentration visible, and the uniform tank concentration has been achieved. No long term fluctuations of the data are evident to within the accuracy of the test.

The last dye experiment was similar to Experiment 3 except that the wave generator was operating at the lower frequency, and the sampling period was much greater. Only one set of concentration samples were obtained from location 1. Figure 3.31 shows that the dye appears to be completely mixed after 1300 seconds, and again no long term cycles variation is evident. The jump in the data at 2300 seconds cannot be readily explained. Nothing unusual was observed during the experiment. It may be the result of a calibration problem with the flourometer, although there is no reason to believe this is so.

C. Surface Drift Velocity:

Results of the experiments with the paper drifters are summarized in Table 3.6. The computed velocities for each of the tracks show that the average velocities on the tank water surface are approximately radially symmetric, at least to within about 1 standard deviation of the data. The scatter in the data can be attributed to the wave action at the tank center. Differences in mean velocity may also be due to asymmetries in the tank and wave generator installation.

Table 3.6 Surface Velocity

WAVE GENERATOR FREQUENCY (cycles/second)	PATH OF PAPER DRIFTERS (see Fig. 3.33)	AVERAGE TIME (seconds)	STANDARD DEVIATION (seconds)	AVERAGE VELOCITY (cm/sec)	VELOCITY RANGE ± 1 STND. DEVIATION
1.33	A_1 A_2	4.2	.6	7.9	6.9 - 9.3
	A_1 A_3	8.9	2.1	5.5	4.4 - 7.1
	B_1 B_2	3.3	.44	10.0	8.8 - 11.5
	B_1 B_3	5.7	.95	8.6	7.3 - 10.3
	C_1 C_2	3.6	.62	9.3	7.9 - 11.2
	C_1 C_3	6.9	.89	7.0	6.2 - 8.0
2.13	A_1 A_2	2.6	.25	12.8	9.5 - 19.8
	A_1 A_3	7.1	0.9	9.0	8.6 - 9.3

An interesting feature of the surface flow becomes evident by comparing the average velocities of the drifters traveling the long paths with the velocities computed for the shorter paths. Since the measurements were all began at the same radius, the slower velocities for the longer paths indicate that the water particles slow down as they approach the tank center. This is exactly opposite to what one would expect from continuity considerations. A possible explanation is that the momentary bursts of reverse flow from the collapsing waves slow the inflow and force it under the surface.

3.5. OIL CONCENTRATION EXPERIMENTAL RESULTS

3.5.1. Introduction

The first ten experiments have been made without the hood in place and with the wave maker operating at either 1.33 or 2.13 cycles per second. All were made with Kuwait Crude, either 60 or 120 ml, and at ambient temperatures which spanned the period from February through August. Tests were made with fresh water and sea water and documented with photographs and 8 mm movies.

Figure 3.34 shows the dimensions of the tank and sampling probe locations. Table 3.1 lists the test conditions and Table 3.2 gives the results of oil concentration verses time for the ten experiments. These results are plotted in Figure 3.35 through 3.44.

3.5.2. Observations and Results: Test 1

The first test, Test 1, was run with 60 ml of oil placed on the surface of cold fresh water. The frequency was 1.33 cps. Fig. 3.35 shows that the amount of oil entrained was the least of all the tests. The ordinate on these graphs is the percent of oil entrained x 10^{-2}. It is also the concentration of the sample divided by the concentration that would exist if all the oil were uniformly distributed throughout the tank.

It is interesting to note the behavior of the oil on the surface. Fig. 3.45 shows that the oil broke up into well defined slicklets with irregular boundaries a short time, about 2 hours, after the beginning of the test. While the diameters of the slicklets were random their average length scale appeared to be about 2" or about 1/2 the wave length. Fig. 3.46 shows the irregular boundaries of these slicklets, and Figure 3.47 shows the oil eight hours after being added.

At the beginning of this test, small oil droplets, from 1 mm to 5 mm in diameter were observed. However, the observed droplets seemed to decrease in number with time and as the slicklets became more stable. While the slicklets appeared stable on the surface of the water, when they were removed, the water separated from the oil in about one hour.

Eight hours after the oil was placed on the surface the wave maker was turned off and the system was allowed to come to equilibrium. Samples were taken 13 hours after shut down and showed a negligible amount of hydrocarbons remaining in the water. The slicklets which had formed broke down into irregular shapes but still maintained their identity.

TEST 2

The only significant difference between test 1 and test 2 is the wave generator frequency which was increased to 2.13 cycles per second. A plot of concentration verses time as shown in Fig. 3.36 shows no appreciable difference from test 1. Fig. 3.48 and 3.49 show the slicklets which formed about two hours after the oil was added. Fig. 3.50 is taken

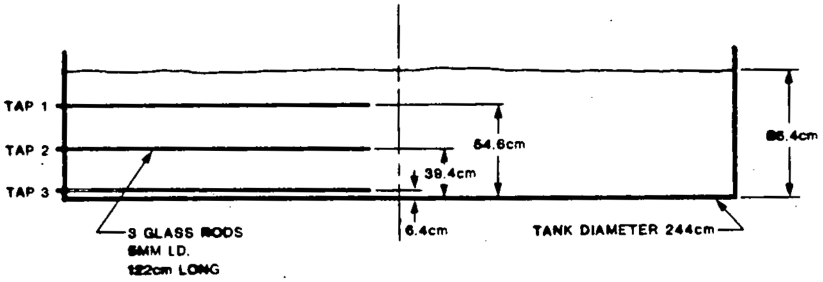


FIGURE 3.34
DIMENSIONS OF TANK AND SAMPLING LOCATIONS

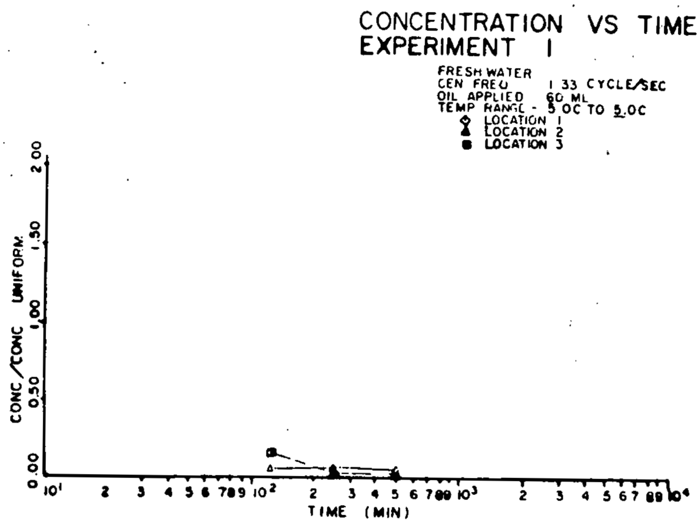


Figure 3.35. Concentration vs. Time Experiment 1

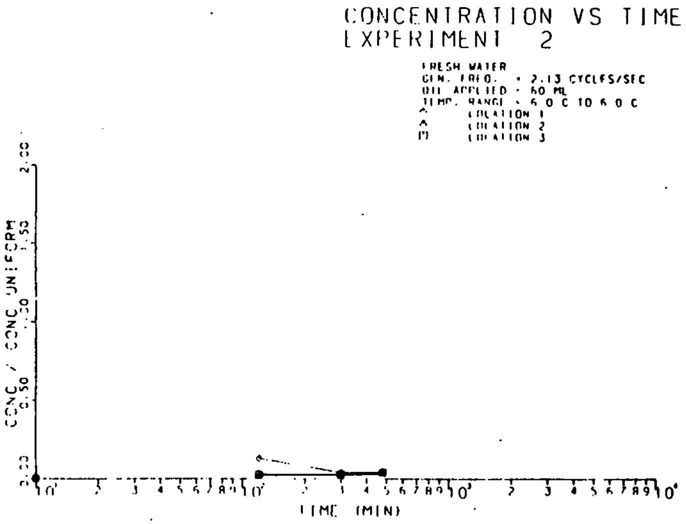


Figure 3.36. Concentration vs. Time Experiment 2

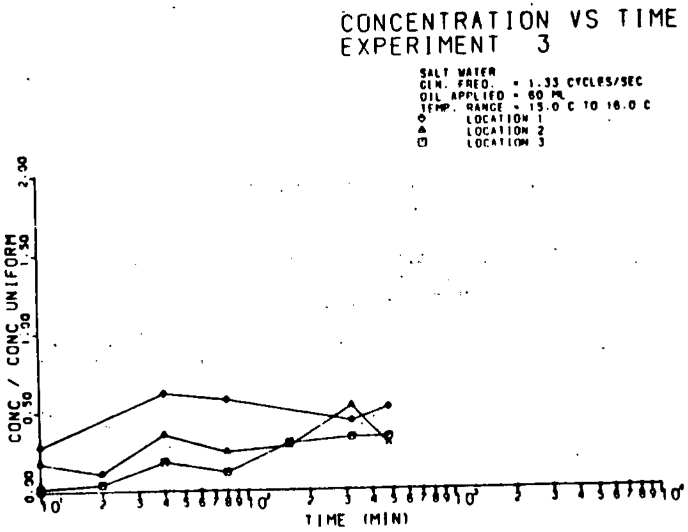


Figure 3.37. Concentrations vs. Time Experiment 3

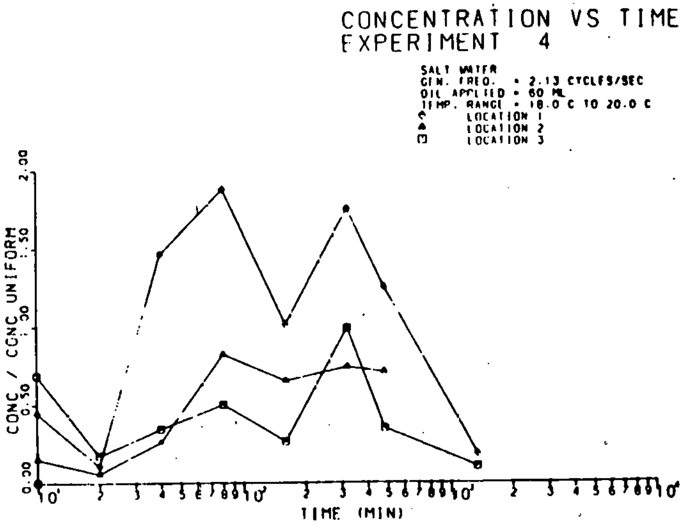


Figure 3.38. Concentration vs. Time Experiment 4

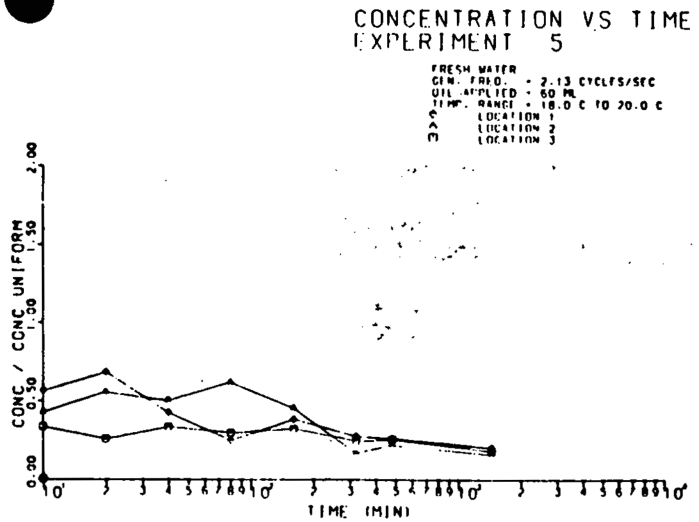


Figure 3.39. Concentration vs. Time Experiment 5

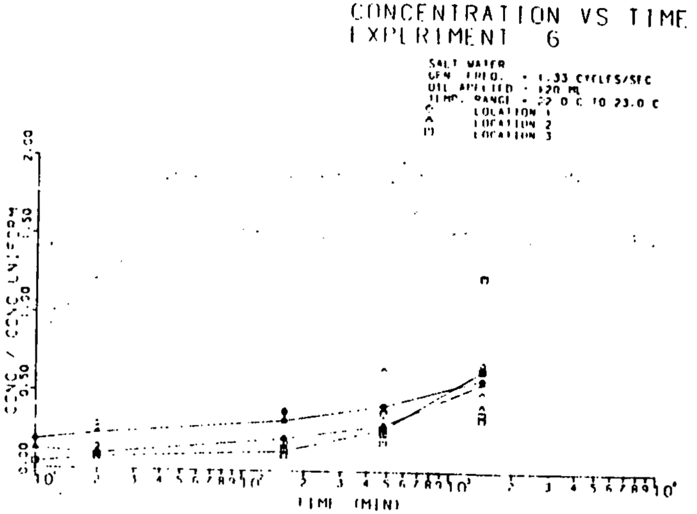


Figure 3.40. Concentration vs. Time Experiment 6

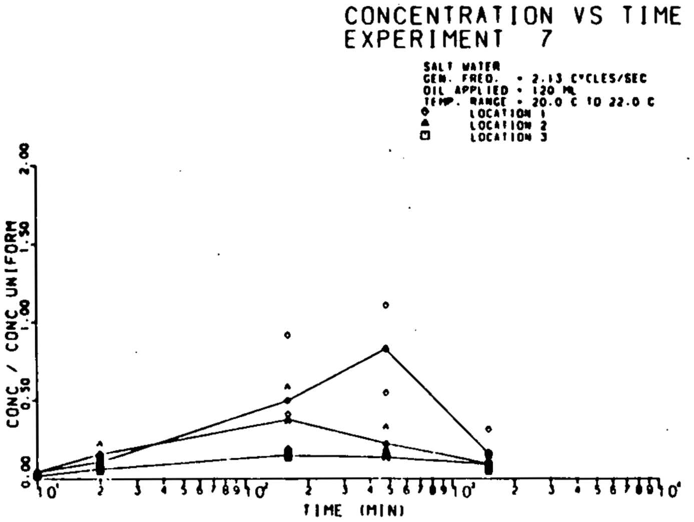


Figure 3.41. Concentration vs. Time Experiment 7

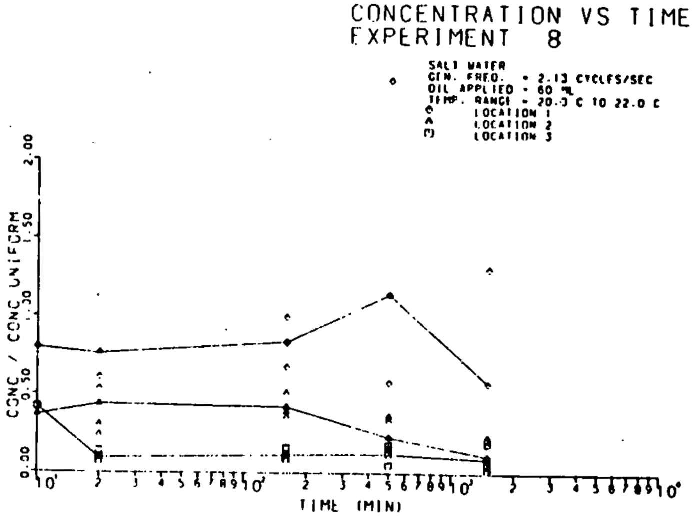


Figure 3.42. Concentration vs. Time Experiment 8

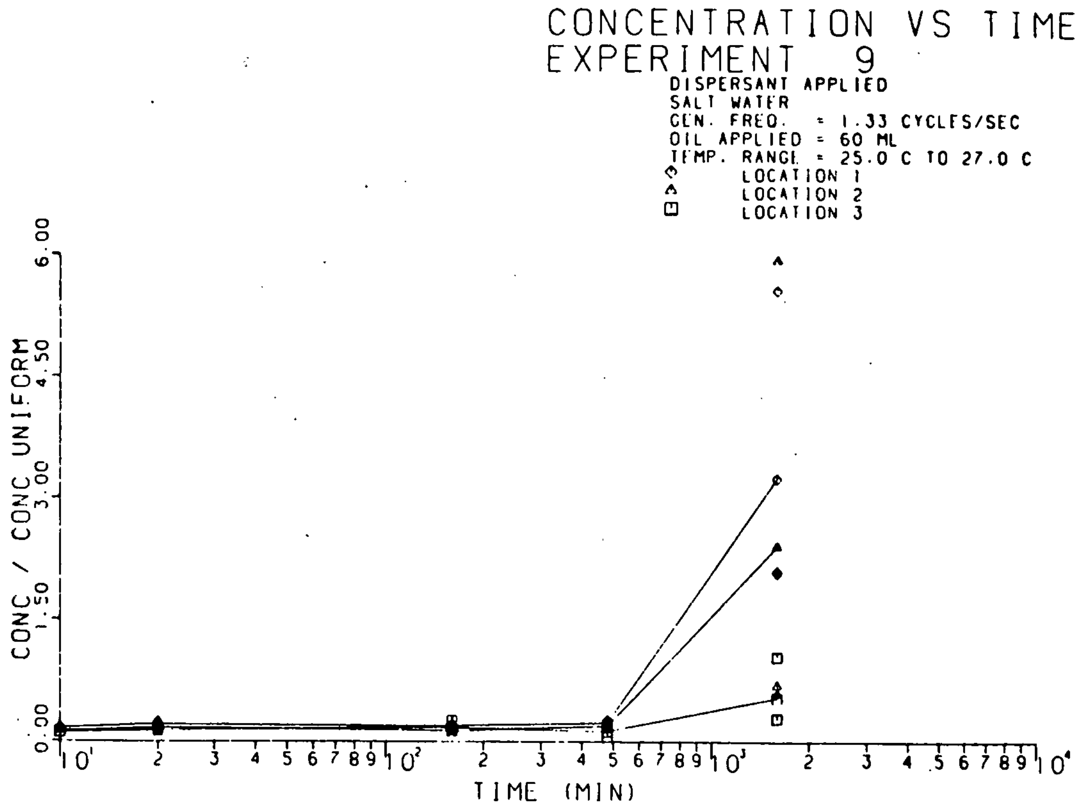


Figure 3.43. Concentration vs. Time Experiment 9

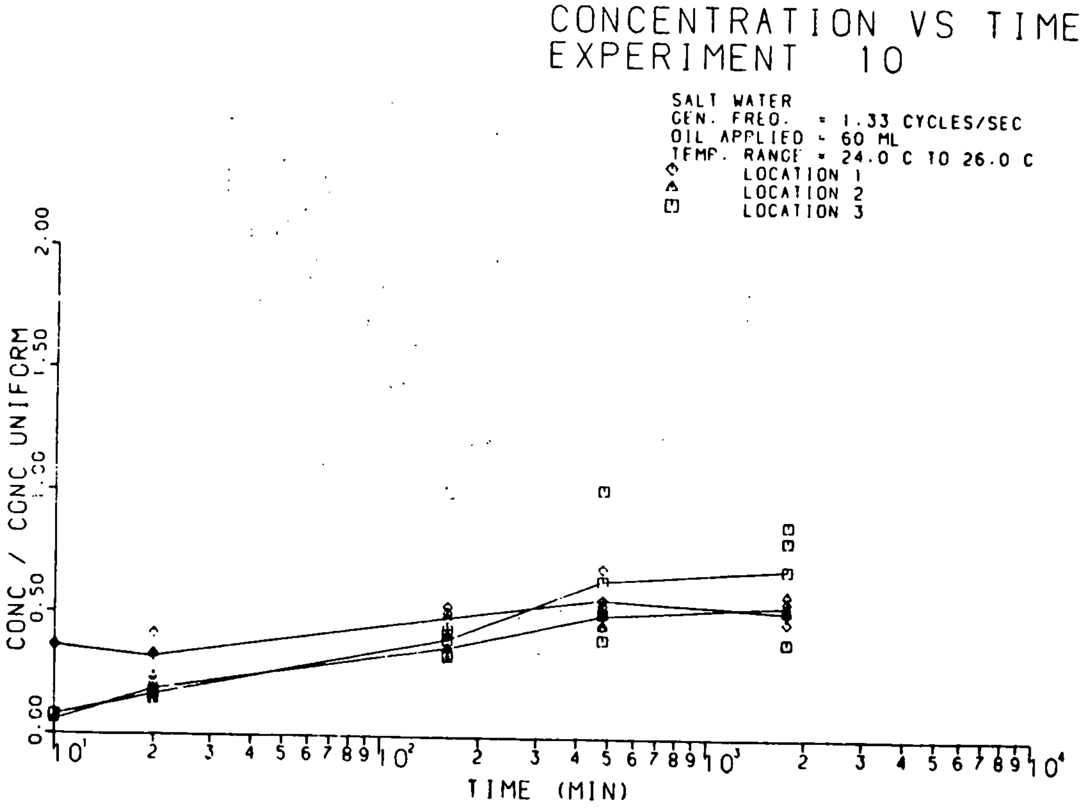


Figure 3.44. Concentration vs. Time Experiment 10

Figure 3.45. Test 1 Fresh Water

Figure 3.46. Test 1 Fresh Water

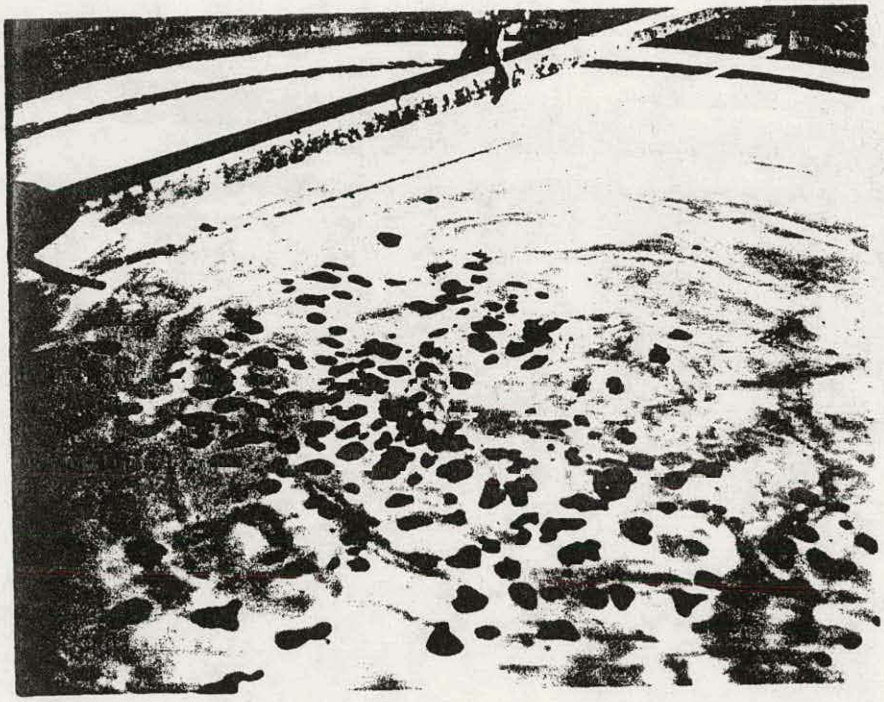


Figure 3.47. Test 1 Fresh Water Weathered 8 hours

Figure 3.48. Test 2 Fresh Water High Frequency

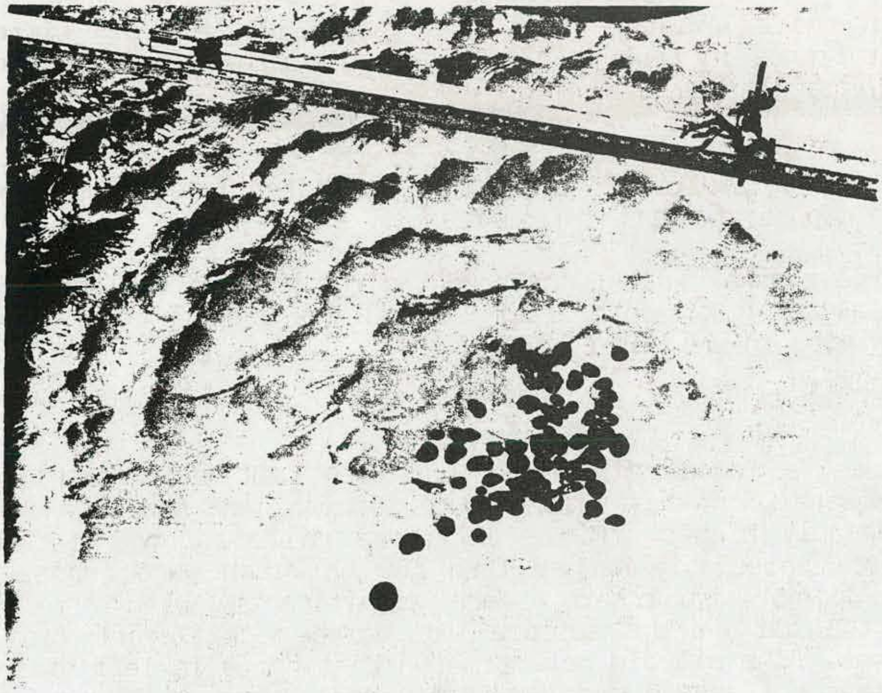


Figure 3.49. Test 2 Fresh Water High Frequency

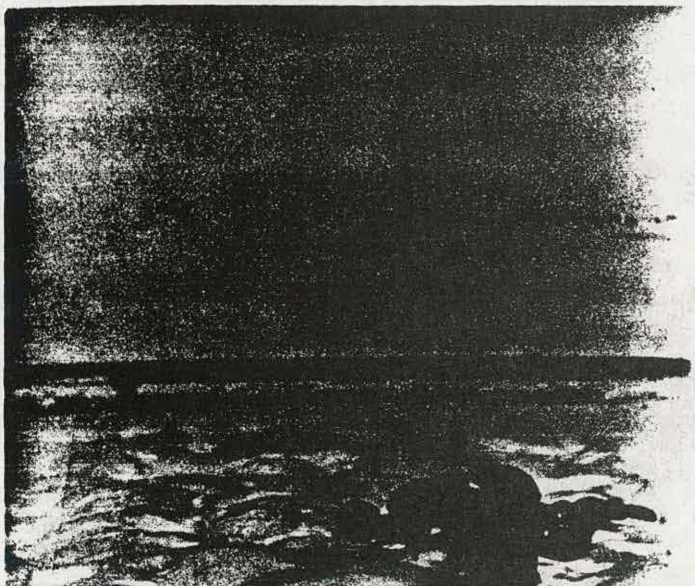


Figure 3.50. Test 2 Fresh Water

from underneath the slicklets. Note that these slicklets are different in appearance to those in test 1. They show a smoother, thicker contour and are not as irregular as in test 1.

This change in appearance must be due to the difference in frequency but the reason is not apparent. Note, also, that the length scale of the slicklets do not appear to differ from test 1.

Again, the wave maker was stopped about eight hours after the oil was added and samples taken 23 hours after the oil was added show a negligible amount remaining in the water column.

Test 3

This test was a repeat of test 1 but with salt water rather than fresh water. However, the test was in June, so that the ambient temperature was appreciably higher. Fig. 3.37 shows the oil concentration in the water column appreciably higher than in the fresh water case. The concentrations do not appear to change significantly with time. The appearance of the oil on the surface was markedly different from the fresh water cases. The oil did not form the distinct slicklets as in the previous two cases but spread more uniformly and formed a cloud of small droplets underneath the slick as shown in Figs. 3.51 and 3.52 taken about 20 minutes after the oil was added. Fig. 3.5 3 shows the appearance 80 minutes after the oil was added. One can see discrete lumps but considerably smaller than the slicklets in the fresh water case. Fig. 3.54 shows the slick after weathering for 22 hours, and the main body of the slick is still contiguous. Fig. 3.55 shows the appearance of the oil from beneath the surface after the wave maker was stopped.

In order to check on the effect of temperature, the tank was cleaned and filled with fresh water and the conditions of test 3 were repeated. As in the previous fresh water cases, the oil broke up into slicklets as shown in Fig. 3.56. We must therefore conclude that it is the composition of the salt water that slows down the formation of slicklets.

TEST 4

Test 4 was a repeat of test 2 but with salt water. It is a repeat of test 3 but at the higher frequency. Fig. 3.38 shows the concentration of oil in the water column. They are substantially higher than in test 3 and we must conclude that the oil concentration increases with the frequency of the waves. Figs. 3.57 and 3.58 show the appearance of the slick 20 and 40 minutes after start. Fig. 3.59 shows the droplets under the slick. Fig. 3.60 shows the slick after five hours of weathering.

After about two hours of weathering, small lumps, about 1/2 inch diameter, started to form between the wave maker and the wall. An emulsion formed on the tank wall at a crack in the resin coating, and it is believed that this formed the nucleus for the lumps. These lumps would escape one at a time and migrate toward the slick at the center of the tank where they would remain as small slicklets and not join the main slick. Fig. 3.61 shows these lumps.

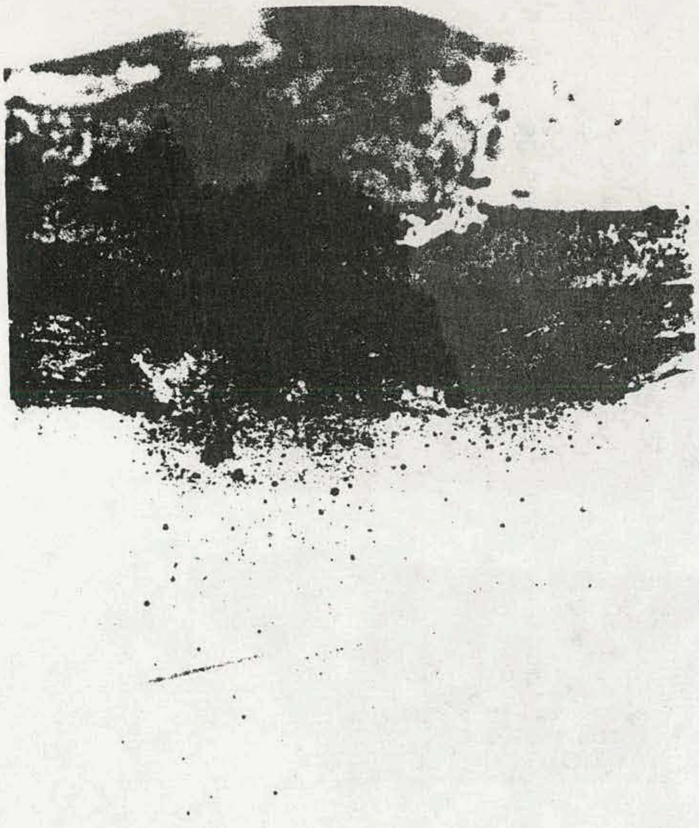


Figure 3.51. Test 3 Salt Water

Figure 3.52. Test 3 Salt Water

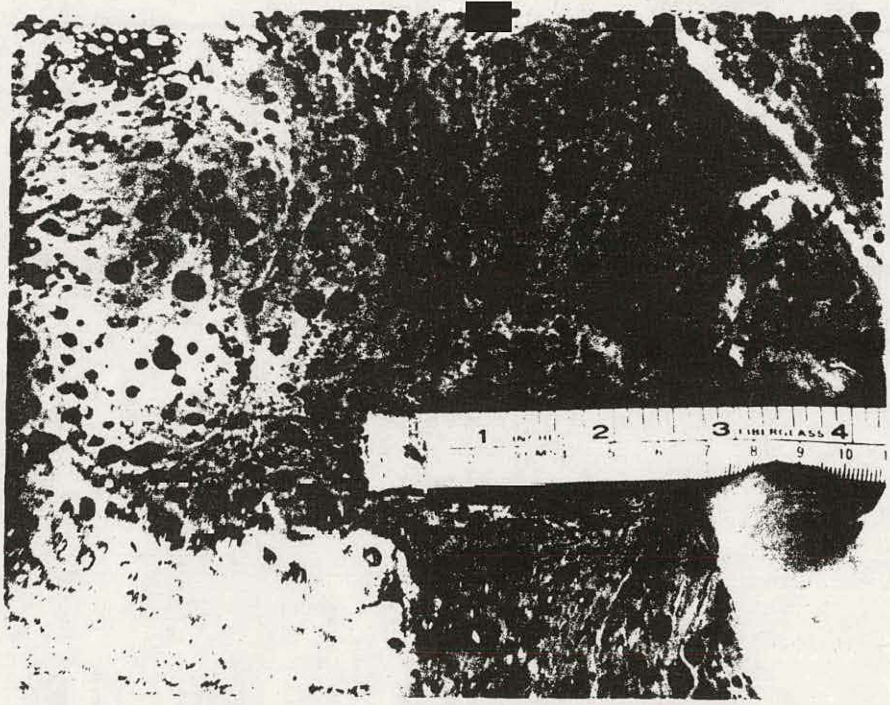


Figure 3.53. Test 3 Salt Water

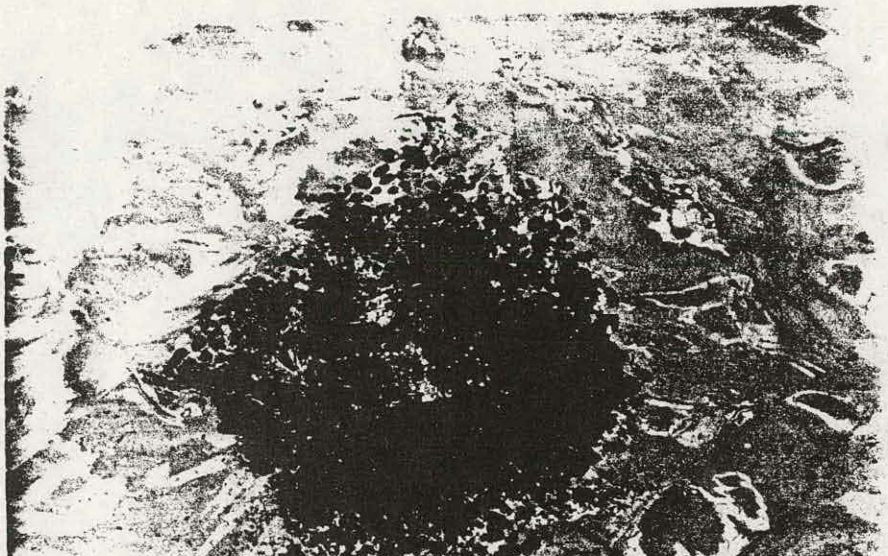


Figure 3.54. Test Salt Water Weathered 22 Hours

Figure 3.55. Test 3 Salt Water After Wavemaker Stopped

Figure 3.56. Repeat of Test 3 With fresh Water

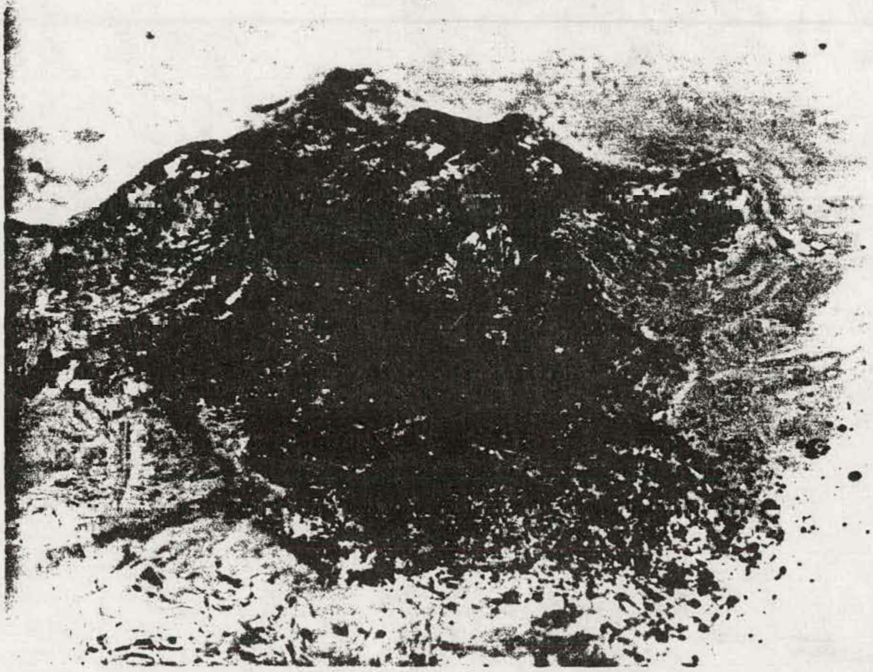


Figure 3.57. Test 4 Salt Water High Frequency

Figure 3.58. Test 4 Salt Water High Frequency

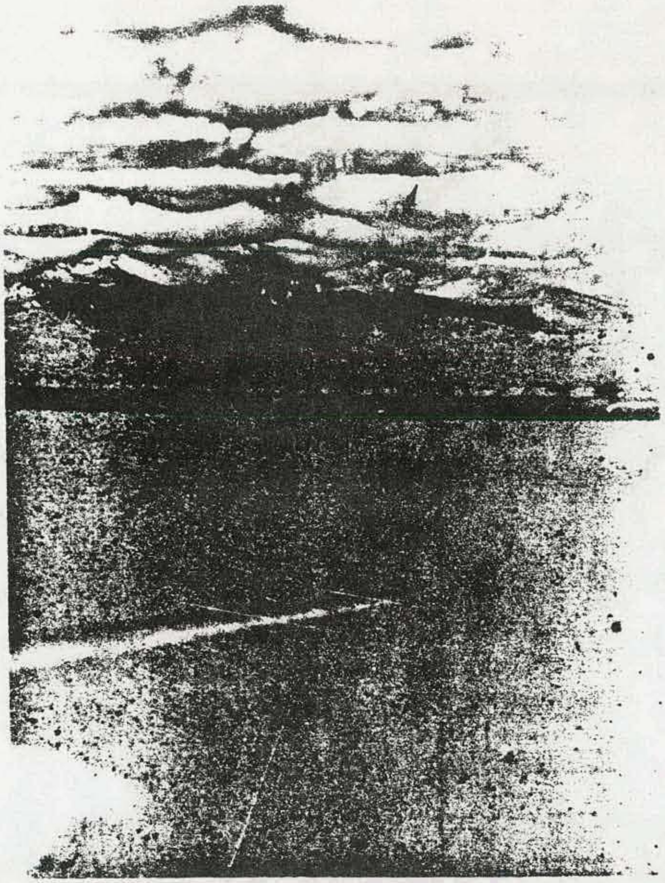


Figure 3.59. Test 4 Salt Water

Figure 3.60. Test 4 Salt Water Weathered 5 Hours

Figure 3.61. Test 4 Slicklets Forming Near Wall

After weathering about eight hours, small string-like pieces of oil could be seen circulating throughout the tank. These were approximately 1/4 mm in diameter and 3 mm long. The slick itself appeared to become an emulsion similar in appearance to chocolate mousse. Some of the tiny particles of oil would come to the surface, break and disappear into a sheen.

TEST 5

Test 5 is a repeat of test 2 but at a higher ambient temperature. Fig. 3.39 shows a higher average concentration of oil in the water column than in test 2. However, this is fresh water and the concentration is substantially lower than test 4 which has identical conditions except that it was done with salt water. It is interesting that the concentration of oil in the water appears to decrease with time in test 5. This is possibly a result of the formation of stable emulsions in the form of slicklets which float on the surface and absorb droplets that come in contact with them. As in the previous fresh water cases, these slicklets formed after about two hours and appear to become more stable with time.

TEST 6

Test 6 was the same as test 3 except that the quantity of oil added was doubled. Also, the ambient temperature was about 7°C higher. The percent concentraton of oil in the water column does not appear to be significantly different from test 3. However, a noticeable increase with time is apparent and this is opposite the trend in the fresh water tests. In Fig. 3.40, the lines are drawn through the averages of several samples taken from each port. Each data point plotted represents a single sample. Fig. 3.62 shows the appearance of the slick 20 minutes after start and Fig. 3.63 is eight hours after start. The oil has broken up and spread over the surface. The oil pieces seen appear to be aerated and not stable emulsions. The wave maker was stopped after about 24 hours of weathering and almost all the visible oil in droplet form appear to be oil covered water. The droplets range from about 0.1 mm to 2 mm in diameter. Fig. 3.64 shows the tank surface after stopping the wave maker.

TEST 7

Test 7 is identical to 6 except at higher frequency. It is the same as test 4 except the quantity of oil was doubled. Fig. 3.41 shows the concentraton of oil in the water versus time. There does not appear to be a significant difference percentage wise, except possibly at the points taken just before shutdown, i.e., after 24 hours of weathering, where the concentrations at the higher frequency are lower. We note this same trend when comparing test 3 with test 4. It appears that after 24 hours of weathering, the concentration at the higher frequency decreases sharply. Figure 3.65 shows the slick 20 minutes after start and Figure 3.66 shows the slick after 24 hours of weathering. It can be seen that the weathering process has produced small slicklets of the order of 1/4 to 1/2 in. size. These are much smaller than those that appeared in the fresh water tests. The lower oil concentration after 24 hours could be a result of the stability of these slicklets and their ability to pick up oil droplets out of the water.

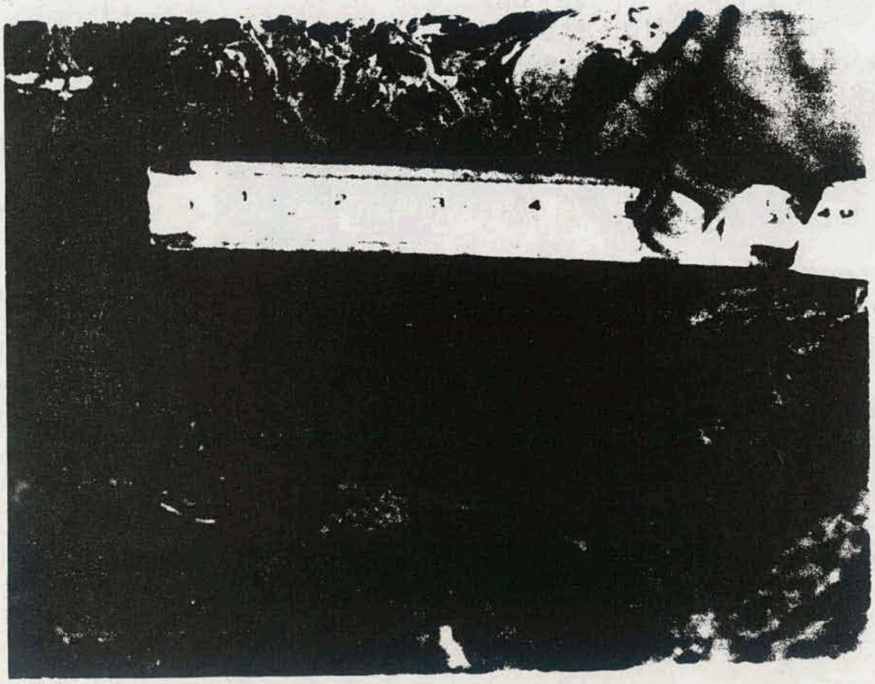


Figure 3.62. Test 6 120 ml Oil Weathered 20 Minutes

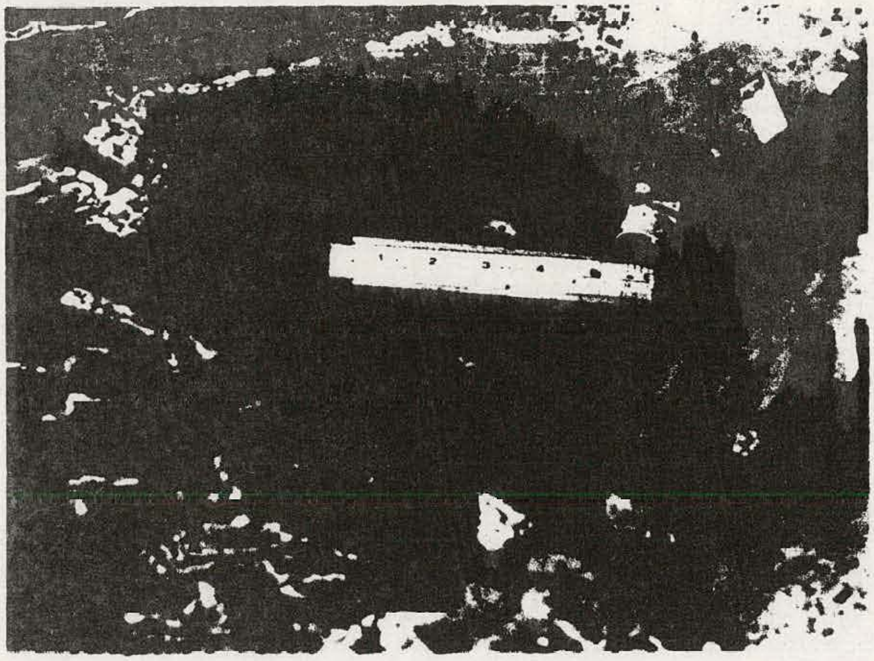


Figure 3.63. Test 6 Weathered 8 Hours

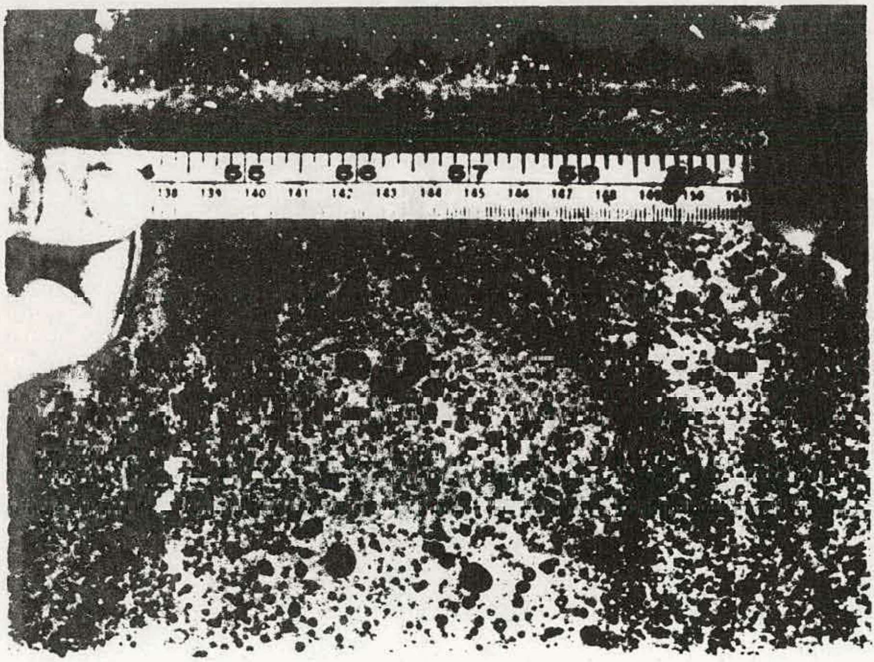


Figure 3.64. Test 6 After Stopping Wavemaker

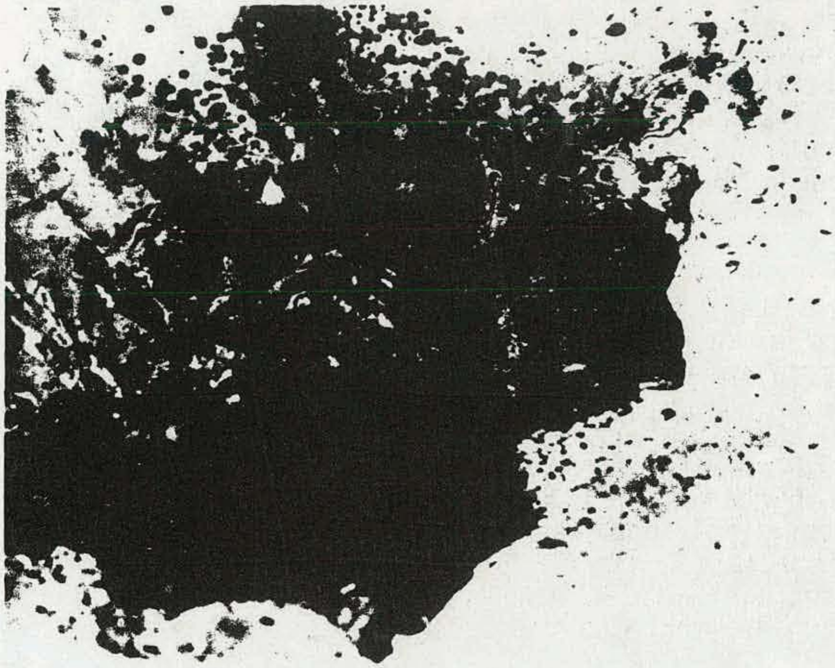


Figure 3.65. Test 7 Weathered 20 Minutes

Figure 3.66. Test 7 Weathered 24 Hours

TEST 8

Test 8 is a repeat of test 4 and similar to test 7 except with half the oil added. The concentrations shown in Fig. 3.42 appear to be higher than 7 during the early stages of the experiment, but become the same order of magnitude as the weathering continues. Again, concentration appears to increase with time, but shows a sudden drop after 24 hours of weathering. Figure 3.67 shows the slick after 24 hours of weathering and the irregular appearance of the oil is apparent. The pieces look as though they have been shredded or torn apart.

TEST 9

Test 9 was performed to test the effectiveness of the chemical dispersant Corexit 9527. The experimental apparatus was set up as usual. The wave generator was set to operate at 1.33 cycles per second and 60 ml of oil was added.

Twelve ml of Corexit mixed with 240 ml of sea water were applied to the slick immediately after the oil was added. Following the manufacturers recommendation, the dispersant was first mixed with the tank water, keeping a water-dispersant ratio of 20:1. The mixture was then sprayed onto the water surface with a hand-held atomizer. (See Fig. 3.68). Care was taken to ensure that the dispersant contacted the entire slick.

The immediate effect of the dispersant was to submerge almost the entire oil slick. A dispersion of very fine (1 mm diameter or less) oil droplets could be seen which gave the near surface water a yellowish appearance. However, within 3 to 5 minutes, almost the entire amount of oil had returned to the surface to form a thin, opaque smooth, contiquous slick at the center of the tank (Fig. 3.69). Whenever a wave broke within the slick, a few droplets of oil would momentarily submerge as before, but they would immediately return to the surface and the contiguous slick would reform. The wave action in the tank appeared to be less violent than in previous tests. The smallest ripples were dampened out completely and the exposed water had a smooth, glossy appearance (Figure 3.70, taken ten minutes after the dispersant was added). Visible turbulent action from collapsing waves was much less. As a result, the circular wave fronts remained intact until the waves reached the very center of the tank where the constructive interference would finally cause the waves to collapse. Thus, the region of active oil submergence was very small.

Twenty minutes after the dispersant was added to the experiment, the water throughout the tank appeared mostly devoid of any oil, Fig. 3.71. Only a few very small oil droplets (again 1 mm or less) could be seen in the water just under the slick at the center. However, these were very small oil droplets, up to 2 mm in. diameter attached to the underside of the slick. The oil slick developed two distinct regions: a dark contiguous glossy slick at the center of the tank, and a transparent tan film that extended out to within a few centimeters of the wave generator.

During the first eight hours, the oil slick changed very little, Fig. 3.72. During periods of relatively more intense wave action, the oil

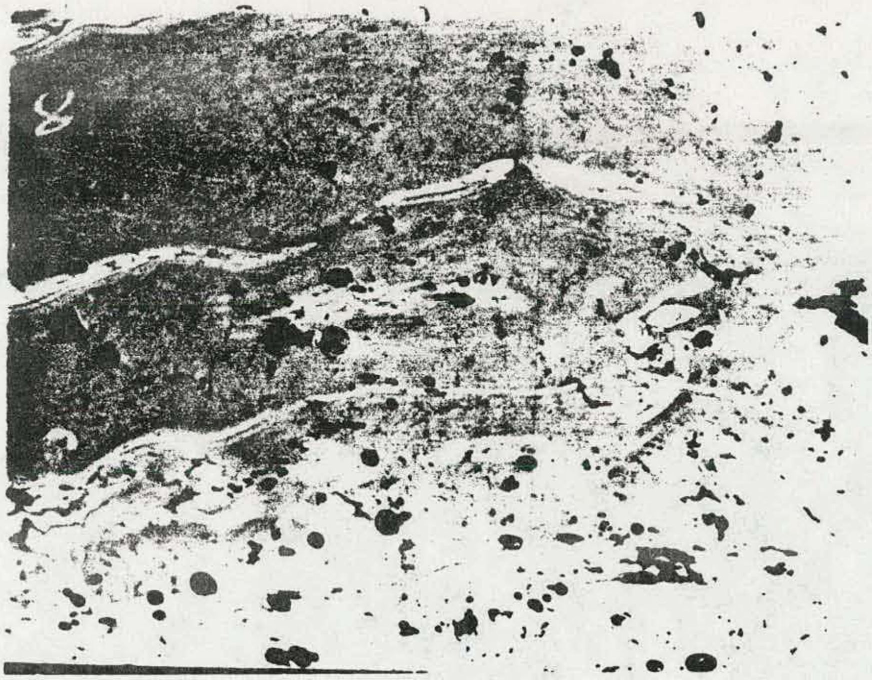


Figure 3.67. Test 8 Weathered 24 Hours

Figure 3.68. Test 9 Spraying Dispersent

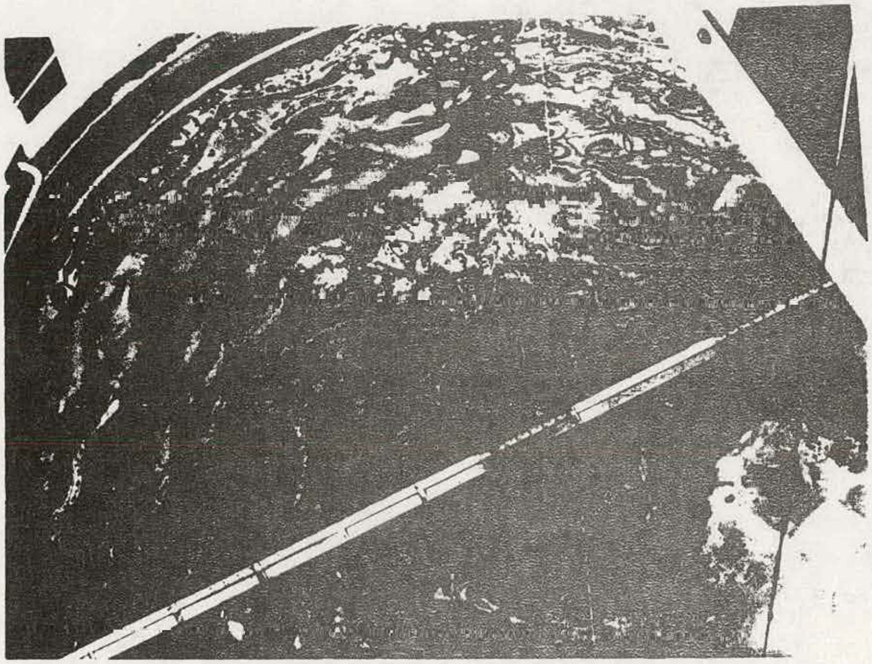


Figure 3.69. test 9 Five Minutes After Adding Dispersent

Figure 3.70. Test 9 Ten Minutes After Adding Dispersent

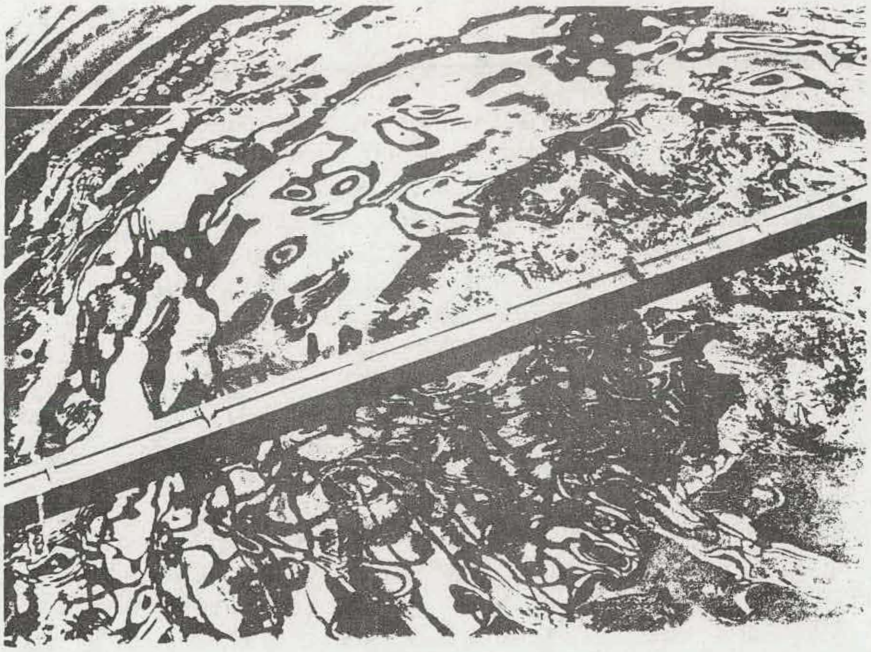


Figure 3.71. Test 9 Twenty Minutes After Adding Dispersant

Figure 3.72. Test 9 Weathered 8 Hours

near the center of the slick would break up into 1 or 2 mm size particles, but would recoalesce where the activity intensity lessened. Progressively more very fine oil droplets were observed in the water as the experiment progressed. However, the amount of dispersed oil continued to appear to be much less than experiments previously performed. The water remained very clear. The two distinct regions in the oil slick changed slightly. After eight hours of wave action, the center region appeared browner, similar to the color of chocolate sauce. The light brown perimeter had about disappeared and was replaced with a transparent sheen which refracted the light. Rough elongated particles of oil could be seen near the center, and some were being submerged.

The appearance of the tank the following morning after the wave generator had run for 22 hours, was radically different, Figs. 3.73 and 3.74. A very faint slick was visible on the water surface consisting of a brown film containing dark granules of oil. Most of the oil had dispersed completely into the tank in the form of small (again < .2 mm) dirt-like particles, although larger particles and oil droplets were also clearly visible. The water was a homogenous light yellow-brown and very murky. The waves in the tank were significantly smaller than usual, and smaller than when the experiment began. The maximum amplitude of the waves in the center was estimated to be less than 3 cm.

The wave generator was stopped 1620 minutes after the oil was added. Some of the large oil particles and droplets returned to the surface forming brown discs about 1 cm in diameter. However, most of the oil remained suspended and there was little noticeable change even one hour later. Many of the dark oil flecks appeared to be neutrally buoyant.

Ten minutes after the wave generator was stopped, 10 ml of tank water was obtained and shaken vigorously with 10 ml of CCl_4. The fine oil droplets dissolved in the solvent as expected, but many of the small dark flecks of oil (.5 - .1 mm dia.) remained intact. Close examination of these oil particles revealed that they had the texture of asphalt. The concentraton verses time plot is shown in Fig. 3.43.

TEST 10

Test 10 was a repeat of test 3 but with water about 10 C warmer. It is also the same as test 6 with 60 ml of oil added instead of 120 ml. Fig. 3.44 gives the concentration verses time curve. It shows the same magnitude and trend as tests 3 and 6. It thus appears that the normalized concentration verses time curve is not dependent on the amount of oil present in this closed system and the quantity of oil being entrained is directly proportional to the amount present. We also note that at the lower frequency the concentration keeps increasing after 24 hours in contrast to the higher frequency, when the concentration decreased markedly after the 24 hour reading.

3.6. CONCLUSIONS AND RECOMMENDATIONS

Kuwait crude oil weathers much differently in fresh water than it does in natural salt water. In fresh water, it rapidly forms slicklets which appear to be stable emulsions and very little oil gets into the water column. In the salt water tests, much more oil entered the water

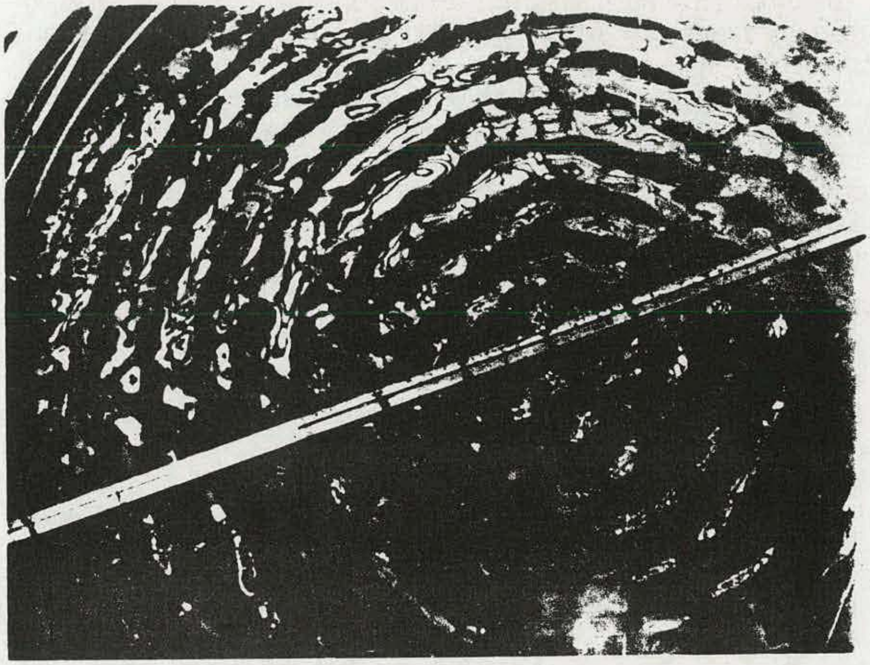


Figure 3.73. Test 9 Weathered 22 Hours

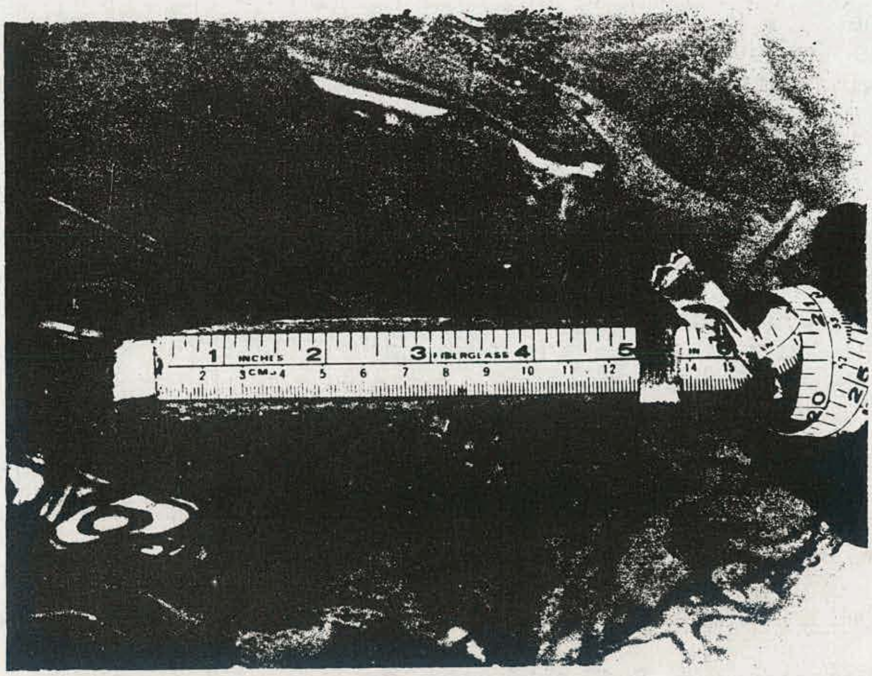


Figure 3.74. Test 9 Weathered 22 Hours

column, and this increased with time except that at the higher frequency, after weathering for 24 hours, the concentration of oil in the water column showed a dramatic decrease. This is attributed to the formation of stable emulsions that had an affinity to the droplets and took them out of the water column. The appearance of the oil in the higher frequency tests, after 24 hours showed a stringiness as though it had been shredded or torn apart. This did not happen with the lower frequency waves, where the concentration increased with time in all the salt water tests. However, it is possible that the same phenomena, the dramatic decrease in concentration, would have been observed if these lower frequency tests were run for a longer period of time. It therefore appears that the effect of increasing the frequency is to speed up the weathering process.

The effect of an increase in temperature is to increase the amount of oil getting into the water column.

Doubling the quantity of oil in the slick did not change the percent concentration of oil in the water column. This would indicate that the amount of oil getting into the water column is directly proportional to the amount present. In the ocean, currents would carry some of the oil away from under the slick.

Tests using the dispersant did not show a sudden increase in concentration of the oil in the water clumn immediately after adding the dispersant as might be expected. The visual properties of the slick and the waves changed, but the oil did not get into the water column until it had weathered over eight hours after adding the dispersant. After 22 hours of weathering, practically all the oil was in the water column.

The scatter in the data indicated that more tests should be made with similar conditions to improve the confidence limits. Additional tests should be made with wind driven waves and measurements taken of the rates of evaporation. Additional tests with wind driven waves and dispersants should be made.

References

1. Julius Bendat and Allan Piersol, Random Data: Analysis and Measurement Procedures, John Wiley and Sons, 1971.

2. Horace Lamb, Hydrodynamics, Dover, 1932.

3. Paul P. Kumar, Beach Processes and Sedimentation, Prentice Hall, 1976.

4.0 The Entrainment of Oil in the Water Column

Leif N. Persen

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4.1 SURVEY

4.1.1. Introduction

The present study of the entrainment of oil from a slick on the ocean's surface to the water column is mainly based on the author's idea about the process as this is explained in [1]. For the sake of completeness, this is reviewed in the next section. The present investigation is based on three experiments conducted within the framework of the Department of Energy project at the University of Rhode Island. These have been initiated and reported in the Interim Report [2] from the DOE project. It has been the present author's fortune to be allowed to influence the conduction of these experiments such that they might be used to prove or to disprove the different concepts of the entrainment. The way in which this is done will be the subject of subsequent sections.

When discussing the entrainment process, the actual quantities used to describe this process should be well defined. Thus the "entrainment rate" ($\dot{m}$) denotes the mass of oil transported from the slick into the water column per unit time and unit area. This quantity is not necessarily a constant. It may vary with time and location and is to be considered a local and not a bulk quantity.

4.1.2 The Entrainment Process

When an oil spill occurs, a slick is formed on the sea surface which will spread and get thinner in the process. The surface of the sea is in motion partially because of the waves, partially because of the wind-wave interaction and partially because of the current in the sea. It is known that the surface tension of the oil-sea interphase plays an important role in the entrainment process. (This is dramatically exhibited by adding a dispersant to an oil slick and thereby reducing the surface tension whereupon an enhanced entrainment is observed.)

It is furthermore recognized that the mechanical agitation that takes place at the sea surface plays an important role in the process. This may lead to the identification of the energy input at the surface as a second important parameter. Realizing however that this energy input may take place in different manners with different results as far as the entrainment process is concerned, one is led to the conclusion that additional parameters must be identified.

Preliminary experimental evidence seems to indicate the following scenario. The mechanical agitation will produce "entrainable" particles of oil mainly when it causes rifts in the oil film, i.e., when the "premissible" surface tension is exceeded. An analogy may be found in the production of fiber particles when tearing a sheet of paper. If that concept is correct, the production of entrainable particles is to be considered a random process even under the most well-defined conditions. Bearing in mind the conditions on the open sea, one will conclude that the production of entrainable oil particles must indeed be considered a random process. One must, however, also be permitted to assume that the average or mean production may be quantified in the same way as mean values in turbulent fluid flow are determined. A support for such an idea may be found in the following observations:

1. The addition of a dispersant makes it easier to produce such rifts, thus enhancing the production of entrainable particles.

2. The production of entrainable particles will appear to be greater at the locations where the oil slick on the surface is thin than where it is thick or perhaps in the form of an emulsion (mousse). This is in complete agreement with observations previously made.

The expression "entrainable" particles needs some extra comments. The violent actions of breaking waves have been widely accepted as the action responsible for the entrainment of oil in the water column.* Such action produces oil particles of different sizes and the larger ones are by the action of buoyancy forces, quickly returned to the surface. The smaller the particles, the easier it is for them to be carried by the mean flow in the upper part of the water column. Thus, the term "entrainable" particles is reserved for those oil particles (or oil covered water droplets) which are "trapped" by this motion. The violent action of breaking waves can only force oil into the water column to a certain depth, the order of magnitude of this depth being the wave height. Thus, the entrainment of oil in the water column is very much dependent on the re-circulating motion connected with the waves in the upper layers of the water column. (It should be emphasized that the concept of "entrainable" particles makes entrainment possible also in the absence of breaking waves.)

There is, however, also another type of re-circulating flow in the ocean which is caused not by the wave motion, but by the non-uniform horizontal velocity distribution in the direction of the wind. This type of re-circulating motion will bring the entrained oil particles down to depths which are orders of magnitude larger than those in the previous cases. This type of motion can be modeled analytically on the turbulent plane jet flow or on the turbulent boundary layer type flow. This will be shown subsequently.

The picture given here of the entrainment envisages a semi-steady case in which a certain amount of oil is trapped by a re-circulating type of flow. If the conditions on the surface change, the amount of entrained oil will change. Assume, as an example, that the surface became completely calm, and that the re-circulating flow died out completely. Then only the extremely small droplets of oil which could be held in suspension would remain "permanently" entrained in the water column, the rest of the oil would resurface (or some might sink due to change in physical properties).

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*See [3] Phani P.K. Raj: "Theoretical Study to Determine the Sea State Limit for the Survival of Oil Slicks on the Ocean" Final Report, No. Cg-D-90-77, Task No. 4714-21. Department of Transportation, U.S. Coast Guard, June 1977. p. 4-9

A consequence of the given description of the entrainment process is the fact that the so-called entrainment rate at the surface can no longer be considered a quantity determined by surface conditions alone. (Energy input, etc.). It is intimately connected with the re-circulating flow in the sea. As a further consequence, the search for "new" parameters to describe the entrainment rate will have to be replaced by a search for a more or less semi-empirical description of the recirculating flow from which the entrainment rate can be deduced.

One may, as a matter of fact, envisage a mechanism whereby the effect of the mechanical agitation that takes place at the surface (waves, breaking waves, raindrops, wind, etc.) is mainly to produce an adequate supply of entrainable particles in the immediate neighborhood of the surface. How many of the entrainable particles will be trapped by the re-circulating flow is then determined by the "strength" of this flow (whereby the strength of this flow will subsequently have to be defined in more exact terms).

One may contemplate this situation somewhat further. If the re-circulating flow is steadily "trapping" new particles, average concentration of oil in the region of this re-circulating flow must be steadily increasing. If it is not, i.e., if a semi-steady state is reached, the concentration will be constant and the entrainment rate zero. This can only occur in two cases. In the first case, there is no more production of entrainable particles at the surface, a situation that may well be feasible in view of the changes that the oil undergoes as it is being weathered on the surface. In the second case, an adequate supply of entrainable particles is present in the surface layer, but the re-circulating flow is returning formerly trapped particles at the same rate as new ones are being trapped.

The entrainment process described above has made no mention of the fact that the oil changes as it stays on the water surface and is being mechanically treated, a fact that is frequently referred to as "weathering" of the oil. Well known features of this process are the evaporation of the lighter components of the oil and the formation of chocolate mousse in some cases. It is evident that these processes will influence the composition of the entrained oil. Thus, it is already clear from the start that the entrained oil is different from the originally spilled oil, a fact that becomes important in the experimental investigation of the entrainment process.

4.1.3 Scope of the Experimentation

The entrainment process is a very complex one, not only because of the complexity of the surface conditions, but perhaps even more by the fact that the boundary conditions for the process change both with time and space. This may perhaps best be illustrated by observing that at one particular instant the situation downstream of a source continuously feeding a slick can be subdivided into several regions in which different predominant conditions prevail:

1. Immediately after the source, the oil is in its virgin state, but in this region is rapidly being changed due to evaporation of its lighter components.

2. The first region is overlapped by the second in which the situation is described in an undated report by the JBF Scientific Corporation (no identified author) for the American Petroleum Institute, p. 37:

   > "One of the important physical characteristics of crude oil slicks which is often neglected in the literature is the existence of one or more thick oil patches surrounded by a thinner film of oil. These thick areas have been referred to as 'lenses' or 'globs'. Investigators who have considered such thick patches report that they may contain 90% of the total oil in the slick, and that the patches are normally several millimeters thick as opposed to thousandths of a millimeter for the thinner surrounding film."
   >
   > "Under conditions of no wind, the slick most probably spreads radially from the lens. However, in the presence of wind and waves, the radial spreading from the leading edge is continually overrun by the higher-velocity lens. The wind and wave activity cause the lens to break up into long windrows, each of which continues to act as a generator or reservoir of oil."

   Most probably the important amount of entrained oil is coming from the thin film surrounding the lenses.

3. The next region which may be identified is the one in which "chocolate mousse" is being formed. According to the same report:

   > "Patches of 'chocolate mousse' should be conceptually distinguished from the lenses, because lenses appeared immediately after the oil was spilled and tended to remain roughly circular while 'chocolate mousse' was formed some time later and became elongated in windrows during the tests."

4. The last region to be specified is so far downstream of the source that the weathering of the slick is more or less complete in the sense that further changes do not take place. The formation of tar balls is starting and the slick seems to be more or less disintegrated.

It is clear that with boundary conditions as complex as those described above, the entrainment process is not easily accessible to analytic treatment. A study of the process should, therefore, start with experimentation under clearly identified and simplified boundary conditions.

The way in which the entrainment process has been visualized in the preceding section has reduced the importance of a detailed analysis of droplet formation at the slick. The main importance is now placed on the re-circulating motion and its ability to "trap" the droplets which presumably are being produced in adequate quantities. This production can be related to certain input data characterizing the surface conditions, and it is emphasized that now the overall (bulk) production is being at the center of interest, not the details of droplet formation.

If one is faced with the problem of designing experimental set-ups which would give adequate information on the droplet formation, one would most probably have to consider a so-called "semi-steady" situation whereby the net bulk entrainment rate is zero. A change in the surface situation which could be achieved without changing the re-circulating motion could, through measurement of the concentration of oil in the water column, be interpreted to give information on the droplet production.

Because this experiment is such that the surface conditions and the re-circulating motion can be manipulated separately, the experiment will allow for a study of the "trapping" mechanism of the re-circulating motion. Thus, an adequate quantification of what is previously called the "strength" of this motion can be made. The "raindrop experiment" to be considered in detail later, is just an experiment of the type mentioned above.

The situation where the re-circulating motion is caused directly by the local wind-wave interaction at the sea surface is to be studied in the so-called "wind-wave experiment". Since the re-circulating flow is being monitored, the possibility of relating the results from this experiment to the others is present.

The situation which arises when the re-circulating motion dies out is to be studied in the so-called "drop size experiment". This experiment also provides the opportunity to study the entrainment from a slick exclusively driven by the turbulent motion in the sea (connected with the re-circulating flow).

4.1.4 The Drop-Size Experiment

This experiment was originally conceived of and conducted by Dr. T. Kim and Mathew Cherian. The first results were reported in detail in [2] where the major emphasis was placed on the influence of interfacial tension on drop size. The apparatus used is shown in Fig. 4.1 and consists mainly of a cylindrical tank and a centrally mounted impeller which can be operated at different angular velocities. The tank is filled with sea water on the surface of which a certain amount of oil is poured. To prevent the whole content of the tank from rotating with the impeller, the tank is supplied with baffles.

At very high angular velocities (of the impeller), the oil is almost totally "whipped" into the water column. Depending both on the angular speed and on the length of time when the impeller is run, different concentrations of oil in the water column are observed as a function of the time elapsed since shut off of the impeller. This result may be correlated with drop-size measurements. The fact that a certain portion of the entrained oil seems to remain "permanently" in the water column may be the most important part of the entrainment from a biology standpoint because it allows for a long term influence of the oil on marine life.

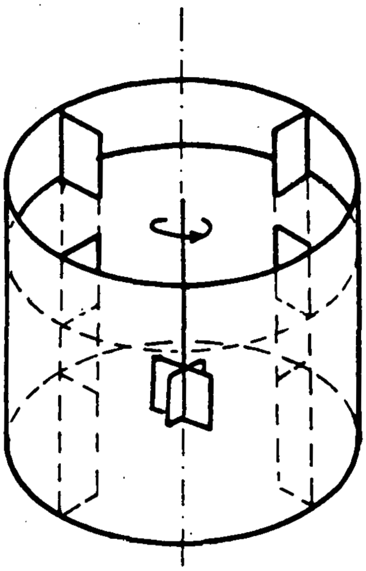


Fig. 4.1 Apparatus for the Drop-Size Experiment

The same arrangement may, however, be used to study entrainment from a slick due exclusively to small scale turbulent motion underneath it. In this case, no mechanical agitation due to waves or rain, etc. takes place at the surface. The speed of the impeller is small, and the effect of the baffles is to more or less break up the horizontal rotation of the fluid. A special type of flow, in which vortices starting out from the surface can be identified, is produced and since the flow field can easily be monitored, the entrainment process under these special circumstances can be related to the observed entrainment in the other experiments. Whatever quantity related to and characterizing the flow is best suited as a relating parameter to the entrainment, will emerge as a result of the investigation.

4.1.5 The Raindrop Experiment

This experiment was first conceived of and conducted by Dr. Peter Cornillon and the results were reported on in [2]. The geometry of this experiment is shown in Fig. 4.2 where the "rain" is produced as drops falling from the needles in the bottom of the *B* container and is falling onto the water surface of the container *C*. On this surface, an oil slick is being placed and one has an arrangement whereby the mechanical agitation at the surface can be manipulated by adjusting the "intensity" of the rain, i.e., by changing the kinetic energy per unit area of the impacting raindrops. In its original form, as conducted by Dr. Cornillon no re-circulating flow was created. The apparatus has been changed by

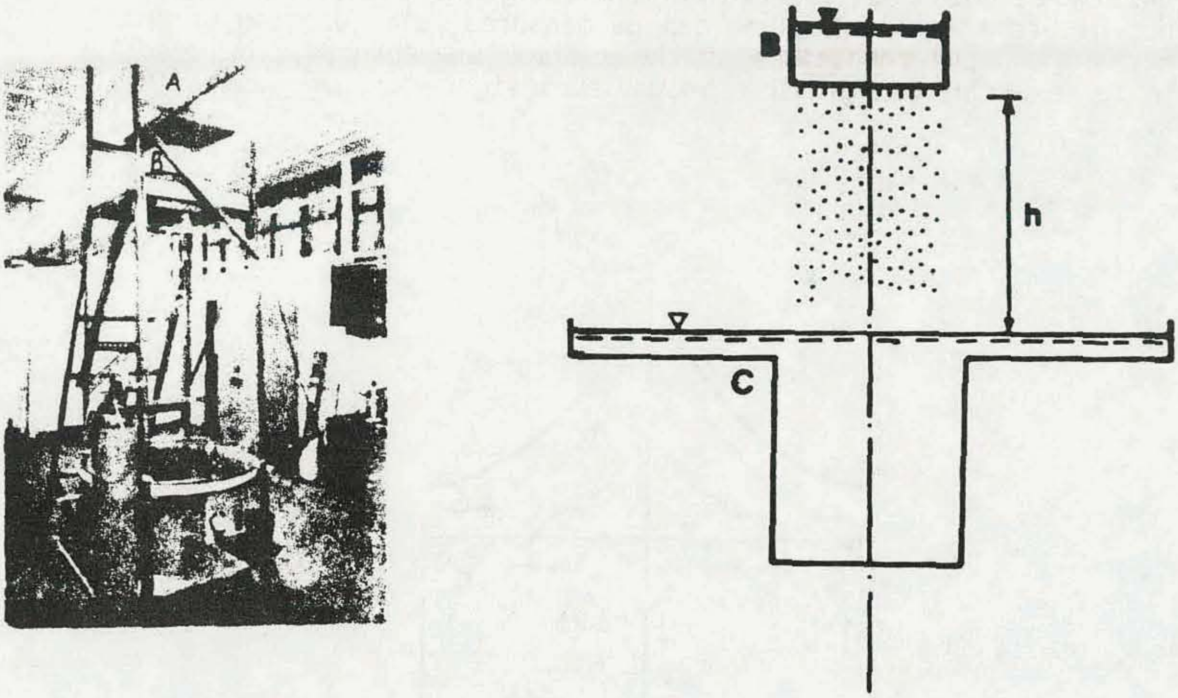


Fig. 4.2 Sketch of the Raindrop Apparatus

the introduction of an impeller and baffles of the same type as in the drop-size experiment. In this way provisions have been made to create the same type of small scale turbulent motion underneath the slick as in the first experiment, and the influence of the mechanical agitation at the surface can thus be experimentally explored. It should be mentioned that the initial experiments with this apparatus have shown that with no re-circulating motion in the water column, entrained oil in the water column is not found below the immediate layer underneath the slick. This is in complete agreement with the concept of the entrainment process already outlined in the Introduction, and may be considered as experimental support for the concept.

4.1.6 The Wind-Wave Experiment

This experiment was originally conceived of by Dr. Rodger Dowdell and was conducted by Steven Parks (see Section 3). The arrangement is shown in Fig. 4.3. A circular tank *A* is filled with water on the surface of which an oil slick may be applied. A doughnut shaped wave-maker *C* is shown close to the surface and by agitating this doughnut vertically at different frequencies and/or amplitudes, a pattern of radially moving surface waves may be created. In addition, a hood may be placed over the surface and by suction applied to the top of the hood *B*, a radially directed wind over the surface is created. The shape of the hood is such that the wind is of constant velocity. The arrangement seems to be well suited for a study of the wind-wave interaction and the influence on the oil slick of this action. The wave action as well as the wind action will create a re-circulating flow as shown in the sketch, Figure 4.3. Since this re-circulating flow can be monitored, and the concentration of entrained oil in the water column can be measured as a function of space and time as the input conditions on the surface are changed, the results from these experiments provide valuable insight to the entrainment process.

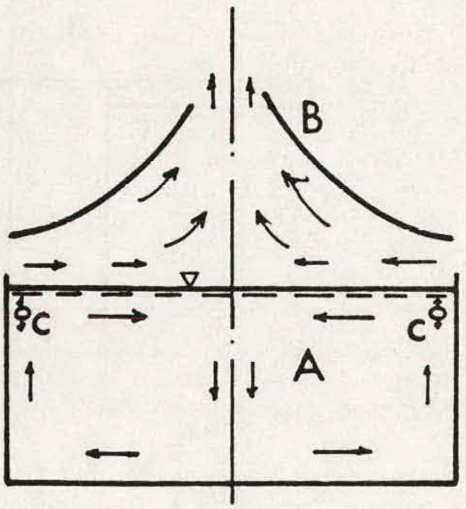


Fig. 4.3 The Wind-Wave Experiment

4.1.7 Experiment-Reality Correlation

The presentation of the experimental efforts has put the emphasis on the re-circulating flow underneath the slick as a common feature of all experiments whereby the different phases of the entrainment process are being studied. If these experiments are being properly executed, and provided the proper range of variation of the input data can be achieved, they present a range of conditions which cover most of those occurring along the slick as described in Section 4.3. Even the production of chocolate mousse can be expected to occur in the wind-wave experiment.

If, however, this information is going to be applicable to the real life situation at sea, the re-circulating flow which occurs at sea will have to be ascertained. This can be attempted experimentally by proper in-situ experimentation. Most probably one will find that the re-circulating flow connected with the waves can be experimentally explored, but that the very large scale motion connected with the non-uniform horizontal velocity of the surface layers cannot.

This, then is the point at which the re-circulating large scale motion may be theoretically explored through an analytic approach using the method described by Leif Persen [4] and applied successfully to turbulent boundary layers. It should be mentioned that this approach does not include the influence of a possible thermal stratification in the ocean, but it will be sufficient as a first approximation. A later sophistication of the approach may be attempted when deemed necessary.

4.2 THE RECIRCULATING FLOW IN THE OCEAN

4.2.1 Introduction

The flow in the upper layer of the ocean will, where there is a gradient in the horizontal direction of the wind, exhibit a horizontal velocity which varies with the distance in the horizontal direction. This will give rise to a vertical motion of the fluid which goes to large depths compared with the wave heights. It is this motion which is responsible for the entrainment of oil particles at large depths. In the present section this motion is modeled on similar turbulent flows, i.e., flows which exhibit a change in the magnitude of the main velocity component with a correspondingly induced transverse velocity component which will then be responsible for a spreading effect. It is a fact that if one limits the scope to two-dimensional cases, such turbulent flows exhibit similarity properties of some kind, and it is easy to imagine this feature carried over to the turbulent flow in the upper part of the ocean.

The present approach will consist of an examination of the two-dimensional boundary layer flow and the two-dimensional jet flow in order to prepare the path for an examination of the fate of oil droplets in such flows. It will also show how these situations are relevant to the flow in the ocean.

4.2.2 The Turbulent Boundary Layer

The flow in the turbulent boundary layer on a flat plate may be described in a simplified way by assuming the existence of a law of the wall: [4]

$$u^+ = f(y^+) \tag{2.1}$$

or

$$y^+ = \phi(u^+) \tag{2.2}$$

The essence of this law is that the turbulent flow is such that it prescribes a one-to-one correspondence between the non-dimensional wall distance y^+ and the non-dimensional velocity u^+ parallel to the wall. It should be noticed that these quantities are defined as

$$u^{+} = \frac{\bar{u}}{v_*} , \quad y^{+} = \frac{y v_*}{\nu} \tag{2.3}$$

where

$\bar{u}$ = mean velocity parallel to the wall (x-direction)

$\bar{v}$ = mean velocity perpendicular to the wall (y-direction)

x = coordinate along the wall

y = coordinate perpendicular to the wall

v_* = shear velocity = $\sqrt{\tau_w/\rho}$

τ_w = shear stress at the wall

ρ = density of the fluid

ν = kinematic viscosity of the fluid

The mathematical problem of solving the basic equations and seeking the implications of the statement in (2.1) are shown in detail in |4|, and only some results need to be drawn upon here:

1) The variation of the shear stress τ in the fluid is given as

$$\frac{\tau(x, u^{+})}{\tau_w} = 1 - \frac{G(u^{+})}{G(\xi)} \tag{2.4}$$

where

$$\left. \begin{aligned} G(\xi) = \frac{1}{3}\xi^3 + \frac{A}{\kappa^2}\Big[e^{\kappa\xi}[(\kappa\xi)^2 - 2\kappa\xi + 2] - 2 - \frac{1}{3}(\kappa\xi)^3 - \\ - \frac{1}{4}(\kappa\xi)^4 - \frac{1}{10}(\kappa\xi)^5 - \frac{1}{36}(\kappa\xi)^6\Big] \end{aligned} \right\} \tag{2.5}$$

Here ξ is the value of u^{+} at the outer edge of the boundary layer, i.e.

$$\lim_{y \to \delta} u^{+} = \xi = \frac{U_o}{v_*} \qquad \lim_{y \to \delta} y^{+} = y_c^{+} = \frac{\delta v_*}{\nu} = \phi(\xi) \tag{2.6}$$

and y_o^+ is the corresponding value of y^+. The constants A and κ have been determined by D.B. Spalding [5]: $A = 0.1108$, $\kappa = 0.4$.

2) The vertical velocity $\bar{v}$ is given as

$$\bar{v} = -\frac{\nu}{v_*}\frac{dv_*}{dx}\, y^+ f(y^+) \qquad (2.7)$$

3) The solution to the problem renders ξ as a function of x:

$$G(\xi)\frac{d\xi}{dx} = \frac{1}{\nu} U_o \qquad (2.8)$$

where as before U_o denotes the constant outer velocity. Through a combination of (2.7) and (2.8) it is now possible to establish the following equation for $\bar{v}$:

$$\bar{v} = U_o \frac{y^+ f(y^+)}{\xi G(\xi)} \qquad (2.9)$$

and at the outer edge of the boundary layer the limiting value $\bar{v}_\infty$ is obtained

$$\bar{v}_\infty = U_o \frac{y_o^+ f(y_o^+)}{\xi G(\xi)}$$

Since (2.8) gives the relationship between ξ and Re_x one may use ξ to indicate a certain position along the wall:

$$Re_x = \frac{U_o x}{\nu} = \int_0^\xi G(z)\,dz \qquad (2.10)$$

Then the relation (2.9) may be interpreted as a variation of $\bar{v}$ at a given position x (given through ξ) as y varies from zero (at the wall) to y_o^+ (at the outer edge of the boundary layer). The implication of the law of the wall is however that (2.9) also describes the variation of $\bar{v}$ at a given value of y as x varies. This is schematically shown in Fig. 4.4 where y = *constant* is shown to

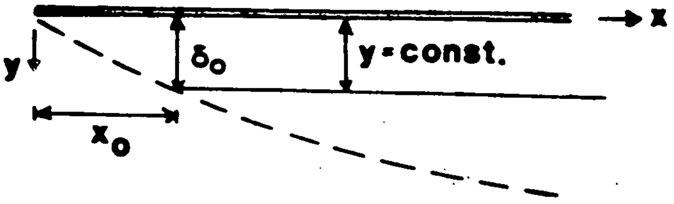


Fig. 4.4

hit the outer edge of the boundary layer at $x = x_o$. The corresponding value of ξ is ξ_o and at this point the vertical velocity $\bar{v}$ is from (2.9) found to be

$$\bar{v}_o = U_o \frac{y^+_{o.o} f(y^+_{o.o})}{\xi_o G(\xi_o)} \tag{2.11}$$

where now $y^+_{o.o}$ represents the value of y^+_o at $\xi = \xi_o$. Since ξ is related to the local Reynolds number Re_x through (2.10) it is observed that the lowest value for Re_x for a given value of y is

$$Re_{x_o} = \frac{U_o x_o}{\nu} = \int_0^{\xi_o} G(z)dz \tag{2.12}$$

It is now easily shown that for a given value of y the variation y^+ as one progresses in the x-direction is given as follows:

$$y^+ = \frac{y v_*}{\nu} = \frac{y U_o}{\nu} \cdot \frac{1}{\xi} \tag{2.13}$$

where the variation of x is expressed through ξ. Since this starts to be valid at $x = x_o$ one has (since the constant value of y equals δ_o)

$$y^{+}_{o.o} = \frac{\delta_o v_*}{\nu} = \frac{yU_o}{\nu} \cdot \frac{1}{\xi_o} \tag{2.14}$$

Thus the variation of y^{+} with x (or ξ) will be:

$$y^{+} = y^{+}_{o.o}\,\frac{\xi_o}{\xi} \tag{2.15}$$

Finally, it has been shown [6] that the shear stress τ can be expressed as:

$$\frac{\tau}{\rho U_o^2} = \frac{1}{\xi^2}\left[1 - \frac{G(\frac{\bar{u}}{U_o}\,\xi)}{G(\xi)}\right] \tag{2.16}$$

and the stream function Ψ may be given as

$$\Psi = \int u\, dy = \int u^{+} v_* dy = \nu \int u^{+} dy^{+} = \nu \int u^{+} \frac{d\phi}{du^{+}}\, du^{+} \tag{2.17}$$

Using D.B. Spalding's formulation [5] one will get:

$$\left.\begin{aligned} \Psi = \nu\Bigg[\frac{(u^{+})^2}{2} + A\Big(e^{\kappa u^{+}}(\kappa u^{+} - 1) - (\kappa u^{+})^2/2 \,- \\ - (\kappa u^{+})^3/3 - (\kappa u^{+})^4/8 - (\kappa u^{+})^5/30\Big)\Bigg] \end{aligned}\right\} \tag{2.18}$$

This ends the exhibition of the implications of a turbulent boundary layer. It is not accurate, the procedure used has been improved, but for the present purpose it ought to be sufficient.

4.2.3 The Flow in the Upper Layer of the Ocean

The flow in the ocean is turbulent and this is also the case in its upper layer. In this layer however, surface waves are creating recirculating motions and sometimes these phenomena tend to obscure the large scale motions responsible for carrying oil particles to much larger depths than the wave heights. This large scale motion is not easily recognized experimentally except for the fact it is also responsible for the entrainment of organic particles which makes life exist to large depths.

One may use ones knowledge of turbulent flows in general to come up with an adequate analytic approach to the problem of describing the flow. First one observes that the ordinary linear approach to the wave mechanisms furnishes a flow field which exhibits recirculation but which has no mean motion in the direction parallel to the surface of the sea. The recirculating motion connected with the waves becomes insignificant at depths greater than a couple of wave heights. Closer examination of the fluid motion in the upper layer shows however that there is a mean horizontal velocity component "superimposed" on the wave motion, and this velocity component may vary with the horizontal distance. A simple consideration of the equation of continuity will then show that under such circumstances a vertical velocity component in the ocean is inevitable, and that it will penetrate to depths comparable to the distance over which the change in the horizontal velocity components take place. This may be an order of magnitude larger than the wave height.

There is no immediate and direct way of predicting this type of mean motion. One may however use the boundary layer flow which is described in Sec. 4.2.2 to exhibit a certain relevant case. Fig. 4.5 shows the upper layer of the ocean in which there is a horizontal current U_o as shown by the velocity profile. (A two-dimensional situation is assumed.) At the surface (the waves have been neglected) a horizontal shear stress in the x-direction (opposite to U_o) is supposed to act due to wind. If now this shear stress varies in the proper way, a boundary layer type of flow will develop in the upper layer and the situation is similar to that of Fig. 4.4. Thus the results of Sec. 4.2.2 are immediately applicable to the situation at hand and several cases of shear stress distribution on the surface have been considered whereby the following quantities have been computed as functions of the non-dimensional distance $(Re_x - Re_{xo})$:

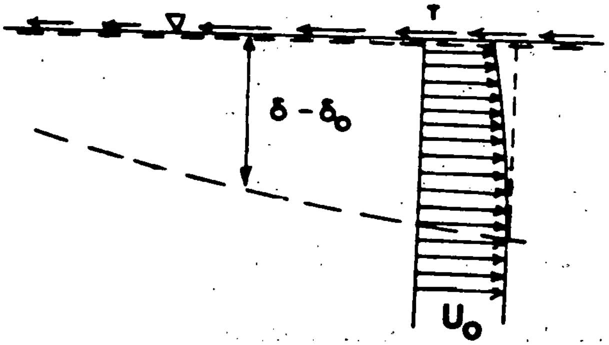


Fig. 4.5

$\tau/\rho U_o^2$ = non-dimensional shear stress distribution

$\bar{u}/U_o$ = non-dimensional horizontal velocity component at the surface

$\bar{v}/\bar{v}_o$ = non-dimensional vertical velocity component at the surface

$\bar{v}_\infty/\bar{v}_o$ = non-dimensional vertical velocity component at a depth equal to and/or greater than the boundary layer thickness $\delta - \delta_o$.

The computations are based on the equations of Sec. 4.2.2 and the computer programs used are exhibited in the Appendix. Fig. 4.6, 4.7, and 4.8 give the variation along the "surface" of the different quantities. The corresponding streamline pattern is exhibited in Fig. 4.9 where the dashed line represents the boundary of the region in which the expressions used are valid. It is seen how the streamlines indicate a vertical velocity (downwards) and the fate of oil droplets in this environment will be discussed in Section 4.3.

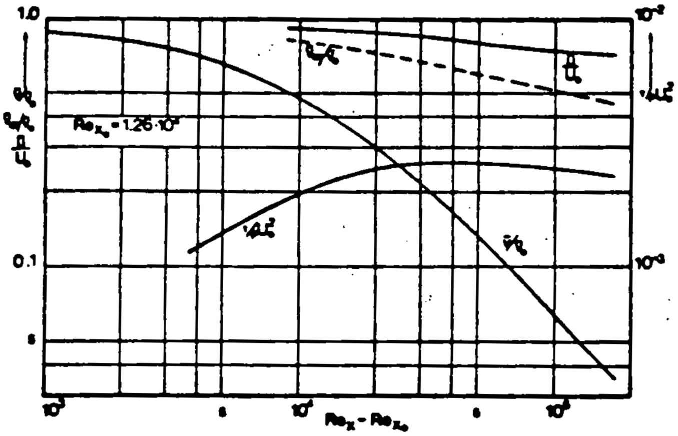


Fig. 4.6

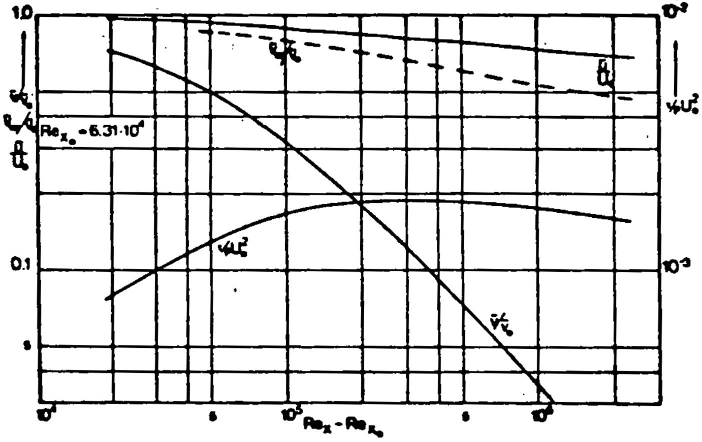


Fig. 4.7

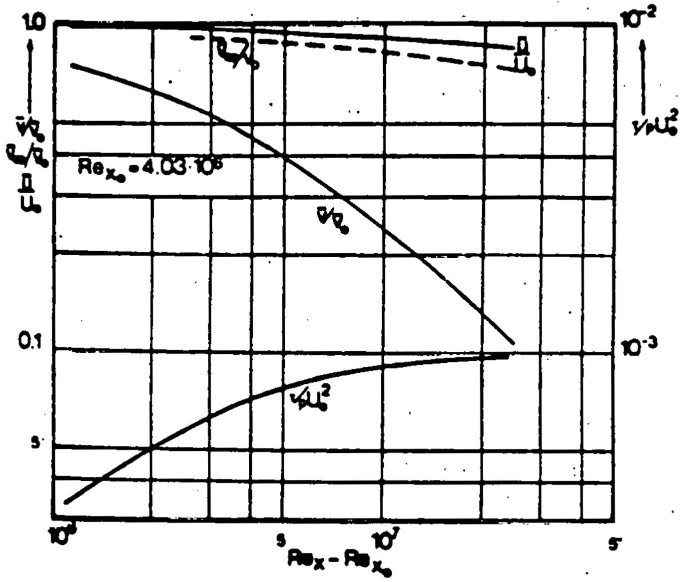


Fig. 4.8

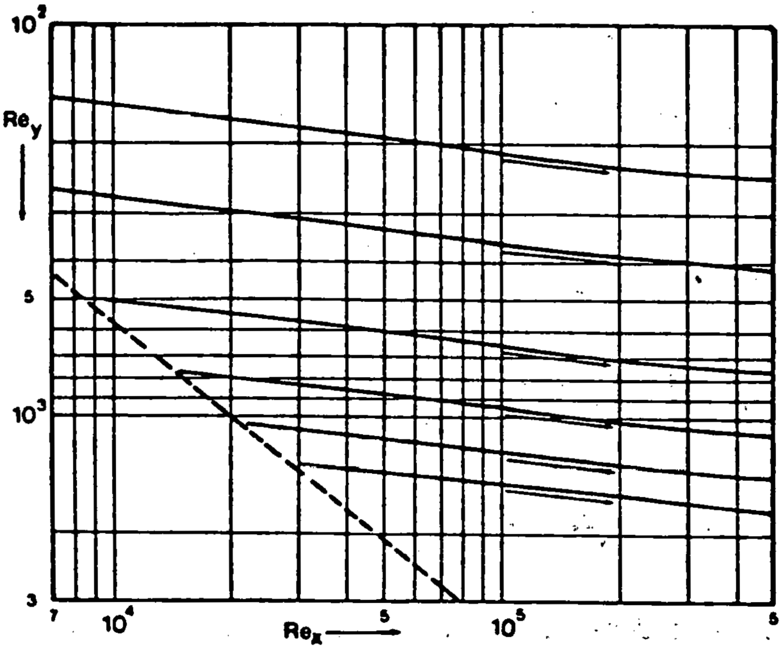


Fig. 4. 9

4.2.4 <u>The Jet Flow</u>

It has been shown how the turbulent boundary layer can be used to model the downward flow in the ocean which in a certain case will occur and which is caused by the horizontal component of the mean velocity gradient. Since this only represents a special situation, one may try to find other models which will be useful in other situations. One such type of flow is the jet flow.

The jet flow is characterized by the fact that it is a self-similar type of turbulent flow. However, most of the jet investigations operate with a velocity field which corresponds to a non-vanishing velocity component at infinity normal to the jet-axis. The more proper velocity field would be one exhibiting recirculation, and Persen-Skaug [7] have suggested just that type of velocity profile. The present investigation will start from this assumption and present the flow field as

$$\left.\begin{aligned} \frac{\bar{u}}{U_c} &= (\xi^2 + 1)^{-1/4} f(\eta) \\ \frac{\bar{v}}{U_c} &= \frac{1}{2}(\xi^2 + 1)^{-3/4}\xi\{2\eta f(\eta) - \int_0^\eta f(z)dz\} \end{aligned}\right\} \qquad (4.1)$$

where $f(\eta)$ is a non-specified velocity profile, η is the non-dimensional distance normal to the jet axis and ξ is the non-dimensional distance along the jet axis.

$$\left.\begin{aligned} \xi &= (x - x_o)/A \\ \eta &= \frac{y}{A}(\xi^2 + 1)^{-1/2} \end{aligned}\right\} \qquad (4.2)$$

Here A and x_o are parameters important in the description of the jet flow but for the moment these are left for future consideration in the present context.

With this preliminary information one may now explore the jet flow somewhat closer. The velocity profile $f(\eta)$ is specified as

$$f(\eta) = e^{-\eta^2} - \frac{2B\eta^2}{\sqrt{\pi}(B^2 + \eta^2)} \qquad (4.3)$$

where B is a constant to be determined later. It is observed that

$$\int_0^\eta f(z)dz = \int_0^\eta e^{-z^2} dz - \frac{2B}{\sqrt{\pi}} \int_0^\eta \frac{z^2}{(B^2 + z^2)} dz \qquad (4.4)$$

which can be rewritten as:

$$\int_0^\eta f(z)dz = \frac{\sqrt{\pi}}{z}\, erf(\eta) + \frac{\eta B}{\sqrt{\frac{2}{\pi}}}(B^2 + \eta^2)^{-1} - \frac{1}{\sqrt{\pi}} arc\ tan(\frac{\eta}{B}) \qquad (4.5)$$

It is seen that

$$\left.\begin{aligned} &\lim_{\eta\to\infty} \int_0^{\eta} f(z)dz = 0 \\ &\lim_{\eta\to\infty} f(\eta) = 0 \end{aligned}\right\} \quad (4.6)$$

This means that the velocity field dies out (in view of (4.1)) as $\eta \to \infty$ (i.e. for large values of y).

The stream function Ψ for the flow under consideration will now be expressed as

$$\Psi = AU_c(1 + \xi^2)^{1/4} \int_0^{\eta} f(z)dz \quad (4.7)$$

4.2.5 The Analogous Flow in the Ocean

Just as the boundary layer flow exhibited in Section 4.2.2 was shown to have a bearing on the flow in the upper layer of the ocean, the jet flow may also be shown to be applicable. If one imagines the scenario when a wind has produced a mean horizontal velocity in the upper layer of the ocean and then ceases to blow, the situation will be as shown in Fig. 4.10 where the velocity profile is similar to that of the jet with a zero velocity gradient at the surface indicating the absense of a shear stress at the surface. The horizontal velocity will eventually die down and a

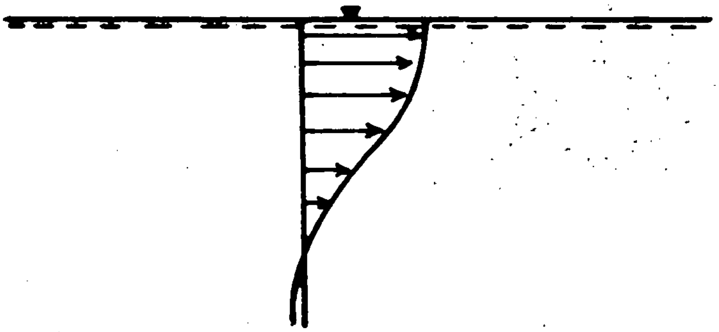


Fig. 4.10

velocity gradient in the horizontal direction will produce a downward flow in the ocean. Thus the jet flow has found its analogue in the large scale flow structure in the ocean. The flow is illustrated in Figs. 4.11 an 4.12. It is seen that the flow patterns are very similar even though the parameter is $B = 2$ and $B = 5$ respectively. Consequently, only one case will be treated subsequently when the fate of oil droplets in this type of flow is considered in Section 4.3.

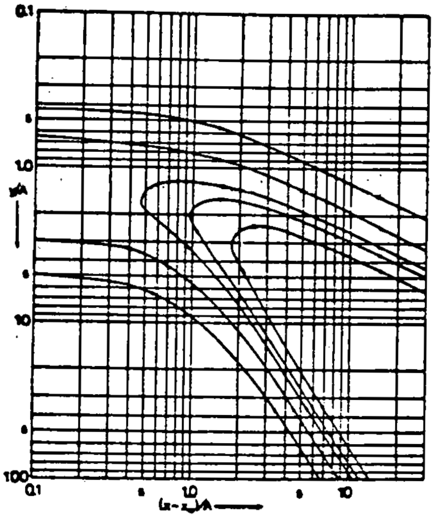


Fig. 4.11 Streamlines in the recirculating flow, $B = 2$

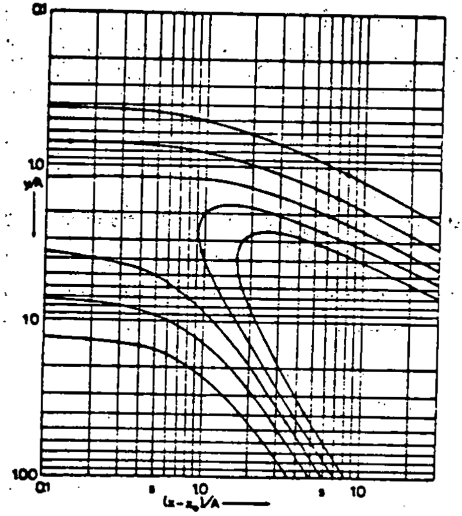


Fig. 4.12 Streamlines in the recirculating flow, $B = 5$

4.3 THE PATHS OF OIL DROPLETS IN THE OCEAN

4.3.1 Introduction

It has been shown that the entrainment of oil in the water column is governed by the recirculating motion which can be found in the ocean due to the nonuniform velocity distribution of the horizontal velocity component in its upper layer. It is the purpose of this paper to explore the possibility of studying this process more in detail.

4.3.2 The Equations of Motion

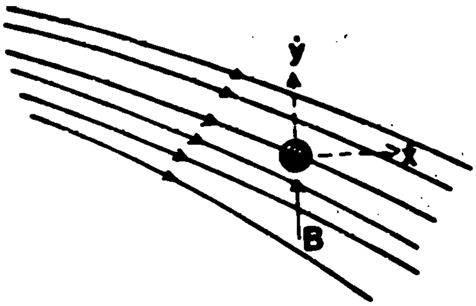


Fig. 4.13 Oil Droplet in a Flow field

It will be assumed that the motion of an oil droplet can be described on the basic assumption that its motion does not affect the flow field. One will then have the flow field described through the velocity components $u(x,y)$ and $v(x,y)$ which may be considered as given or known functions. The position of an oil droplet will be, x,y, its velocity $\dot{x},\dot{y}$ and its acceleration $\ddot{x},\ddot{y}$. Its mass is m.

The set of equations of motion will now be:

$$\left.\begin{aligned} F_x &= m\ddot{x} \\ F_y + B &= m\ddot{y} \end{aligned}\right\} \qquad (2.1)$$

where B is the buoyancy force, and F_x and F_y are the forces exerted on the droplet by the fluid. The latter forces will depend on the relative velocity between the droplet and the fluid. The drag force on a sphere (droplet) is given as a function of the Reynolds number

$$Re = \frac{VD}{\nu} \qquad (2.2)$$

where V is the relative velocity of the sphere to the fluid
D is the diameter of the sphere

ν is the kinematic viscosity of the fluid

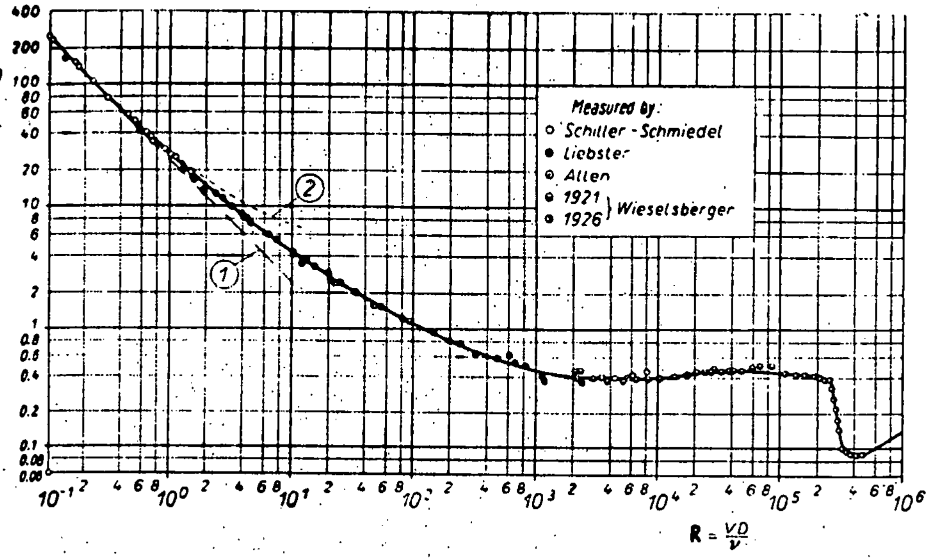


Fig. 1.5. Drag coefficient for spheres as a function of the Reynolds number
Curve (1): Stokes's theory, eqn. (6.10); curve (2): Oseen's theory, eqn. (6.13)

Fig. 4.14

The drag force on a sphere in a cross flow is given in Fig. 4.14 which is a reproduction of Fig. 1.5 in H. Schlichting [8], where c_d is defined as the drag force $\bar{F}$ normalized with the stagnation pressure $\frac{1}{2}\rho V^2 A$, A, being the central cross section of the sphere. The drag force is seen to be proportional to the velocity for very small Re-numbers and proportional to the square of the velocity in the range $10^4 < \mathrm{Re} < 10^5$. The most likely situation for small oil droplets seems to be in the lower range of Re-numbers, and consequently the components of the drag force will be:

$$\left.\begin{aligned} F_x &= -k[\dot{x} - u(x,y)] \\ F_y &= -k[\dot{y} - v(x,y)] \end{aligned}\right\} \quad (2.3)$$

where k is a proportionality factor. Introduced into (2.1) this will give

$$\boxed{\begin{aligned} m\ddot{x} + k\dot{x} &= ku(x,y) \\ m\ddot{y} + k\dot{y} &= kv(x,y) - B \end{aligned}} \quad (2.4)$$

which are the basic equations governing the motion of the oil droplet.

One may now assume that the flow field exhibits a characteristic length A and a characteristic velocity U_c by means of which the following non-dimensional quantities can be introduced:

$\xi\ (x - x_o)\ /A$ = non-dimensional x-coordinate

$$\left.\begin{array}{ll} \zeta = y/A & = \text{non-dimensional y-coordinate} \\ \tau = t\,\dfrac{U_c}{A} & = \text{non-dimensional time} \end{array}\right\} \quad (2.5)$$

$$\left.\begin{array}{l} u^* = u/U_c \\ v^* = v/U_c \end{array}\right\} = \text{non-dimensional velocity components}$$

With these quantities the basic equations will appear in the form:

$$\boxed{\begin{aligned} \frac{d^2\xi}{d\tau^2} + \lambda\,\frac{d\xi}{d\tau} &= \lambda u^*(\xi,\zeta) \\ \frac{d^2\zeta}{d\tau^2} + \lambda\,\frac{d\zeta}{d\tau} &= \lambda v^*(\xi,\zeta) - \beta \end{aligned}} \qquad (2.6)$$

where

$$\left.\begin{array}{l} \lambda = \dfrac{kA}{mU_c} \\[2ex] \beta = \dfrac{B \cdot A}{mU_c^2} \end{array}\right\} \qquad (2.7)$$

The physical quantities in these dimensionless parameters are:

U_c = the characteristic velocity of the flow field

$m = \rho_o V$ = mass of the droplet

$V = \frac{\pi d^3}{6}$ volume of the droplet

d = diameter of the droplet

$$\left.\begin{array}{ll} A & = \text{characteristic length of the flow field} \\ B = g(\rho - \rho_o)V & = \text{buoyancy force of the droplet} \\ k & = \text{proportionality factor for the drag force} \\ & \quad\text{which is here assumed proportional to the} \\ & \quad\text{velocity} \end{array}\right\} \qquad (2.8)$$

From Fig. 4.2 one finds the drag force F under such conditions as

$$F = 25\cdot\frac{1}{2}v^2\rho\frac{1}{4}\pi d^2\left(\frac{vd}{\nu}\right)^{-1} \qquad (2.9)$$

$$= 9.81\cdot v\mu d \qquad \text{i.e.} \quad k = 9.81\cdot\mu\cdot d$$

One may now reformulate the two parameters in (2.7) as follows:

$$\lambda = \frac{9.81\cdot\mu\cdot d\cdot A}{\rho_o\,\frac{\pi}{6}\,d^3 U_c} = 18.74\,\frac{\rho}{\rho_o}\,\frac{\nu}{U_c d}\,\frac{A}{d} \qquad (2.10)$$

$$\beta = \frac{(\rho - \rho_o)g\,\frac{\pi}{6}\,d^3\cdot A}{\rho_o\,\frac{\pi}{6}\,d^3 U_c^2} = \left(\frac{\rho}{\rho_o} - 1\right)\frac{gA}{U_c^2} \qquad (2.11)$$

The dimensional quantities will here have the following numerical values.

ρ = density of water (or sea water) $1.0\ [gr/cm^3]$

ρ_o = density of oil $0.86[gr/cm^3]$

ν = viscosity of water $= 1.0\cdot 10^{-6}[m^2/s]$

A = length characterizing the flow field (2.12)

$1\ [m] < A < 10\ [m]$

U_c = velocity characterizing the flow field

$1\ [m/s] < U_c < 5\ [m/s]$

d = diameter of a droplet $10^{-6}[m] < d < 10^{-4}[m]$

A Reynolds number for the problem may now be formed as

$$Re = \frac{U_c d}{\nu} \qquad (2.13)$$

and with the numerical values given above the following range of variation of Re is obtained:

$$1 < Re < 500 \qquad (2.14)$$

Furthermore, the two parameters λ and β will have a range of variation like:

$$\left.\begin{aligned} &4.36\cdot 10^{2} < \lambda < 2.18\ 10^{8} \\ &0.064 \quad < \beta < 16 \end{aligned}\right\} \quad 2.15)$$

It is now from the magnitude of the parameter λ rather obvious that cases may occur where the acceleration terms in (2.6) become negligible, and consequently the equations reduce to:

$$\left.\begin{aligned} \frac{d\xi}{d\tau} &= u^{*}(\xi,\zeta) \\ \frac{d\zeta}{d\tau} &= v^{*}(\xi,\zeta) - \beta/\lambda \end{aligned}\right\} \quad (2.16)$$

This may be carried even further by observing that the flow field is two-dimensional and that in the case of an incompressible fluid, one then has a stream-function Ψ for the flow from which the velocity components are deduced:

$$\left.\begin{aligned} u^{*} &= \frac{\partial\bar{\Psi}}{\partial y}/U_{c} \\ v^{*} &= \frac{\partial\bar{\Psi}}{\partial x}/U_{c} \end{aligned}\right\} \quad (2.17)$$

Introducing the two non-dimensional quantities ξ and ζ from (2.5) one may rewrite this

$$\left.\begin{aligned} u^{*} &= \frac{\partial\Psi}{\partial\zeta}/AU_{c} \\ v^{*} &= -\frac{\partial\Psi}{\partial\xi}/AU_{c} \end{aligned}\right\} \quad (2.18)$$

which may be introduced into (2.16) to give:

$$\left.\begin{aligned} \frac{d\xi}{d\tau} &= \frac{\partial\Psi}{\partial\xi}/AU_{c} \\ \frac{d\zeta}{d\tau} &= \frac{\partial\Psi}{\partial\xi}/AU_{c} - \beta/\lambda \end{aligned}\right\} \quad (2.19)$$

The ratio of these equations may be written

$$\frac{d\zeta}{d\xi} = \frac{-\frac{\partial\Psi^*}{\partial\xi} - \beta/\lambda}{\frac{\partial\Psi^*}{\partial\zeta}} \tag{2.20}$$

which is the differential equation for the path of the droplet given by ζ as a function of ξ and where Ψ^* is defined as

$$\Psi^* = \Psi/U_c A \tag{2.21}$$

The solution to (2.20) is easily found by introduction of the path-function Θ:

$$\Theta = \Psi^* + \xi\beta/\lambda \tag{2.22}$$

Equation (2.20) now reduces to

$$\frac{d\zeta}{d\xi} = -\frac{\partial\Theta/\partial\xi}{\partial\Theta/\partial\zeta} \tag{2.23}$$

with the solution

$$\boxed{\Theta = constant.} \tag{2.24}$$

Under the given conditions, the path of an oil droplet is given in terms of the streamfunction of the flow as

$$\boxed{\Psi^*(\xi,\zeta) + \xi\beta/\lambda = const.} \tag{2.25}$$

This general solution will now be examined in the two cases of recirculating flow treated earlier.

4.3.3 Particle Paths in a Boundary Layer Type Flow

In the discussion of the recirculating flow in the ocean (Section 4.2) the boundary layer type flow was treated and the analytic description of the flow was carried so far that expressions for the streamlines in the flow were established. Since the path of oil particles (droplets) of the size of interest here is given in terms of the streamfunction of the flow (2.25), the program STREAM (Appendix) has been used to plot the particle paths in environments given as the flow of Fig. 4.9. The result of such computations is shown in Fig. 4.15. As seen from (2.25) the results will depend on the Particle-number $P = \beta/\lambda$.

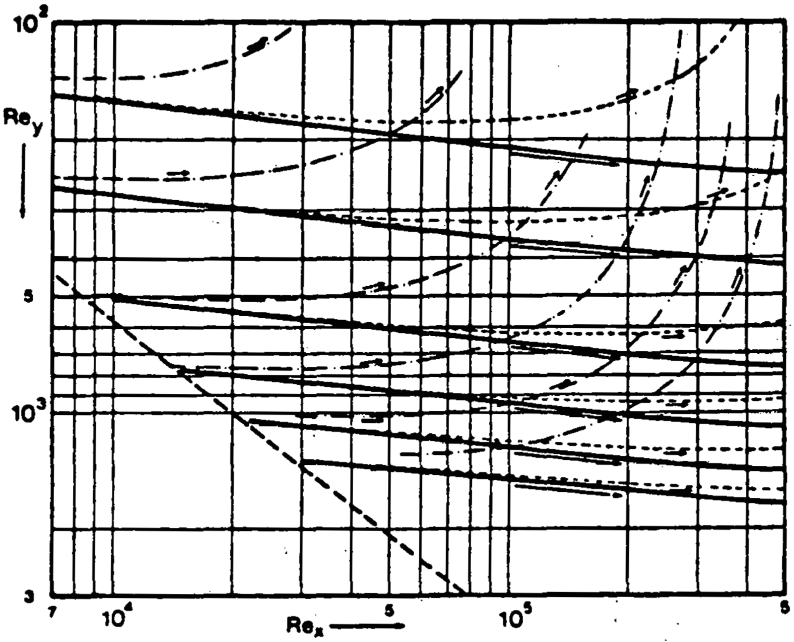


Fig. 4.15 Paths of Oil Particles in a Boundary layer type flow _·_·_·_· $P = 0.001$
— — — — $P = 0.0001$

This P-number can be expressed through (2.10) and (2.11) as

$$P = \frac{(\rho - \rho_o)gV}{kU_c} = \frac{\textit{buoyancy force}}{\textit{characteristic drag force}} \qquad (3.1)$$

or as

$$P = 0.0534\left(1 - \frac{\rho_o}{\rho}\right)\frac{gd^2}{\nu U_c} \qquad (3.2)$$

It is easily seen that the P-number decreases with decreasing droplet size and increasing characteristic velocity of the flow. The P-number for the particles in question will be very small and for this reason Fig. 4.15 has been prepared with P = 0.001 and P = 0.0001. In the first case, the oil particles are seen to rise relatively rapidly, i.e., they have enough buoyancy to "loosen the grip" that the flow has on them. In the latter case it is seen that the particle is "trapped" by the mean flow over a much longer distance before it is able to rise to the surface. For P = 0.00001, the paths of oil particles become indistinguishable from the streamlines within the frame of Fig. 4.15. By contemplating the consequence of (2.25), one may conclude that the smaller the particle is, the further downstream and the further down from the surface it will be carried before being released by the dying out of the recirculating flow. The entrainment mechanism is therefore well explained.

4.3.4 Particle Path in a Jet Type Flow

In the discussion of the re-circulating flow in the ocean the special case was modeled on the plane jet flow. Since also in this case the analytical deductions were carried to the point where the expression for the stream function was established, the computation of the path of oil particles may follow just as easily as in the previous case. The program OIL2 (Appendix) was used for this purpose and the result is shown in Fig. 4.16. The flow corresponds to Fig. 4.12. The same remarks which were made in the previous section apply also in this case. One additional

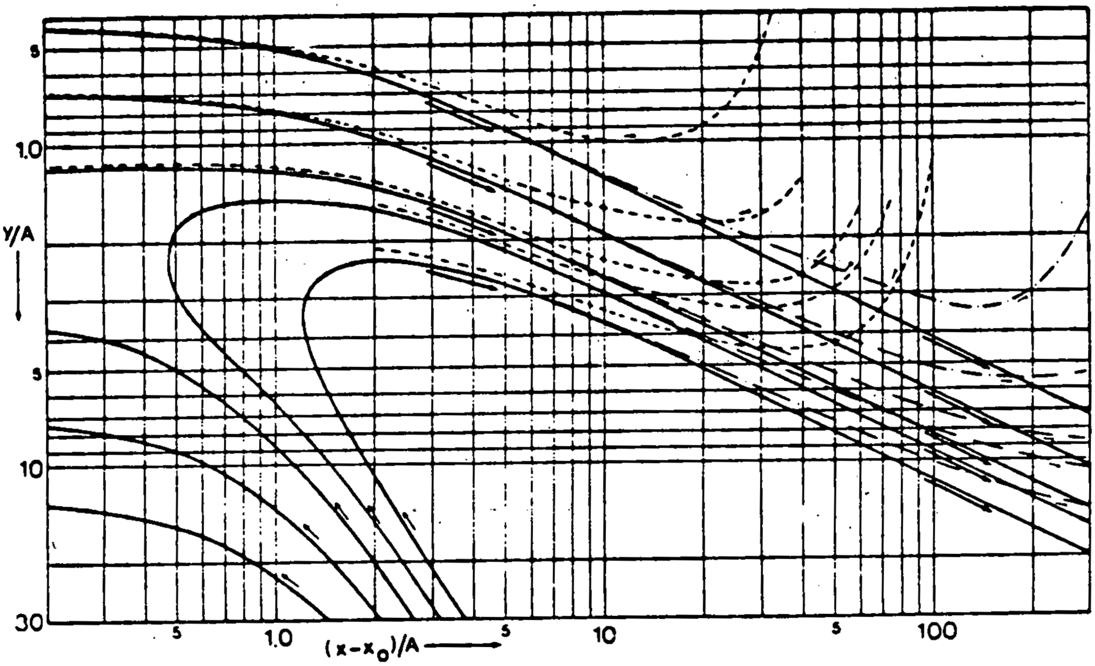


Fig. 4.16 Paths of Oil Particles in a Jet Type Flow

_._._._. P = 0.001
_ _ _ _ P = 0.01

remark may be made. From Fig. 4.16 one may pick out the non-dimensional depth d to which an oil particle will be carried if it initially is placed at a depth d_i.

	$P = 0.01$		$P = 0.001$	
d_i/A	d/A	d/d_i	d/A	d/d_i
0.43	1.00	2.33	3.30	7.67
0.70	1.85	2.64	5.60	8.00
1.20	3.30	2.75	10.00	8.33

This shows that a particle can, depending on its P-number, be carried to depths many times the original depth to which it is being brought by actions at the surface.

4.4 THE EXPERIMENTS

4.4.1 Introduction

Three different experiments pertaining to the entrainment process are described in Section 4.1. The Wind-Wave experiment was conducted by Steven Parks under the supervision of Dr. R. Dowdell and a description of this activity is found in Section 3 of this report.

The Drop-Size Experiment was conducted by Mathew Cherian and the results obtained in his 20 gallon tank will be given here and commented upon.

The Rain-Drop Experiment was conducted by Ted Kawazoe and both experiments were supervised by the author. The earlier experimentation in the rain drop apparatus was supervised by Dr. Cornillon.

4.4.2 The Parameters

Conditions under which the experiments are conducted are determined by several parameters whose importance may not be initially recognized. One may easily identify such parameters as surface tension, temperature, oil slick thickness, intensity of the recirculating flow, etc. as important ones, but it is difficult offhand to judge their relative influence. One or more may be of such importance that it obscures the influence of others. The experimentation was originally planned exclusively in sea water but practical considerations led to some experiments being performed in fresh water. The influence of the type of water on the entrainment could thus be commented on.

Because of difficulties in keeping a constant quality of the sea water to be used, it was decided to measure the surface tension of the water/air interface. In this way one hoped to be able to detect natural surfactants that might be present in the water. For that purpose, a test was made to see how sensitive such a measurement would be to the presence of the dispersant COREXIT 9527 in the water. The result of this test is shown in Fig. 4.17. It is seen that very small concentrations give very large effects and that the surface tension water/air for a concentration of 2.5[mg/l] is almost as small as for COREXIT 9527 alone.

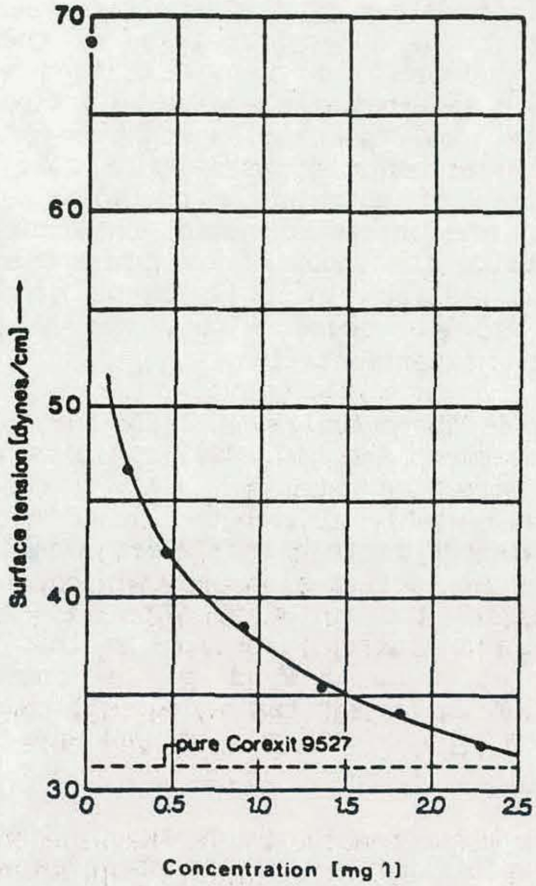


Fig. 4.17 The Effect of Addition of a Dispersant on Measured Surface Tension Water/Air

During this experiment it was discovered that the actual result of a measurement was dependent on the person who performed the test, i.e., that an element of personal judgment was involved. The values should therefore only be given a relative importance.

The next step in the investigation of the parameters was to find a way to ascertain the "strength" of the recirculating flow which presumably is responsible for the entrainment. For that purpose, a hot film Anemometer DISA with a probe 55A87 (conical, quartz coated) was used.

Its performance was examined in a towing tank for calibration and subsequently used for examining the flow created in the tanks by the impellers.

The results of the flow measurements in the 20 gallon tank of the Drop-Size-experiment are shown in Fig. 4.18 where a plot of a plane through the centerline of the tank is shown with the measuring stations indicated by small circles and with curves of equal mean velocity. The plots are shown for different values of the impeller speed (measured in rpm) and it is observed that the general features of the flow pattern seem to be preserved with an increase in mean velocities as the impeller speed is increased. It is clear that a closer examination of the velocity field in the immediate subsurface region might be of interest when exploring the details of entrainment in cases where the flow itself is responsible for the creation of entrainable particles. Such a study must, however, in light of the increased demand on accuracy, equipment and time be considered outside the scope of the present effort. It is, however, observed that the radial velocity gradient along the surface increases with increasing impeller speed. Thus, the impeller speed may be used as a parameter in the experimentation.

The recirculating flow is characterized also by the turbulent intensity. This quantity was measured and Fig. 4.19 exhibits the results in the 20 gallon tank of the Drop-Size experiment. It is observed that the turbulent intensity is rather evenly distributed throughout the tank. A feature which may be of interest is that the lowest impeller speed seems to create a greater turbulent intensity close to the impeller than do the higher speeds. In all cases, the turbulent intensity is of the same order of magnitude. Thus one may already conclude at this point that any influence on the entrainment process, which may be observed due to a change in impeller speed, may be attributed to a corresponding change in velocity gradient along the surface and not necessarily to a change in turbulent intensity.

These remarks conclude the preliminary remarks on the parameters of the experiments. The effect of each one of the other parameters will be discussed in the presentation of the results.

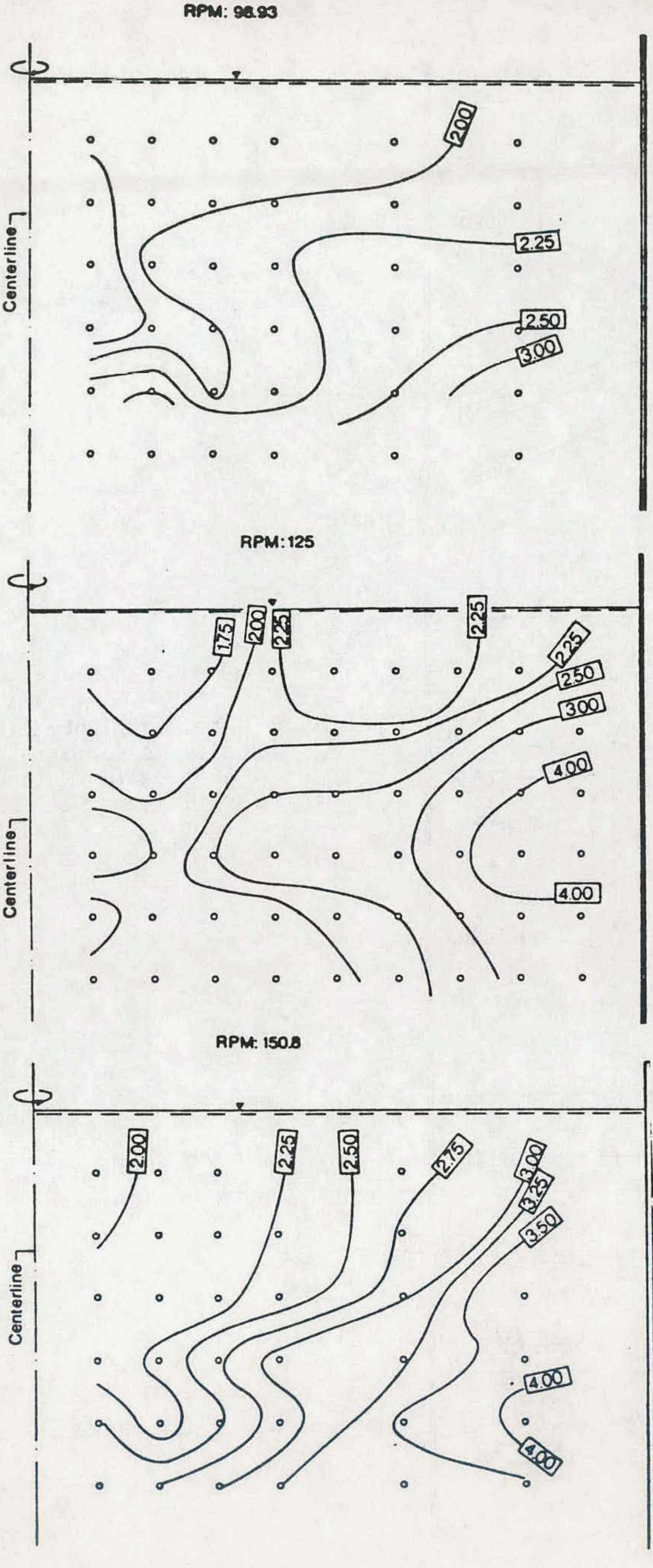


Fig.4.18 The mean velocity of the turbulent recirculating flow in the 20 gallon tank measured at different impeller speeds.

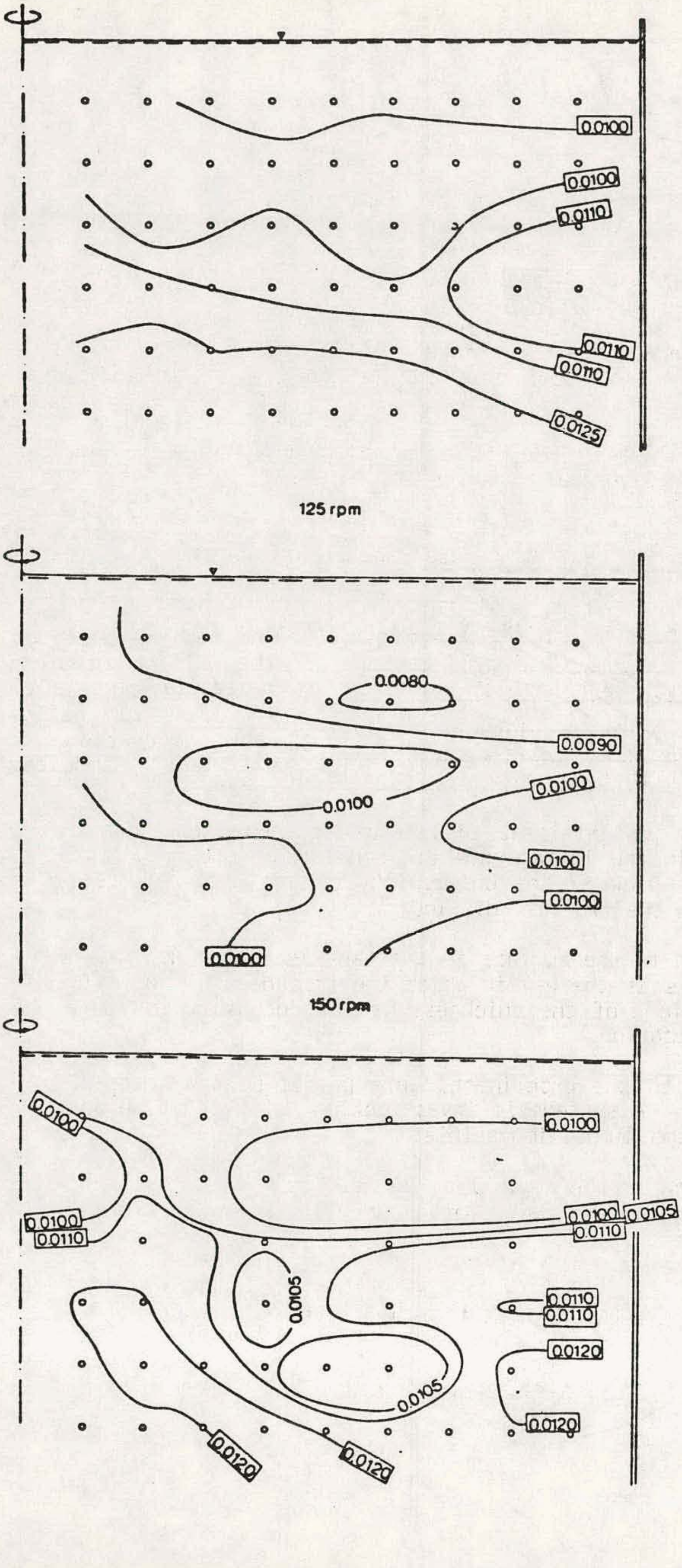


Fig.4.19 The turbulent intensity measured in the 20 gallon tank's upper part at different impeller speeds.

4.4.3 The Drop Size Experiment

In the exposition of the author's concept of the entrainment process, a mechanical agitation of some sort, acting at the surface was supposed to be responsible for the creation of "entrainable particles". In the Rain Drop Experiment (Section 4.4.4), the rain impinging on the oil slick is such a mechanical agitation. As pointed out in Section 4.1, some focus their attention on the breaking waves as the mechanism for introducing the necessary action. In the present experimentation no mechanical agitation other than what is being brought about by the recirculating flow (impeller) is present at the surface. It is important to show that entrainment can be brought about even in the absence of breaking waves.

Table 4.1 shows the values of the different parameters used in the different experiments. It is noticed that the surface tension data indicate what may seem an insignificant difference between fresh water and sea water. The data in the latter case are consistently higher, but with a difference which in view of the uncertainty of the measurements, makes a distinction between the two very difficult.

Table 4.1 Experimental Parameters of Drop-Size Experiments

	10/17	10/29	11/16	12/07	12/19	02/02	02/21	03/08
WATER:	FRESH	FRESH	SEA	SEA	SEA	FRESH	FRESH	SEA
TEMPERATURE:	21.5°-22°C	25°C	20°-16°C	17°-14°C	7°-4°C	17°-14°C	19°-14.5°C	-
OIL ADDED:	42.8	44.8	41.6	97.0	95.4	50.2	47.3	48.2
SURFACE TENSION:	68.1	68.3	69.4	69.2	69.9	69.1	68.8	69.4
IMPELLER SPEED:	65.8	149.6	155.9	150.6	148.7	310	153.5	230

The amount of oil added to the surface in the tank is either approximately 30 ml or 60ml. This is the way in which the thickness of the oil is varied. A finer gradation of the thickness is not necessary in view of the scope of the investigation.

The temperature at which the experiments were performed was imposed by the ambient temperature. A systematic investigation of the influence of this parameter thus became almost impossible.

Fig. 4.20 shows a sketch of the so-called "20 gal. tank". It is seen to be equipped with 4 taps at different depths under the surface through which samples of the water with the entrained oil can be taken. The impeller was placed very close to the bottom of the tank and the measurements of Figs. 4.18 and 4.19 were made in the region above a depth of 10", i.e. well above the impeller. The entrainment was measured as concentrations of oil in the samples taken through the taps according to a determined time schedule. This schedule ran first for 4 hours and was later changed to 10 hours; in both cases control samples were taken after

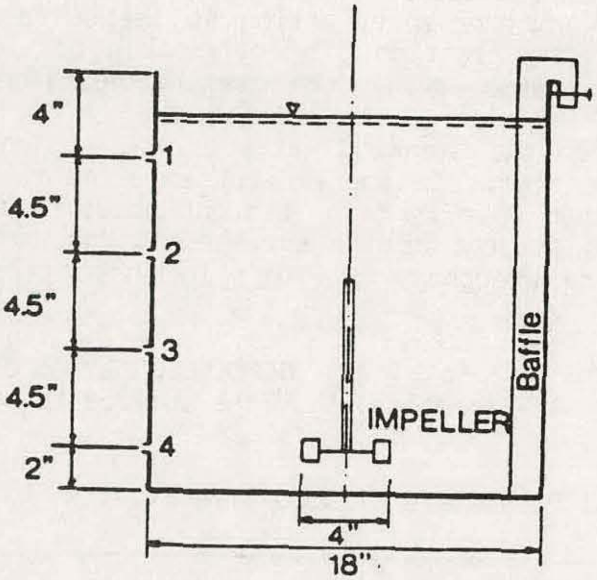


Fig. 4.20 The "20 gal. tank" of the Drop-Size-Experiment

24 hours. The results of these measurements are exhibited in Figs. 4.21a - d. The running time for the impeller is shown in the diagrams.

In contemplating the conclusions which may be drawn from these results the scarcity of them, and consequently their inherent uncertainty, should not be overlooked. However, some results seem well established and will also be supported from other sources.

Starting with Fig. 4.21b, one observes that the three experiments have been made under almost identical conditions as far as water type, impeller speed and surface tension is concerned. In E 12/07 and E 12/19 even the same amount of oil was added. The temperature during the experiments differs however by approximately 10 C without any noticeable difference in entrainment. Thus it seems that the temperature is not a parameter which in this range strongly influences the entrainment. If however the third experiment E 11/16 is considered, a comparatively large increase in entrainment is noticed and since temperature is ruled out, this can only be attributed to the fact that in the latter case the oil film is thinner (only half as much oil added). So, with the slim background of three experiments (E 11/16, E 12/07, E12/19) the following conclusions are attempted:

1. Within the range of variation of the temperature (4^o - 14^oC) the influence of temperature on entraiment seems negligible.

2. The entrainment from a thin slick is, under the same conditions, larger than from a thick slick.

These preliminary conclusions will be examined in the light of later results.

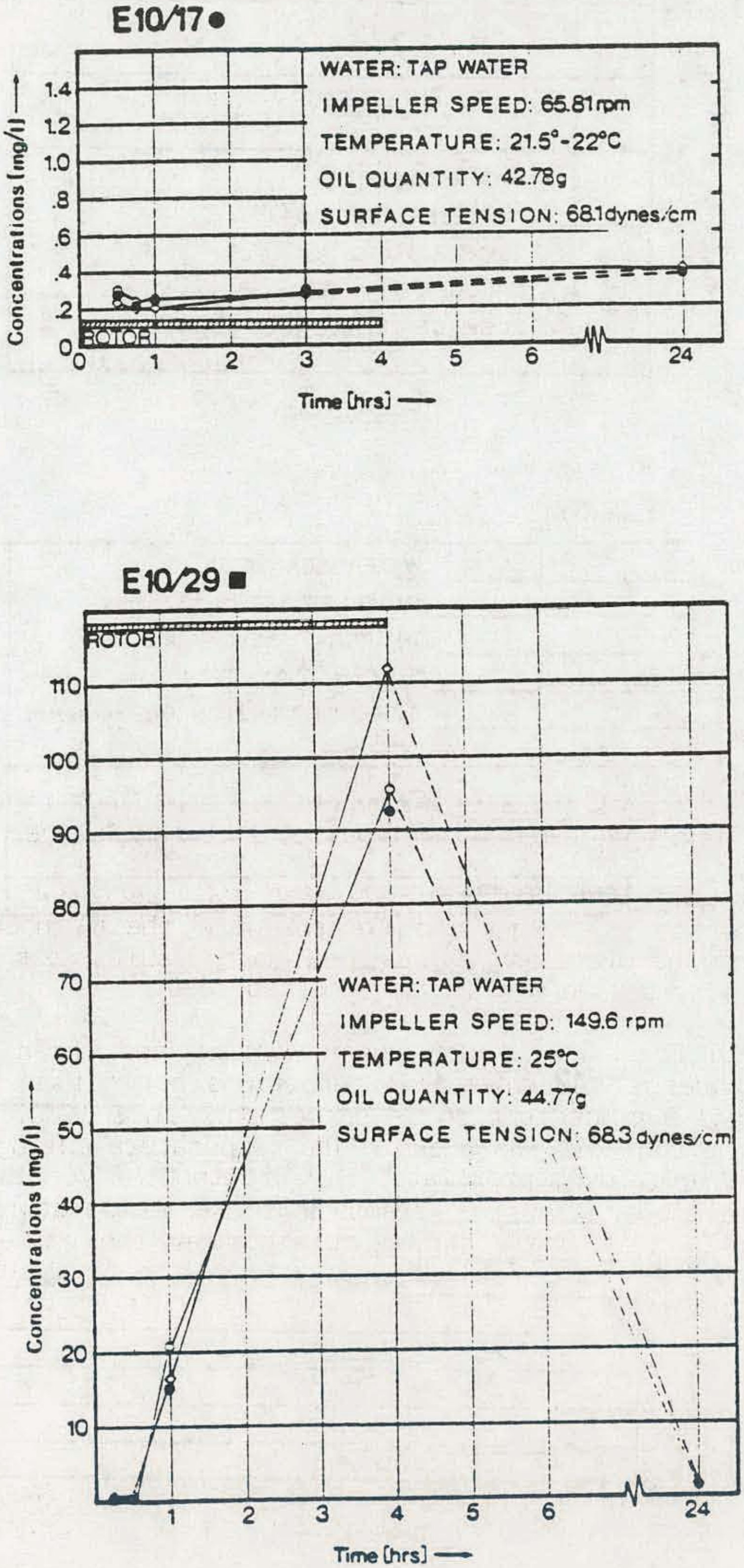
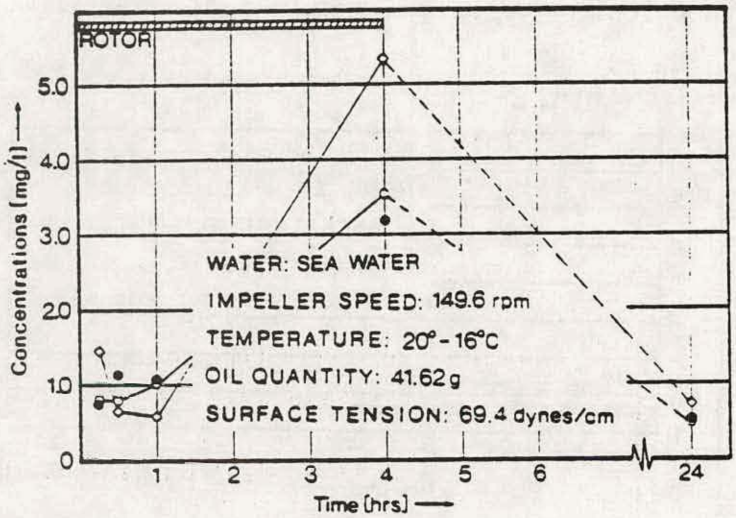
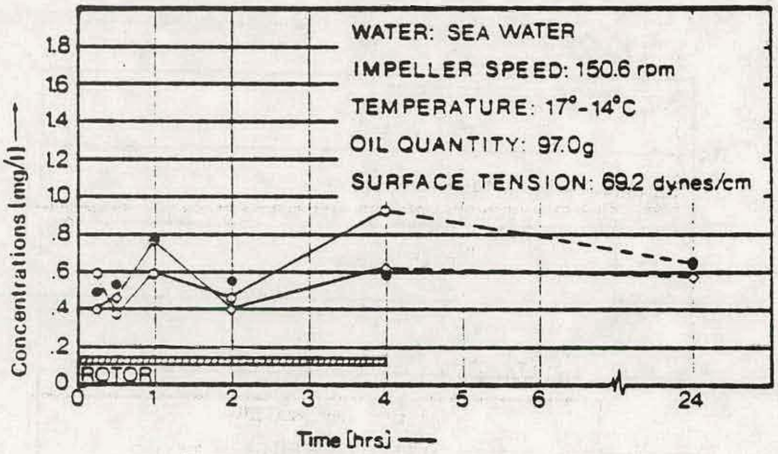


Fig. 4.21a

E11/16 △



E 12/07 □



E12/19 ○

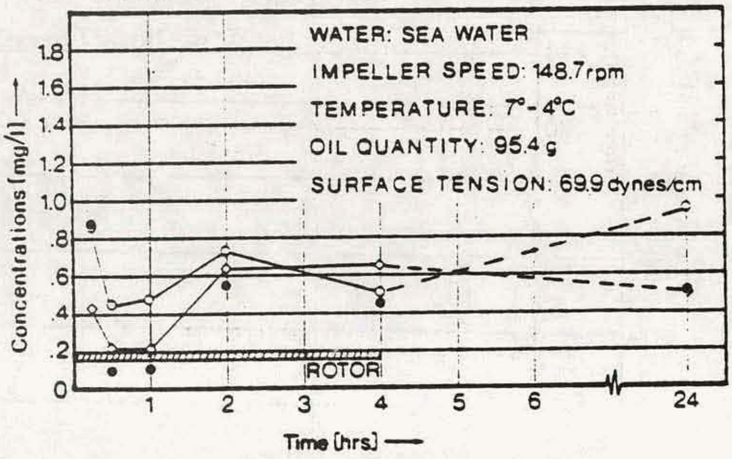


Fig. 4.21b

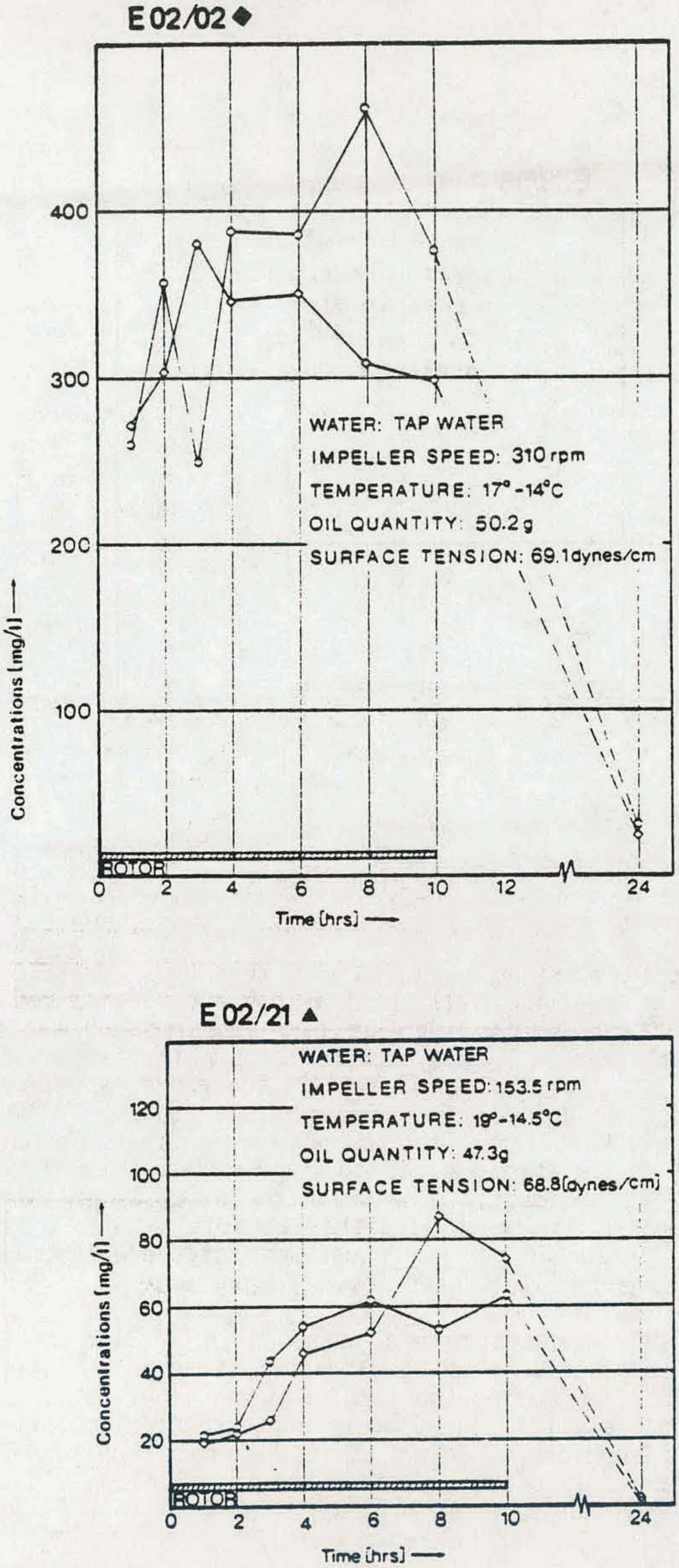

E 02/02 ◆
400
300
200
100
Concentrations [mg/l] ⟶
WATER: TAP WATER
IMPELLER SPEED: 310 rpm
TEMPERATURE: 17°-14°C
OIL QUANTITY: 50.2 g
SURFACE TENSION: 69.1dynes/cm
ROTOR
0
2
4
6
8
10
12
24
Time [hrs] ⟶
E 02/21 ▲
WATER: TAP WATER
IMPELLER SPEED: 153.5 rpm
TEMPERATURE: 19°-14.5°C
OIL QUANTITY: 47.3g
SURFACE TENSION: 68.8[dynes/cm]
120
100
80
60
40
20
Concentrations [mg/l] ⟶
ROTOR
0
2
4
6
8
10
24
Time [hrs] ⟶

Fig. 4.21c

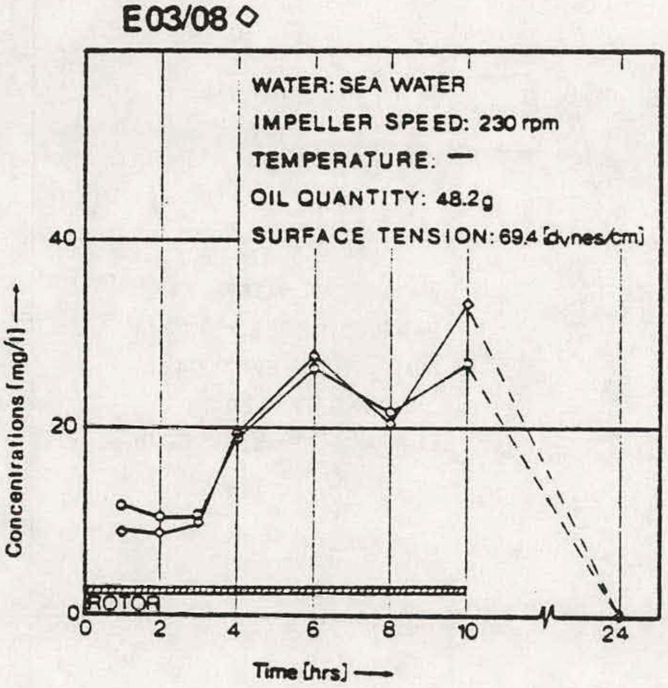


Fig. 4.21d

At this point it might be mentioned that the impeller speed was adjusted in such a way that small vortices could be identified as "dents" in the water surface, which moved around, appeared and vanished in an apparent stochastic manner. This occurred at impeller speeds of approximately 150 rpm, i.e., at the speed used in the above experiments. It is thought that the occurrence of such vortices represent the mechanism whereby the oil slick is fragmented and whereby entrainable particles are being produced. It is then logical to deduce that this "fragmentation" due to vortices is more easily done where the slick is thin than when it is thick (in complete agreement with the result). Since it is desirable to establish the influence on the entrainment of the recirculating flow, the variation of the impeller speed becomes important.

If one considers the entrainment obtained in E 12/07 and E 12/19 one will find that very little is being entrained, in fact so little that the concentrations obtained during the time when the impeller is rotating are equivalent to those still found 20 hours after the recirculating flow was "stopped." This suggests a lower limit for the impeller speed below which very little oil is being entrained and this limit may depend on the oil slick thickness. This point will be reexamined in the light of subsequent results.

Consider now the results of Fig. 4.21a. A comparison between E 10/29 and E 11/16 shows that the values of temperature, oil slick thickness, impeller speed and surface tension are almost equal. Thus the tremendous difference in entrainment in the two cases may be attributed to the fact that one experiment is done in fresh water and the other in sea water. On the other hand, the experiment E 10/17, which is done under almost identical conditions except for the impeller speed being much less, show almost no entrainment. One is now faced with the following possible conclusions:

3. The entrainment of oil in the water column under otherwise equal conditions seems to occur much more easily in fresh water than in sea water. This is in contrast to other observations (see Section 4.4.5 Final Remarks)

4. Entrainment of oil in the water column is very strongly dependent on the "strength" of the recirculating flow.

The results at this point show that the samples from the different taps are influenced so much by occasionally trapped larger oil droplets that a concentration gradient in the vertical direction may not be experimentally determined. Thus the conclusions so far have been drawn on the basis of mean values of the instantaneous concentrations measured at the 3 taps.

It has furthermore been assumed that after 4 hours some kind of equilibrium state has been reached. This is tested in the experiments shown in Fig. 4.21c-d. where the period over which samples were taken is increased. It seems to be confirmed that the "equilibrium" has been reached after 4-6 hours.

The experiment E 02/21 is seen to be almost identical to E 10/29 as far as most parameters are concerned. There is however a difference in temperature between the two cases of approximately 10 C. This means that the previous statement about the influence of temperature perhaps must be modified, because there is a difference of 10 - 15% in concentration between the two cases which can be explained as the influence of temperature. The rather high concentration measured seems, however, to be a consistent result. The result of E 02/02 are obtained with a rather high value of the impeller speed. During the experiment it seemed as if all oil on the surface was being entrained. If one assumes from the data a uniform concentration of 350 [mg/l] in the water, the totally entrained mass of oil will be 26.5 [gr] or approximately half the oil added. Apparently this high value of the impeller speed represents the upper limit for sensible experimentation in the apparatus used.

Fig. 4.21d shows the results for a rather high value of the impeller speed and with sea water. Gathering all results, one may now present them as done in Fig. 4.22 where the mean maximum concentration is plotted as a function of the impeller speed. The legend used to identify the experiments are shown in Figs. 4.21 a-d.

It seems as if the following conclusions may be drawn:

1. The influence of temperature on the entrainment may hardly be estimated from the results of these experiments. Emphasis is

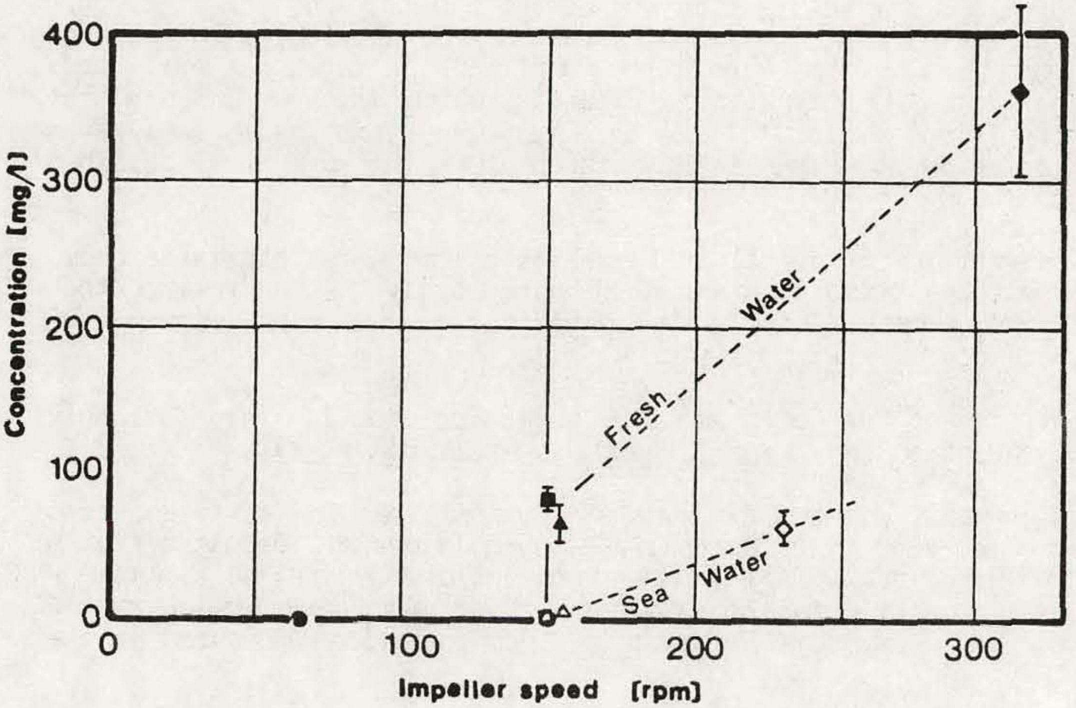


Fig. 4.22. Entrainment as a function of the "strength" of the recirculating flow (i.e. the impeller speed)

put on the scarcity of experimental evidence and the limited temperature range. (See the Rain-Drop experiment, section 4.4.4).

2. The entrainment from a thin slick is under the same conditions, larger than from a thick slick. (As before).

3. The entrainment of oil in the water column under otherwise equal conditions seems to occur much more easily in fresh water than in sea water. (As before, with reservations).

4. Entrainment of oil in the water column is very strongly dependent on the "strength" of the recirculating flow. (As before).

4.4.4. The Raindrop Experiment

This experiment is discussed in Section 4.1.5. It distinguishes itself from the experiment originally carried out in the same rig by the fact that an impeller has been installed at the bottom of the receiving tank. This creates a recirculating flow which, in the author's concept, is responsible for the entrainment. This experiment also distinguishes itself from the previous one (preceding section) in the presence of a mechanical agitation (rain falling) at the surface.

The parameters of the experiment are the same as in the preceding section but now one has the rain intensity as an additional parameter. The rain maker (tank B, Fig. 4.2) had a variable performance due to the clogging up of the needles producing the raindrops. This is due to the fact that salt water (sea) was used to produce the rain to avoid the complication of having a mixture of salt and fresh water at the surface. The rain intensity was attempted to be kept constant during the conduction of an experiment, but variations of 10% had to be accepted. The rain intensity may be expressed in different ways. One may give it as the amount of rain falling over the entire surface per unit time [ℓ/hour]. One may however give it as the kinetic energy of the raindrops as they hit the surface. In this latter case, the rain intensity may be the same for different heights and different drop sizes as well as for different drop frequencies. An examination of this effect has so far not been made, and for the present purpose the first way of describing the rain intensity has been used.

Fig. 4.23 shows a sketch of the receiving tank. Water samples are being collected through the taps 1 - 4 where glass tubes go almost to the center of the tank. Thus water samples are collected at different depths and ought to reflect a possible vertical gradient in the concentrations of oil in the samples. Such a gradient is indicated by the photo of the tank emptied after one normal experiment. (Fig. 4.24) The oil clinging to the outside of the glass tubes is dependent on the size and frequency of the droplets hitting the tubes. The photo shows that much more oil is collected by the upper tubes than by the lower ones. A corresponding gradient in the concentrations measured in the samples is not present because it is obscured by the large variations one may have due to occasional pick up of large oil droplets during sampling. This is, of

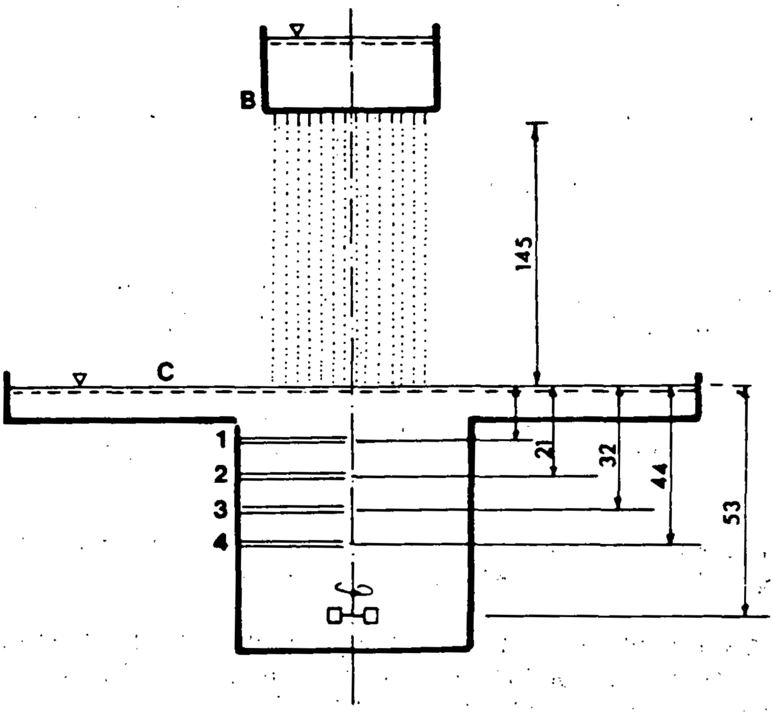


Fig. 4.23. The receiving tank in the rain drop experiment.

course, a source of inaccuracy in the experimentation which might have been avoided by increasing the physical size of the apparatus or by taking ensemble averages over a large number of identical runs. With these remarks in mind one may turn to Table 4.2 where a survey is given

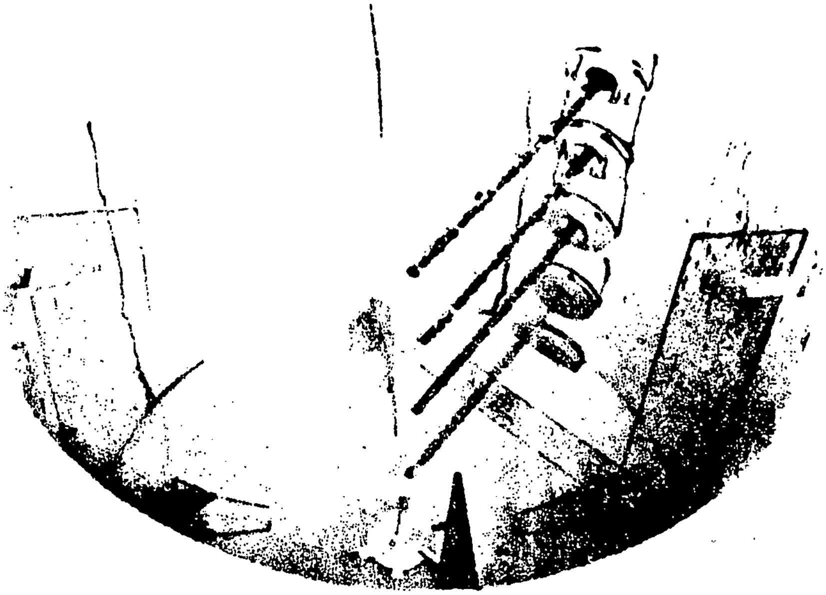


Fig. 4.24. Photo showing the gradient in the oil collected by the glass tubes.

over the variation of the parameters in the experiments RD-7 through RD-18. In addition, the results of each experiment are shown in Figs. 4.25a-j as a record of the concentration of oil in the water column as a function of the time at which the samples were taken, the time t = 0 being the time at which the oil was applied to the surface. (A steady state of the rain as well as of the recirculating flow is assumed established beforehand). It should be noted that the size of the impeller as well as of the tank differ from those of the preceding section and no comparison can therefore be directly obtained between the two cases.

One may start the examination of the results by considering RD-11, RD-12, RD-14, RD-15, and RD-16 which all are cases where the rain has been stopped hours before the rotor was shut off. All of these show that regardless of the impeller speed (within the range of variation used) the concentration of oil entrained in the water column drops off dramatically as soon as the rain stops, i.e. as soon as the production of entrainable particles stops, even though the recirculating flow is maintained. Since the level of concentration reached after shutting off the rain is close to that after 24 hours one may conclude that in contrast to the drop size experiment the impeller speed is in this case kept so low that the recirculating flow does not contribute significantly to the production of entrainable particles. Its main effect is the transport of oil particles from the vicinity of the surface down into the water column. Apart from RD-14 this is a feature common to all experiments in this series, and it

Table 4.2 Experimental Parameters for Raindrop Experiments with Circulation.

No.	Amount of oil [ml]	Impeller Speed [rpm]	RAIN RATE [l/hr] At beginning		At end	Rain rate [l/hr]	Temperature °C	Fall distance [cm]	Water	Surface tension	Drop Size [g]	Intentions	Remarks
RD-7	300	176.5 no further checks	-	-	-	-	-	146	Sea	-			
RD-8	300	178.8 no further checks	-	-	-	-	18° (room) 19° (water) at 0 hrs	146	Sea	-		Repeat of RD-17	cancelled
RD-9	300	169.1	2.68	-	2.32	2.37	18° at 0 hrs 20° at 9 hrs 22° at 24 hrs	145	Fresh	-	(.000011)		Drop size: .000011 g/drop (From RD-14)
RD-10	300	146.1 176 at break	2.57	2.60	-	-	27° at 0 hrs	145	Fresh	77.4 77.2 76.0	(.000011)	Sea water/Fresh water could not be distinguished based on surface tension	cancelled Drop size: .000011 g/drop (From RD-14)
RD-11	160	149.7 at 0 hrs. 171.6 at 6 hrs.	2.98	3.09	3.33	3.35	19° at 0 hrs 22° at 6 hrs	144	Fresh		.0000169		
RD-12	160	149.7 at 0 hrs. 159.2 at 6 hrs.	3.22	3.40	3.68	3.48 at 4.5 hrs. 4.22 at 6 hrs.	16.5° at 0 hrs (water)	145.5	Sea	76.0	.000017	Repeat of RD-11 (diff. water)	
RD-13	160	147.5 at 0 hrs. 164.7 at 6 hrs.	3.44	3.64	3.60	3.22 at 4.5 hrs. 3.69 at 6 hrs.	15° at 0 hrs 18° at 8 hrs 19.6° at 26hrs	145	Sea	76.0 - 73.6	(.0000179)	Repeat of RD-12	Drop size from RD-15
RD-14	300	250.0 at 0 hrs. 259.1 at 6 hrs. 266.4 at 10 hrs.	1.92	2.12	-	2.68 at 24 hrs.	11° at 0 hrs 14° at 8 hrs 13° at 24 hrs	145.6	Sea	72	.0000112		
RD-15	160	156.1 at 0 hrs. 166.9 at 7 hrs.	3.10	3.02	3.04	3.23 at 2 hrs. 2.79 at 3 hrs. 3.03 at 4 hrs. 2.84 at 5 hrs.	9° at 0 hrs 10° at 8 hrs 10° at 24 hrs	146	Fresh	75	.0000179	Repeat of RD-11	
RD-16	300	169.0 at 0 hrs. 168.7 at 2 hrs. 166.1 at 8 hrs.	2.83	2.62	2.73	-	10.6° at 0 hrs 13° at 11 hrs 13° at 24 hrs	145	Fresh	74.5(?)	.0000167	Repeat of RD-9	
RD-17	160	155.6 at 0 hrs. 174.4 at 6 hrs. 172.0 at 24 hrs	2.71	2.56 2.69	2.76	2.80	13° at 0 hrs. 15° at 24 hrs.	145.5	Sea	68.3	.0000161	Repeat of RD-12 (modified)	
RD-18	300	151.8 at 0 hrs. 174.8 at 7 hrs.	2.82	2.57 2.5[illegible]	2.77	2.94	24°	141	Sea	64.4 (28°C)	.0000173	Repeat of RD-7	

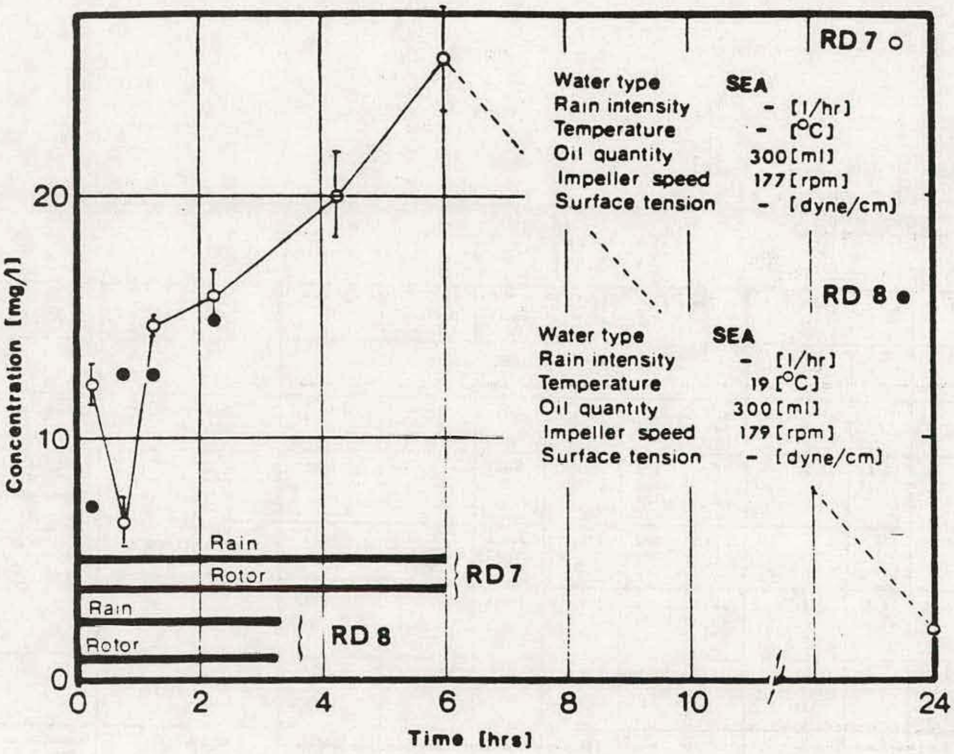


Fig. 4.25a

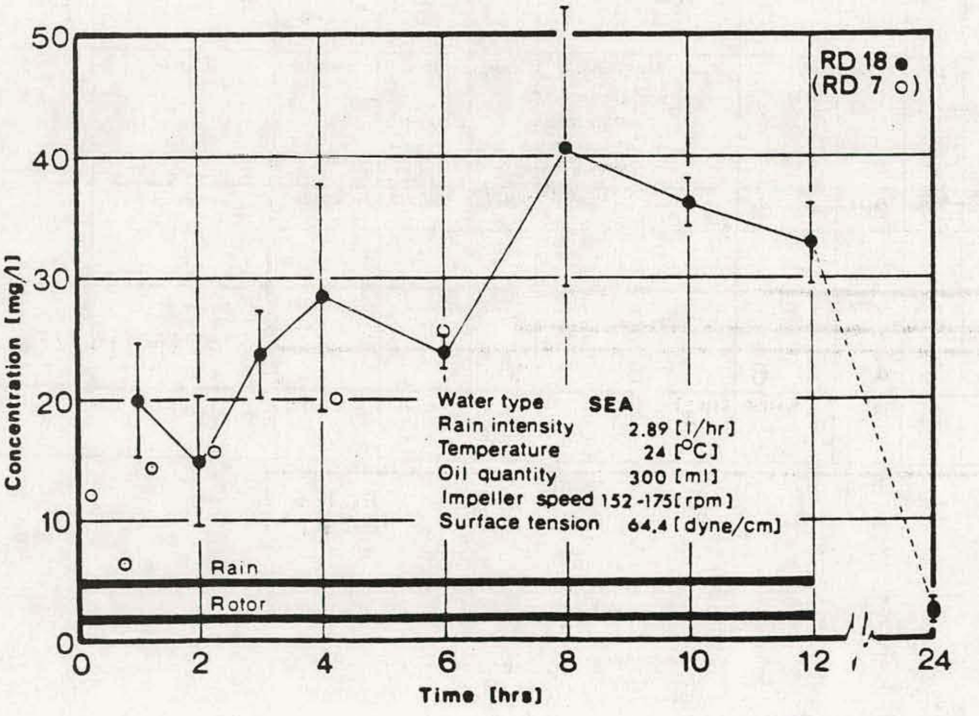


Fig. 4.25b

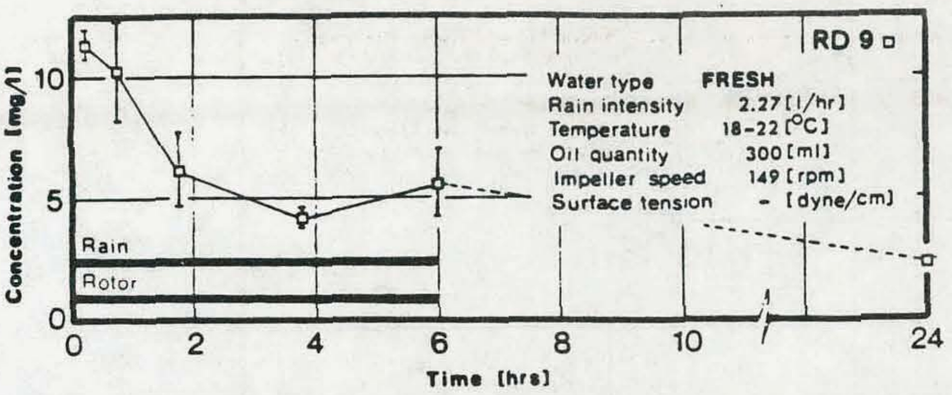


Fig.4.25c

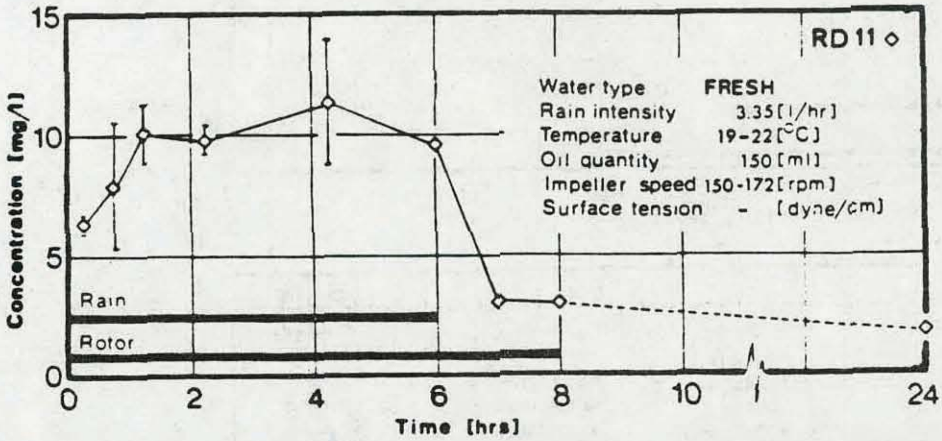


Fig. 4.25d

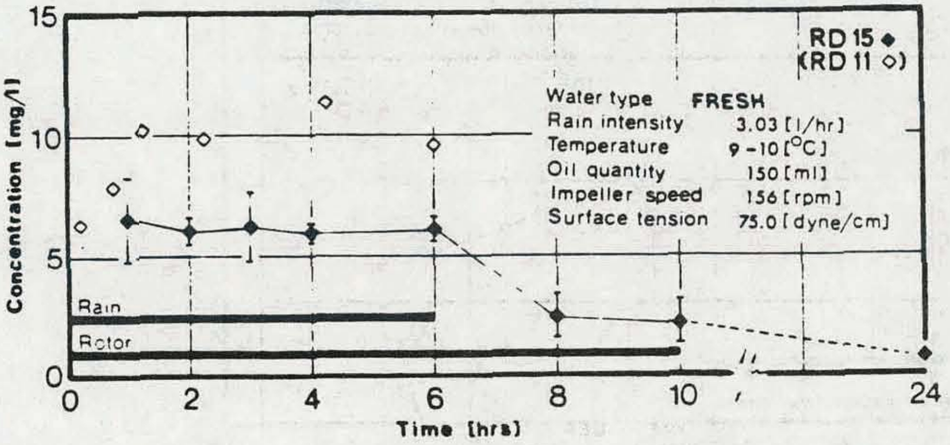


Fig. 4.25e

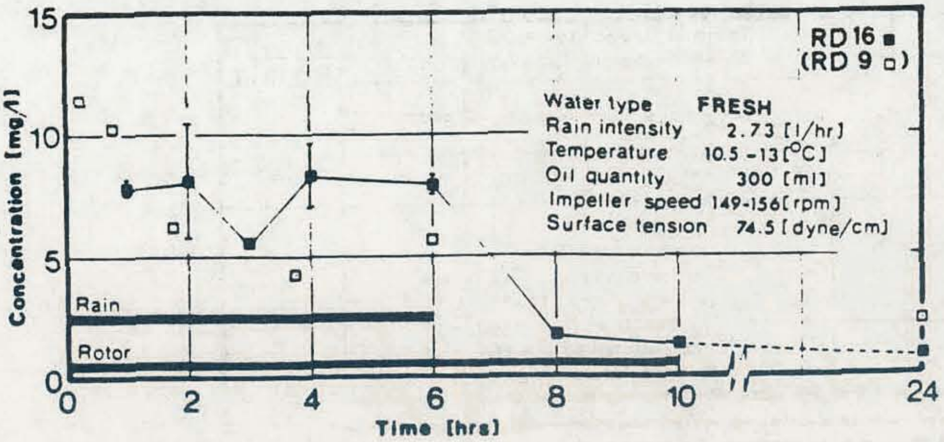


Fig. 4.25f

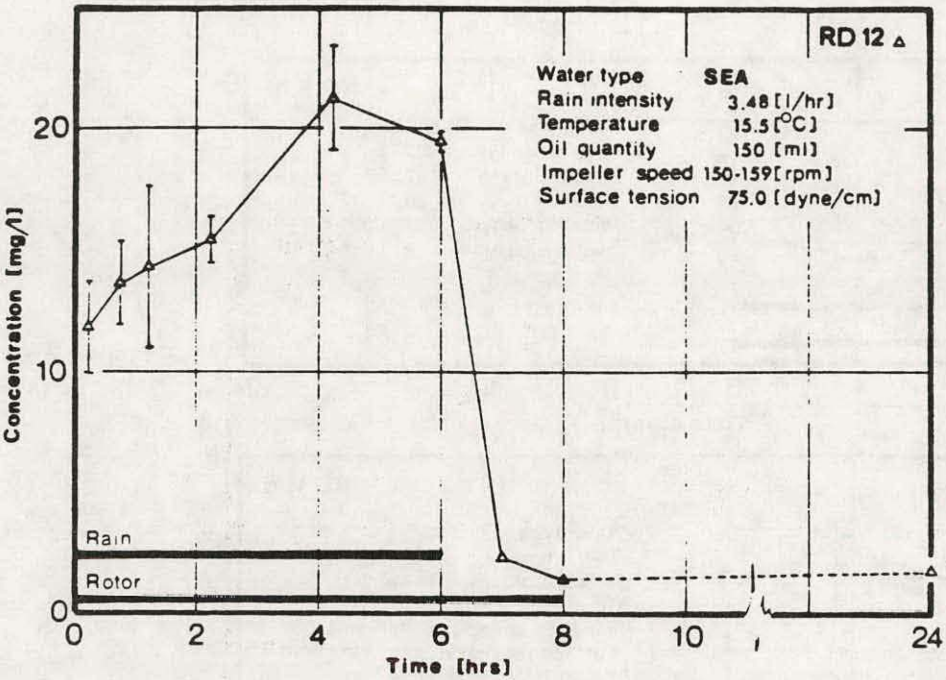


Fig. 4.25g

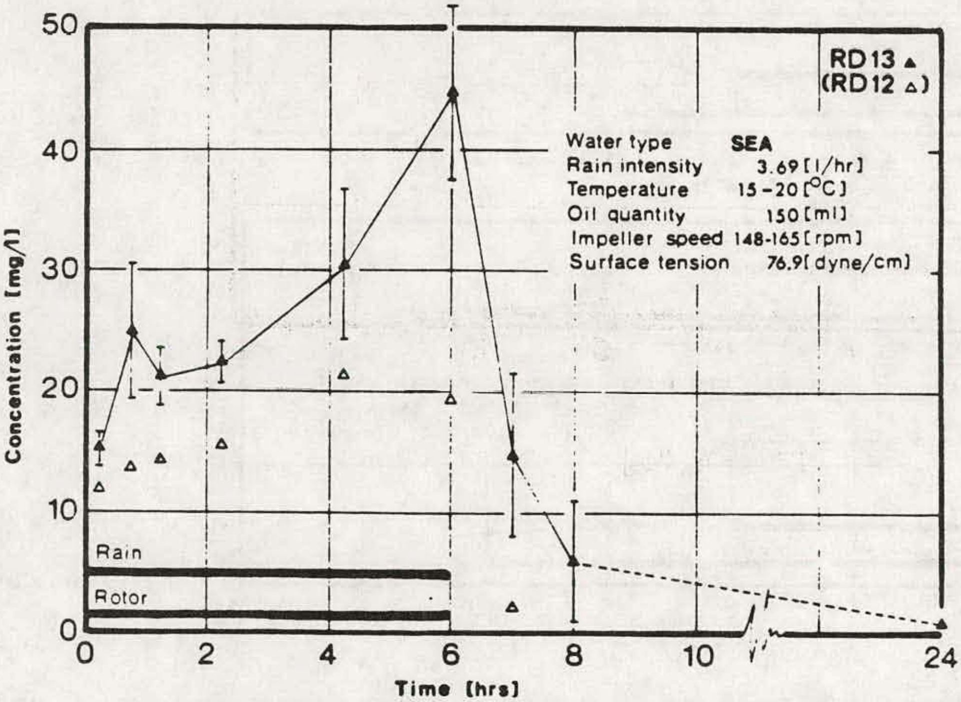


Fig. 4. 25h

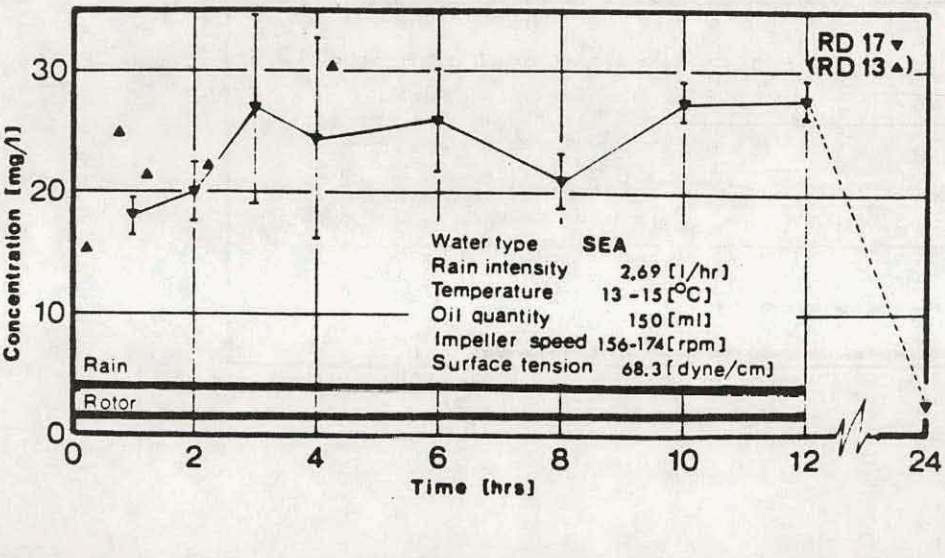


Fig. 4.25 i

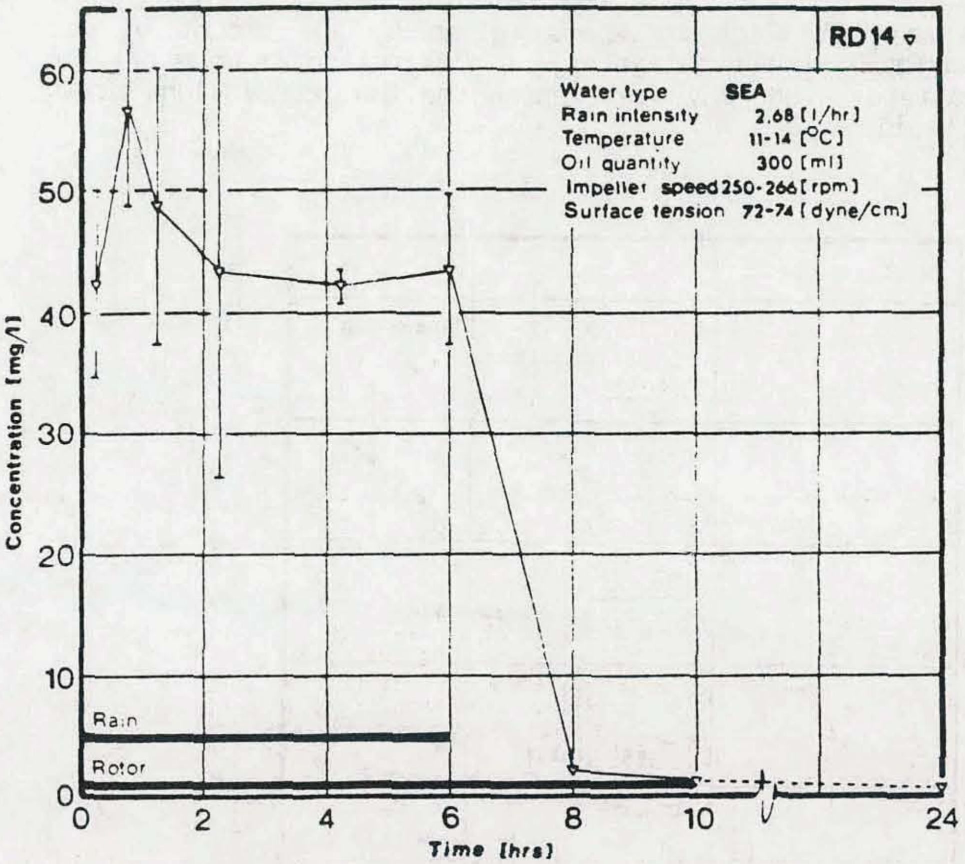


Fig. 4.25j

makes the impeller speed rather unsuited as a parameter. The results can then be used to explore the influence of other parameters such as temperature, slick thickness, etc.

One more comment ought to be given at this point. The entrainment is seen to drop off dramatically when the rain stops, but the same is observed when the rain continues and the impeller stops. This latter case is investigated by Dr. Cornillon and Ted Kawazoe and the result is given in a internal report by Ted Kawazoe.

Fig. 4.26 gives a survey of the results. The average concentration c of oil in the water column after 6 hours is plotted as a function of temperature with the oil slick thickness (given by the amount of oil applied to the surface) as the parameter. A distinction is made between tap water and sea water. One may now examine the four conclusions drawn in the preceding section.

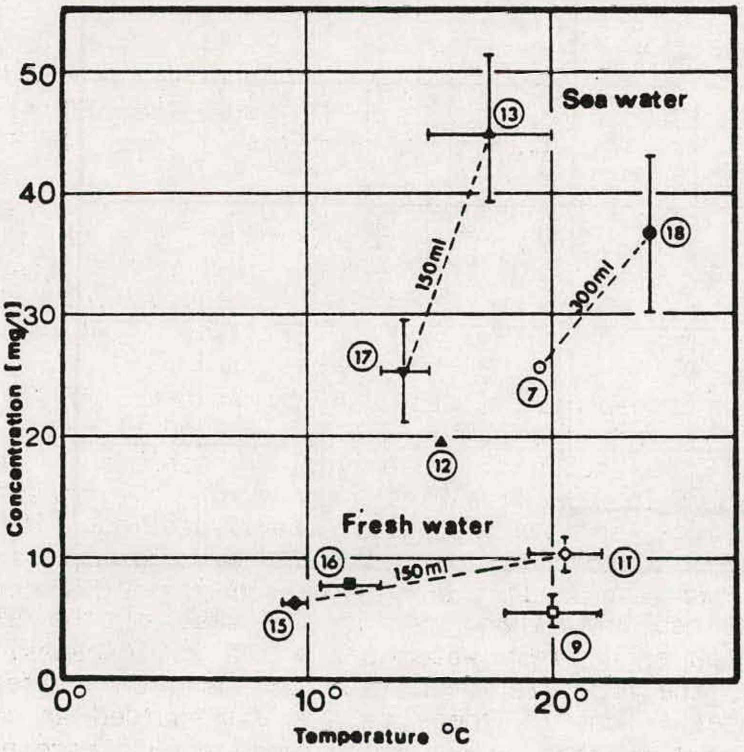


Fig. 4.26. Results of the rain drop experiment 6 hours average concentration plotted as function of temperature.

First, it is confirmed that irrespective of what type of water is used, the entrainment is higher for a thin slick than for a thick one. Conclusion 2 is thus supported.

Second, oil is seen to be much more easily entrained in salt water than in fresh water. This is in contrast to the result in the preceding section, Conclusion 3, and will be commented on in the next section, Final Remarks.

Third, Conclusion 4 of the preceding section cannot be reconsidered here because the influence of the recirculating flow on the production of entrainable particles is totally overshadowed by the action of the rain for the impeller speeds used.

Fourth, the influence of temperature, Conclusion 1 in the preceding section, is here exhibited in Fig. 4.26. It is seen that apparently a weak influence of temperature on entrainment is found in fresh water but an apparently very strong dependence is found in sea water. It is however felt that further experimentation would be needed to form a fixed opinion on this point.

4.4.5 Final Remarks

Summing up the results of these experiments one should not hide the scarcity of information they give and the corresponding uncertainty in the conclusions one may draw. However, some results seem to be fairly well established.

1. In all cases the original concept of entrainment being brought about by one action producing entrainable particles and another action (the recirculation flow) transporting the particles down into the water column has been supported. No evidence to the contrary could be detected.

2. The mechanism responsible for the production of entrainable particles in the rain drop experiment is the action produced by the impinging drops. This action is basically different from the corresponding mechanism in the drop-size tank where the production is caused by the vortices in the turbulent recirculating flow. This difference may be the reason for the apparent discrepancy as regards Conclusion 3 in the two cases. If the evidence for forming an opinion on Conclusion 3 is examined one finds that in the case of the drop size experiment it is based on 3 fresh water and 4 sea water cases. In the rain drop experiment the opposite conclusion is based on 4 fresh water and 4 sea water cases. None of these can be disregarded as "wrong." Thus it is possible that whether or not entrainment occurs more easily in fresh water than in sea water really depends on the mechanism whereby entrainable particles are being produced.

3. Conclusion 2 seems to be fairly well documented and corresponds also to the general picture.

4. The influence of temperature was never really systematically investigated and the last paragraph of the preceding section really expresses the situation fairly well.

4.5 EXPERIMENTS WITH APPLICATION OF THE DISPERSANT COREXIT 9527

4.5.1 Introduction

The influence of a dispersant on the entrainment process was intended to be investigated through application of the chemical during a process which has been investigated previously without such application. It was decided to use only Corexit 9527 as a dispersant and to spray it on to the oil slick in a ratio Corexit/Oil = 1:20. This does however not mean that when hydrocarbons are recovered in the water column this ratio will persist between the part originating from the dispersant and the other part originating from the oil. One task will therefore be to establish a method which rather rapidly can determine this ratio, and this has been accomplished and is reported on elsewhere (see Section 12.2, Appendix B).

It is recalled that all cases reported on here (drop size experiment as well as rain drop experiments) have shown that when the recirculating flow is stopped, the amount of permanently entrained oil in the water column is negligible. A second task for this part of the investigation is to ascertain whether or not this feature, valid for oil only, is affected by the application of a dispersant.

A third important task is to investigate whether or not the application of a dispersant can enhance the entrainment of oil in the water column in the absence of a recirculating flow. One would then have a situation whereby the mechanism of entrainment from being caused by mechanical action is changed to being caused by what might be interpreted as molecular diffusion. The importance of one as compared with the other becomes an interesting question.

4.5.2 The Still Water Experiment

The last problem mentioned in the introduction was investigated in the still water experiment. The tank of the rain drop experiment was filled with sea water and left for 24 hours to let any motion in the water die out. An oil slick of known magnitude was then applied to the surface of the water in the tank. Great care was taken so as to avoid inducing any motion in the tank. After four hours samples were taken in the water column to see how oil alone might have diffused. Immediately afterwards the dispersant was sprayed on to the slick and samples from the water column were taken two hours and seven hours later. All samples were taken through the usual taps in the containers (Fig. 4.20) and they were taken so slowly that no appreciable velocity was induced in the water column. The following data give the details of the experiment:

Oil added:	62.68 [gr]	to still Sea Water
Corexit - Sea Water mixture:	9.49 [gr] Corexit	
	95.28 [gr] Sea water	

Of this mixture 29.69 [gr] was sprayed on the slick giving an applied amount of Corexit = 2.68 [gr]

Ratio Corexit/Oil = r = 0.04280 = <u>1:23.4</u>

Temperature: 27^{o} - 28^{o}C

Since this case also serves as a test case for the determination of the ratio r = Corexit/Oil recovered in the water column, the details of the evaluation is here shown in Tables 4.3 and 4.4. The samples taken are numbered, the time when they were taken is given, the taps from which they originate are indicated together with the legend used in Fig. 4.27 to display the results of each aliquot which also is numbered (i). The actual recovered amount of each aliquot is given as well as the transmittance z and the absorbance a obtained by scanning each aliquot at a wave number of 2930 [cm^{-1}]. Finally, the volume of each sample is given, and this concludes the data of the experiment. The values of z and a appearing in parenthesis are obtained in the region where the spectrophotometer is uncertain and are data which are not considered.

First, samples 1 and 2 contain only oil, no dispersant having been applied when they were taken. Thus, the ordinary calibration coefficient may be used and the concentration c_0 (shown in the column for c_{Ci}) is, at both tap 3 and 4, of negligible magnitude. Thus, even after four hours not very much oil has diffused into the water column. It is seen that only one aliquot was necessary to establish this result.

Table 4.3 SEA WATER

										computed	
No	Time	Tap	Aliquot no. i	Recovered g	Transm. z	Absorb. a	Sample vol. ml	$c_{C,i}$ mg/l CCl_4	$c_{C,i}$ mg/l H_2O	$c_{C,i}$ mg/l H_2O	$c_{C,tot.}$
1	1:50 pm	3	1	45.74	89.5	.048	488	4.09	.24		
2		4	1	45.92	81.5	.089	482	7.64	.45		
3	4:15 pm	3	1	45.62	(13.0)	(.886)	473			4.81	
			2	47.40	28.0	.553		(83.13)	(5.26)	3.07	
			3	46.50	62.2	.206		31.01	1.92	1.96	
			4	47.40	75.5	.122		18.35	1.16	1.25	
			5	46.97	80.8	.093		13.92	.87	.78	
				233.89						11.87	18.18
4		4	1	46.25	22.0	.658	502	(98.88)	(5.75)	2.82	
			2	46.66	35.7	.447		(67.27)	(3.94)	1.67	
			3	46.58	74.7	.127		19.05	1.12	1.06	
			4	47.34	84.0	.076		11.39	.68	.68	
			5	47.23	90.0	.046			.41	.43	
				233.96						6.46	9.89
5	9:35 pm	3	1	46.16	(4.0)	(1.398)	479			3.08	
			2	46.80	(12.0)	(.921)				1.96	
			3	46.65	53.7	.270		(40.61)	(2.49)	1.25	
			4	47.06	82.5	.085		13.36	.83	.80	
			5	47.05	88.5	.053		7.98	.49	.51	
				233.72						7.61	11.65
6		4	1	45.44	(3.0)	(1.523)	478	(46.32)		3.56	
			2	46.82	(10.0)	(1.000)				2.27	
			3	46.44	49.2	.308		(46.32)	(2.84)	1.45	
			4	46.80	78.7	.104		15.64	.97	.92	
			5	46.66	87.0	.060		9.09	.56	.59	
				232.16						8.79	13.46
		salt water	1	45.49			600				
			2	47.20							

Second, samples 3, 4, 5 and 6 contain oil and dispersant in a degree that could be detected with the naked eye. Five aliquots were applied successively and the result of scanning these is given. Now, if the assumption holds that the first 2-3 aliquots extracts the oil and only dispersant is present in the subsequent aliquots, then one may use the calibration curve for Corexit in these. This is shown in Table 4.3 and displayed in Fig. 4.27, which show that indeed the latter aliquots gather around lines with a slope of -0.45. These data are used to find the lines in Fig. 4.27 by linear regression.

Having these, not only the total concentration of Corexit ($c_{C,tot}$) in the sample can be computed but also the concentration $c_{C,i}$ of Corexit indicated by the i^{th} aliquot. This is shown in Table 4.3 where also the sum giving $c_C{}^{(6)}$ is computed.

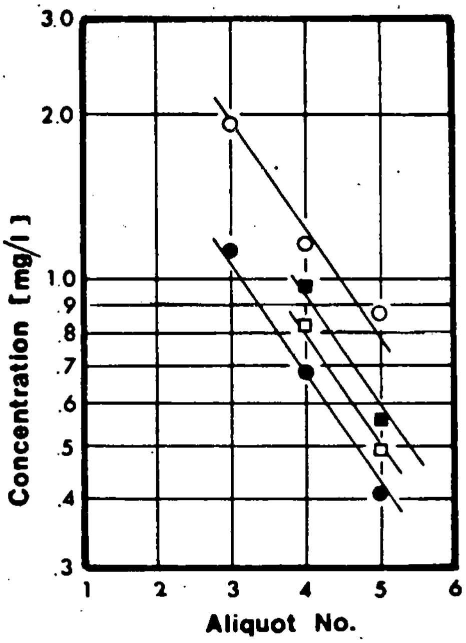


Fig. 4.27. Data shown to agree with the straight line behavior

In Table 4.4 one now proceeds to compute $c_C{}^{(6)}$ which is the concentration of corexit in the sum of all aliquots. When these are added and their sum is scanned at a wavelength of 2930 [cm^{-1}] the absorbance a_m for the mixture is found. The iteration process previously described (see Section 12.2, Appendix B) will now render, and since the total concentration $c_{C,tot.}$ is known it is easy to compute $c_{o,tot.}$ as well as $c_{tot.}$ as shown in Table 4.4

Table 4.4 Extraction of Oil and Corexit from Sea Water

No	$c_C^{(6)}$ mg/l H_2O	Total aliq. [gr]	$c_C^{(6)}$ [mg/l CCl_4]	a_m	r	$c_{C,tot.}$ [mg/l H_2O]	$c_{o,tot.}$ [mg/l H_2O]	$c_{tot.}$ [mg/l H_2O]
3	11.87	233.9	38.05	.3660	3.73	18.18	4.87	23.05
4	6.46	234.0	21.97	.2636	2.03	9.89	4.87	14.76
5	7.61	233.7	24.72	.5323	.73	11.65	15.97	27.62
6	8.79	232.2	28.68	.5850	.79	13.46	17.07	30.53

A tremendous enhancement in molecular diffusion is caused by the application of Corexit. This is independent of whether or not mechanical agitation of some sort is present. It is seen that whereas little oil and much Corexit is found after two hours, the situation has changed after six hours when the content of oil and Corexit seems to be evenly distributed in a ratio close to 1. This result will now be reconsidered in light of similar experiments.

4.5.3 The Drop Size Experiment with Corexit 9527

As mentioned in the introductory remarks, the influence of Corexit on the entrainment should be investigated by applying the chemical to a similar experiment that did not use it. Thus the experiment in the 20 gallon tank was planned as follows:

1. The rotor speed was supposed to be kept so low as to achieve a situation in which very little oil would be entrained from the slick. This was the situation in E 10/17 (tap water) even at a rather high ambient temperature, and an impeller speed of about 65 rpm was decided upon.

2. It was intended to let the experiment run without application of Corexit for approximately 6 hrs. to ensure that a semi-steady state had been reached. Samples were to be taken from taps 2 and 3 at 4 hrs., 5 hrs. and 6 hrs. after applying the slick to the surface (time zero).

3 Corexit would then be applied to the slick in a ratio 1:20 (total amount of Corexit: total amount of oil in the slick). Samples would be taken at 10, 11 and 12 hrs (after time zero).

4. At this time the impeller speed is to be increased to the usual 150 rpm and new samples are to be taken at 24 and 25 hrs. (from time zero).

5. Then the impeller is shut off and final samples are taken at 48 hrs. (after time zero).

The data of the experiment can be summed up as follows:

Water: SEA WATER

Impeller Speed: 64.2 - 150 rpm.

Temperature: 24° - 27°C

Oil quantity: 51.56 gr

Corexit Quantity: 2.89 gr (Ratio: 1:17.8)

Surface Tension: 69.72 dynes/cm

Table 4.5 Experimental Results with Corexit 9527 and Circulantion

No	Time Hrs.	Ratio Corexit/Oil	c_C [mg/l H_2O]	c_o [mg/l H_2O]	$c_{tot.}$ [mg/l H_2O]	Remarks
1	0	0	0	.92	.92	Control Rotor Speed 64.2
2	4	0	0	.23	.23	Oil added at 0 Hrs.
3				.34	.34	
4	5	0	0	.18	.18	
5				.42	.42	
6	6	0	0	.10	.10	
7				.14	.14	
8	10	1.061	250.1	235.7	485.8	Dispersant added at 6 Hrs.
9		1.055	252.9	239.8	492.7	
10	11	1.626	274.2	168.6	442.8	
11		1.209	223.3	184.7	408.0	
12	12	1.191	276.0	231.8	507.8	
13		2.043	302.3	148.0	450.3	
14	24	1.438	218.5	151.9	370.4	Rotor Speed increased to 150 rpm at 12 Hrs.
15		1.233	236.1	191.4	427.5	
16	25	1.312	218.6	166.6	385.2	Rotor stopped at 25 Hrs.
17		1.321	198.3	149.2	347.5	
18	48	2.167	271.5	271.5	396.8	
19		2.903	249.8	86.0	335.8	

The results of the experiment are shown in Table 4.5 and Fig. 4.28. In the latter the mean value of the concentrations at taps 2 and 3 is plotted against time. The results can be summed up as follows:

a. The initial impeller speed is so low that very little oil is being entrained.

b. The addition of Corexit causes a tremendous increase in entrainment.

c. Changing the impeller speed has very little affect on the amount of entrained hydrocarbons.

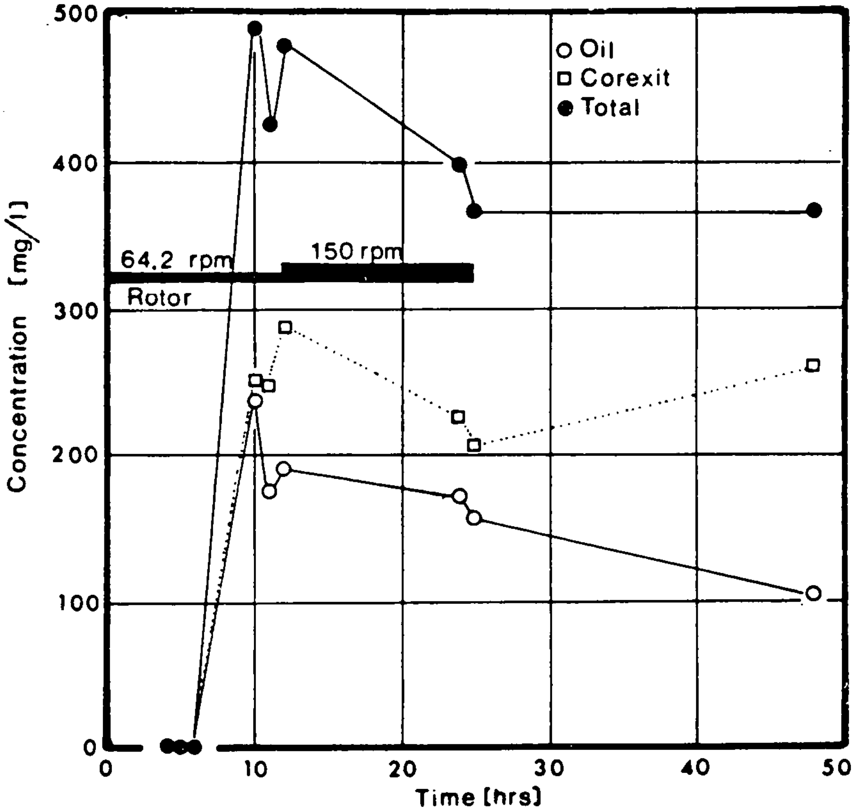


Fig. 4.28. Results of the drop size experiment with Corexit.

d. The amount of hydrocarbons still being entrained 24 hrs. after shut-off of the impeller indicates a very high degree of permanently entrained particles in contrast to the cases with oil alone.

e. The ratio Corexit/Oil in the samples is close to 1 but have a tendency to increase with time (after shut-off).

These results will be reconsidered in view of the results from the rain-drop experiment.

4.5.4 The Rain-Drop Experiment with Corexit

The basic philosophy behind this experiment is the same as explained in the previous case. The conduction of the experiment may be outlined as follows:

1. The apparatus is started up with the rainmaker as well as the rotor operating such that when the oil is applied to the surface, a semi-steady situation is present.

2. Oil is applied to the surface at time zero.

3. Samples are taken from taps 3 and 4 at 4, 5 and 6 hrs.

4. At 6 hrs. Corexit is applied to the slick in a ratio 1: 20 (i.e., mg Corexit: mg oil in the slick 1:20).

5. Samples are taken at 10, 11 and 12 hrs. from the same taps.

6. At 12 hrs. rotor and rain are shut off.

7. At 36 hrs. final samples are taken from the same taps.

The parameters of the experiment are:

Water type: SEA WATER
Rain Intensity: 2.74 ℓ/hr.
Temperature: 26.5° - 29.8°C
Oil Quantity: 300 ml
Impeller Speed: 148.5 - 167.6 rpm.
Corexit Quantity: 12.5 gr (Corexit/Oil = 1:19.99)

The results of this experiment are found in Table 4.6 and displayed in Fig. 4.29. In the latter the mean value of the concentrations of

No	Time [Hrs.]	Ratio Corexit/Oil	c_C [mg/l H_2O]	c_O [mg/l H_2O]	$c_{tot.}$ [mg/l H_2O]	Remarks
1	4	0	0.0	39.1	39.1	
2			0.0	22.5	22.5	
3	5	0	0.0	18.7	18.7	
4			0.0	17.4	17.4	
5	6	0	0.0	14.8	14.8	Corexit added at at 6 hrs. after sampling
6			0.0	13.1	13.1	
7	10	.619	159.1	257.1	416.2	
8		1.036	162.1	156.5	318.6	
9	11	.781	153.0	195.8	348.8	
10		.793	138.2	174.1	312.3	
11	12	.890	135.6	152.3	287.9	Rain and rotor shut off at 12 hrs.
12		1.122	134.1	119.6	253.7	
13	36	2.289	135.6	59.3	194.9	
14		2.457	140.6	57.2	197.8	

Table 4.6 Results of Rain Drop Experiment with Corexit

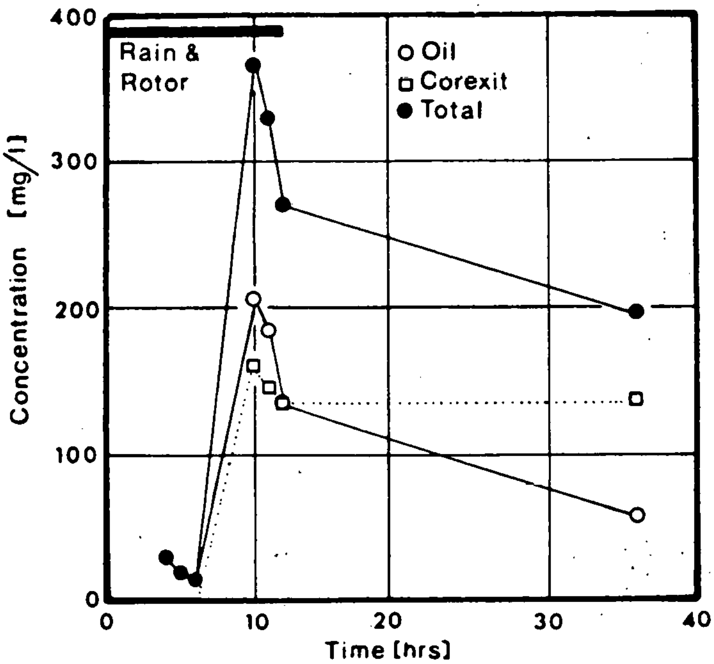


Fig. 4.29. The results of the rain drop experiment with Corexit 9527 applied.

the two taps is shown as a function of time. The results may be summed up as follows:

A. The entrainment achieved by the rain and the recirculating flow within the first 6 hrs. is of the order of magnitude as in RD-18 and thus the previous results are confirmed (Fig. 4.25b).

B. The entrainment obtained after application of Corexit is orders of magnitude larger than before.

C. The ratio between Corexit and oil recovered in the samples is close to 1 but increases to about 2, 24 hrs. after shut off.

D. The seemingly "permanently" entrained hydrocarbons (from oil and from Corexit) is almost independent of the physical situation under which the entrainment was achieved.

4.5.5 Final Remarks

The present experimental investigation has supported the ideas advanced originally by the author to explain the physics of the entrainment process. Thus the importance of the recirculating flow has been effectively demonstrated. Also the importance of the production of entrainable particles has been exhibited, but the influence of temperature is not satisfactorily explored. A difference in the way in which oil is being entrained in fresh water as compared with sea water has been demonstrated. However, the possibility exists that the way in which entrainable particles are being produced may influence the entrainment. Thus the apparent discrepancy between entrainment in the two cases (Figs. 4.22 and 4.26) may be explained. It is however stressed that further experimentation on this point is highly desirable. (See Final Remarks, Section 4.4)

The application of Corexit 9527 to the oil slick has a dramatic effect. Both from the drop-size and the rain-drop-experiments one may draw the conclusion that the effect of the mechanical situation (strength of recirculating flow, production of entrainable particles, etc.) is almost completely overshadowed by the effect of Corexit. This is brought out also by the fact that even in the still water case the entrainment is considerable. Attention in this connection is drawn to the fact that in Fig. 4.28 no apparent effect is found due to the change in the recirculating flow (impeller speed). One may draw the conclusion that the mechanism behind entrainment of oil into the water column is highly affected when Corexit is applied.

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5.0 Sample Application of the Oil Spill Model: Georges Bank Oil Spill Simulations

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Kurt Hansen

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5.0 SAMPLE APPLICATION OF THE OIL SPILL MODEL: GEORGES BANK OIL SPILL SIMULATIONS

5.1 Introduction

In this section, we describe the use of the oil spill fates model as a tool to analyze the effect of various treatment strategies on the fate of a simulated spill. The location of the spill was chosen at the center of the Cod spawning region on Georges Bank (Figure 5.1) and at a time, mid-winter, to affect a maximum impact on the Cod fishery. The output of the model resulting from these simulations was used as input to a fisheries model and is discussed in detail in Reed, Spaulding and Cornillon (1980) and Section 6 of this report. The discussion of these impacts will not be repeated here.

The size of the spill, 34,840 metric tons, as well as its duration, 39 hours, or spill rate, about 900 metric tons per hour (See Figure 5.2 for details of the spill characteristics) were chosen to correspond approximately to the Argo Merchant spill which occurred on Nantucket Shoals in December of 1977. The type of oil selected was a No. 2 like fuel oil also characterized in Figure 5.2.

Five different treatment scenarios were analyzed. By "treatment" we refer to application to the spill of chemical dispersants used to drive the oil on the surface into the water column. Although reducing the surface expression of the spill, such treatment will of course increase the concentration of hydrocarbons in the water column. The oil model has therefore been designed to follow the dispersed oil, and the surface slicks as well as to present the output in a convenient easy to understand graphical format. The five treatment scenarios examined in this section consist of one case in which no treatment was performed and four cases in which various fractions of the oil remaining on the surface were assumed to be driven into the water column, specifically, 25%, 50%, 75% and 100%. All treatment was assumed to take place 48 hours after the spill began, or approximately 9 hours after the last oil had leaked from the source. The various spill scenarios are outlined in Figure 5.3.

5.2 Environmental Variables

Environmental variables input to the model consisted of wind, water temperature and currents. The water temperature was assumed to be constant over the entire study area. The wind data were obtained from the Nantucket Airport Weather Bureau Station at three hour intervals. Missing wind data were obtained by linear interpolation between existing data points.

The current data were constructed from two sources. One source was the seasonal mean data of Bumpus (1973) (Figure 5.4). The data for a given season were assumed to apply only to the first day of that season. All other values were linearly interpolated between the two appropriate seasons. Bumpus' results were obtained from a long term surface drifter study, hence do not in general include short-lived wind induced currents (several days). These events were simulated by a two dimensional vertically averaged wind-current model using the Nantucket wind data as input. The wind induced currents were asssumed to apply only to the

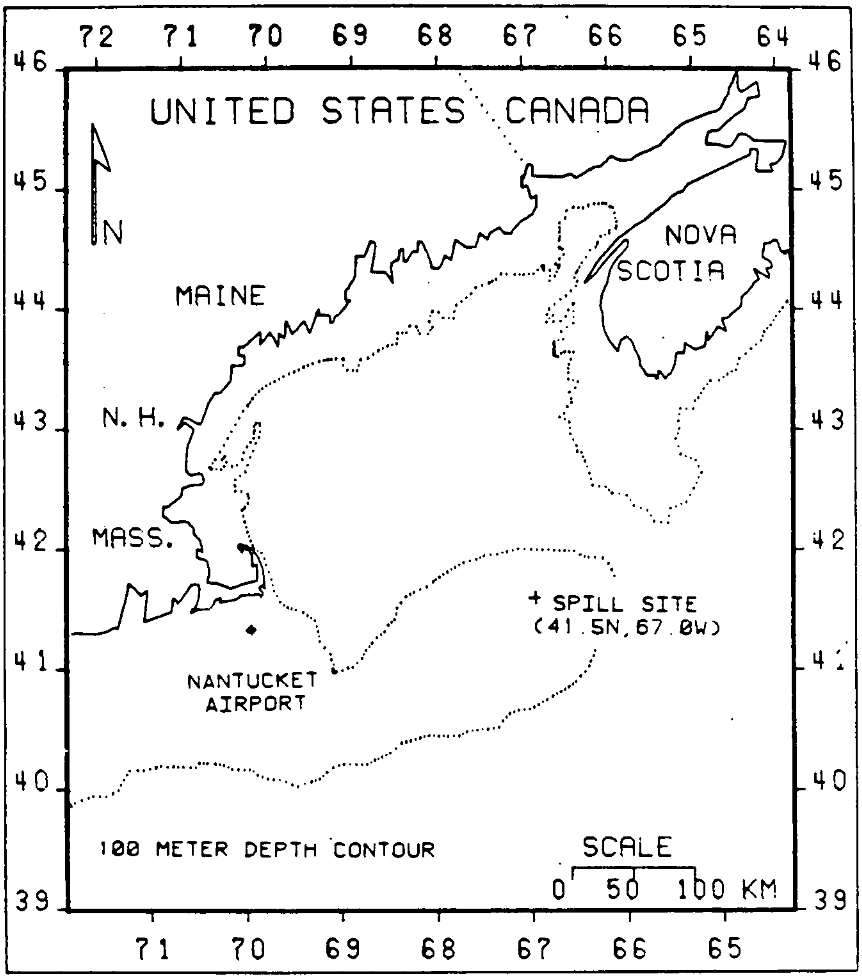


Figure 5.1 Location of Spill

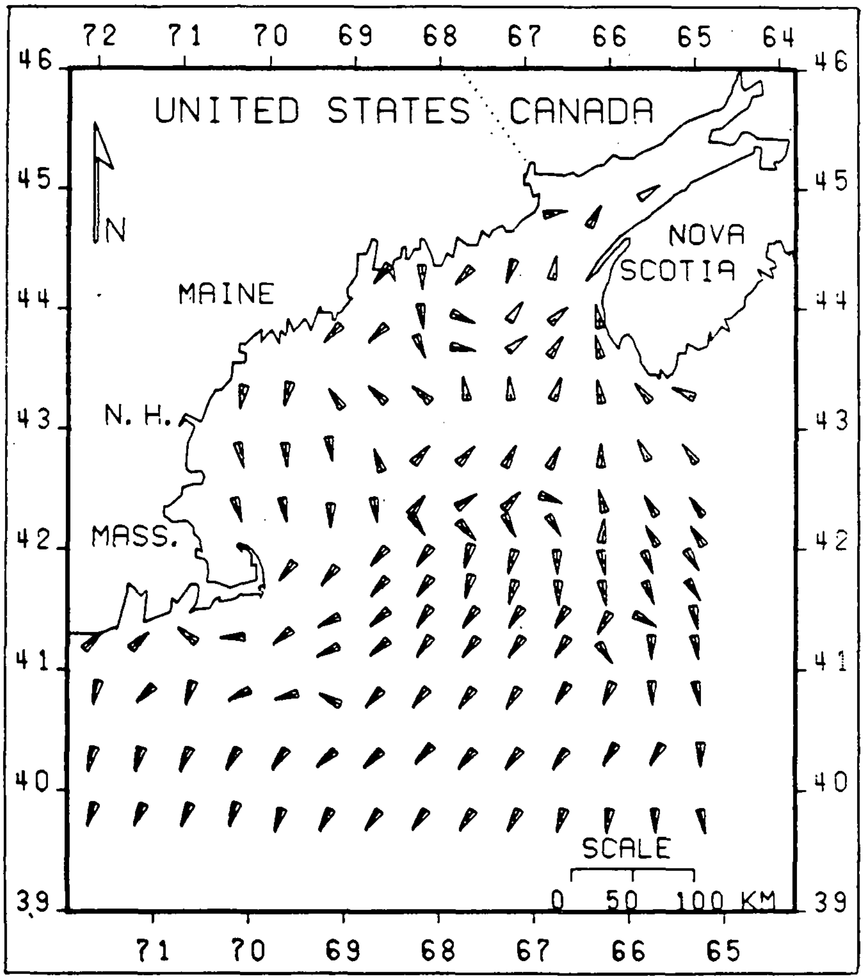
Figure 5.2: Model Input Parameters

Spill location	67°W longitude 41.5°N latitude
Thermocline depth	10 meters
Wind	December 1972
Temperature	December 9°C
Currents	Winter 1972
Oil	
Density	0.647 gm/cm^3
Interfacial tension	30 dynes/cm
Kinematic viscosity	1 centistoke
Oil fractions (by weight)	
Paraffin, C_6-C_{12}	0.1
Paraffin, C_{13}-C_{22}	0.25
Cycloparaffin, C_6-C_{12}	0.15
Cycloparaffin, C_{13}-C_{22}	0.15
Aromatic, C_6-C_{11}	0.15
Aromatic, C_{12}-C_{18}	0.05
Naptheno-Aromatic, C_9-C_{25}	0.15
Residual	0.0
Total	34,840 metric tons
Total number of spillets	13
Oil spill rate	893.33 metric tons/hr
Total spill simulation time	30 days
Time step	3 hours
Horizontal dispersion coefficients	10m^2/sec

Figure 5.3 Cases Run

Case	Site	Wind Temp.	Current	Chemical Disp. After 48 Hours	Diffusion	Entrain	Length
1	Georges Bank	December	Bumpus plus wind induced	0 %	10 m^2/sec	Natural Audunson plus Exponent. Decay	30 Days
2	same	same	same	25 %	same	same	same
3	same	same	same	50 %	same	same	same
4	same	same	same	75 %	same	same	same
5	same	same	same	100 %	same	same	same

Figure 5.4 Winter Currents



upper few meters (down to the thermocline in this case) of the water column. Details of the model are given in Reed and Spaulding (1979), and Section 6 and 12.5 of this report.

5.3 Natural Entrainment of the Spilled Oil

The process of primary interest in the impact analysis discussed herein is dispersion - both natural and chemical. For natural dispersion, which proved to be of significance in the case studied, the entrainment rate obtained by Audunson (1977) in the Bravo Blowout Study is used. Adunson's expression is:

$$\text{Fraction} = 0.1 \frac{(u^2)}{(w_o{}^2)}$$

where:

Fraction is the fraction by weight of the oil remaining on the surface to be entrained;

W_O is a wind speed constant equal to 8.5 m/s

and

u is the measured wind speed at 10 m in units of m/sec.

For this model, Audunson's expression was modified by a factor decaying exponentially with time. The time constant used was two days. The intent of this term, selected in an ad-hoc fashion, is to incorporate weathering of the surface slick into the entrainment process. Often as the surface slick ages it becomes emulsified (water-in-oil) and is not as easily entrained as in the early stages. These effects may well have been masked in the derivation of the original equation for two reasons. First, the Bravo spill occurred over a fairly long period (weeks) so there was almost always fresh oil coming to the surface. Second, the crude oil involved in the Bravo spill did not appear to emulsify as readily as other oils.

In the case of chemical dispersion, a delay of 48 hours was implemented in the model before dispersants were applied. This delay was intended to simulate the time necessary to organize a treatment effort, and is, of course, a parameter that could be experimented with in future applications of the model.

The oil entrained is represented by marker droplets or particles. For each of the simulations discussed here, about 1900 droplets were used. Because the mass of oil in the water column varies from one scenario to the next and the number of droplets was fixed, the mass of oil represented by a marker droplet also varied from one scenario to the next. The particles were distributed randomly under the spill in the horizontal. In the vertical, they were assumed only to occupy the water column above the thermocline, 10 meters in this case. The particles were distributed randomly in these 10 meters.

5.4 Results

5.4.1 Mass Balance

The values of a number of variables of interest in assessing the various strategies are summarized in Table 5.1 for the last day of the simulation. Figures 5.5-9 show the mass balance as a function of time. The oil is very light so that about 40 percent evaporates within several hours of its release. The value is always within two percent of this even when all the oil is dispersed, case 5. Treatment earlier in time would of course decrease the mass to evaporate.

In case 1, no chemical dispersion, 8.6 percent of the original mass is entrained and the remaining 51 percent remains on the surface. These two values of entrained and surface mass increase and decrease, respectively, until, for the 100 percent dispersed case, 60 percent of the mass enters the water column, with none remaining on the surface. There is seven times as much oil in the water column for the totally dispersed case (case 5) as in the non-dispersed case (case 1). The mass distribution for all cases is identical for the period before any treatment.

5.4.2 Horizontal Area Over Which the Concentration exceeds the 50, 100 and 1000 ppb Predefined Values

Figures 5.10-13 are graphs of the horizontal area for which the oil concentration exceeds 50, 100 and 1000 ppb, respectively versus time. For the 50 ppb contours, the final area varies by 60 percent between the first three cases, but the last three high dispersed cases differ by only about 5 percent. For the 100 ppb and the 1000 ppb contours, only the last two dispersed cases are within 5 percent of each other. There is about a 10 to 20 percent reduction in the area covered when going from the 50 ppb contour to the 100 ppb contours. The area covered by the 1000 ppb contour is smaller in all cases. In the non-dispersed case, the final area for the 1000 ppb contours occurs at day 15 and the maximum concentration at day 30 is 476 ppb. The maximum concentration at day 30 for the dispersed cases exceeds 1650 ppb.

There are a couple of interesting points concerning these curves. First, for cases 2 to 4, the area which the 50 ppb contour covers is larger than the 100 percent dispersed case for the first 15 days. The areal extent for the 100 percent dispersed case does not exceed the others until between days 15 through 20. This is due to the natural dispersion which continues after treatment. The surface spillets movement causes the naturally treated mass to be entrained further to the east than the treated mass and thus increases the area covered. The amount of mass entrained after treatment decreases with an increase in percent dispersed as a result of lesser amounts of oil on the surface. The maximum difference between areas due to this increase in area is 25 percent and occurs at day 5 between the 25 percent and 100 percent cases. The difference in areal coverage between these two cases decreases to 20 percent for the 100 ppb contour and is less than 3 percent for the 1000 ppb contours. The areal extent during this same period for the 100 percent dispersed case (50 ppb) is less than the 50 percent and 75 percent dispersed cases by 20 percent and 5 percent respectively. For the 100 ppb contour, the 50 percent and 75 percent dispersed cases at day 5 are within nine

Table 5.1 Data for Cases Run

				Final Area (km^2) of Subsurface			ppb
% Disp.	% in Atmosphere	% on Surface	% in Water Column	50 ppb	100 ppb	1000 ppb	Highest Conc. at day 30
0	40.2	51.2	8.6	1138	808	27[1]	476
25	39.9	38.5	21.6	1505	1239	206[2]	1651
50	39.9	25.6	34.5	1701	1384	374	2774
75	40.7	12.8	47.5	1763	1491	577	4413
100	39.6	0	60.4	1792	1524	583	6257

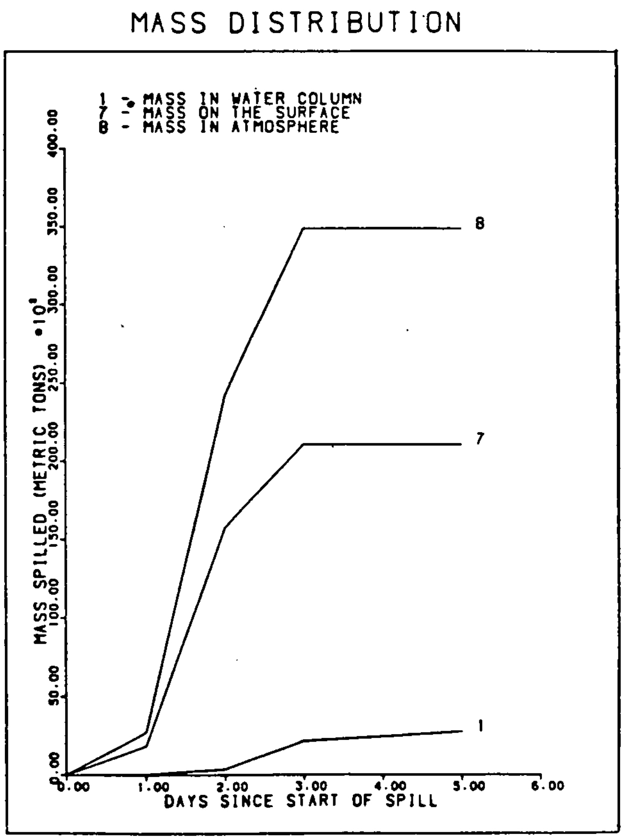


Figure 5.5 Mass Balance 0% Dispersed

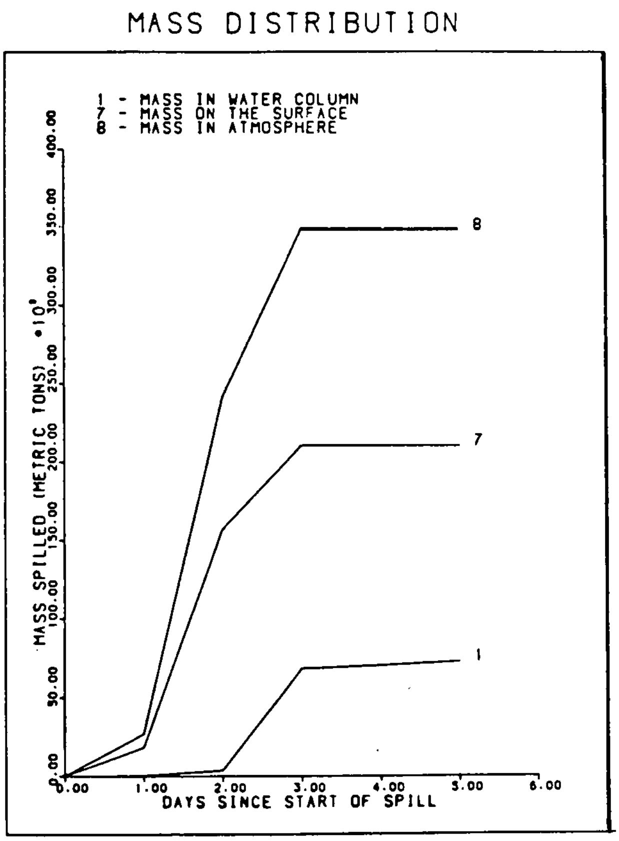


Figure 5.6 Mass Balance 25% Dispersed

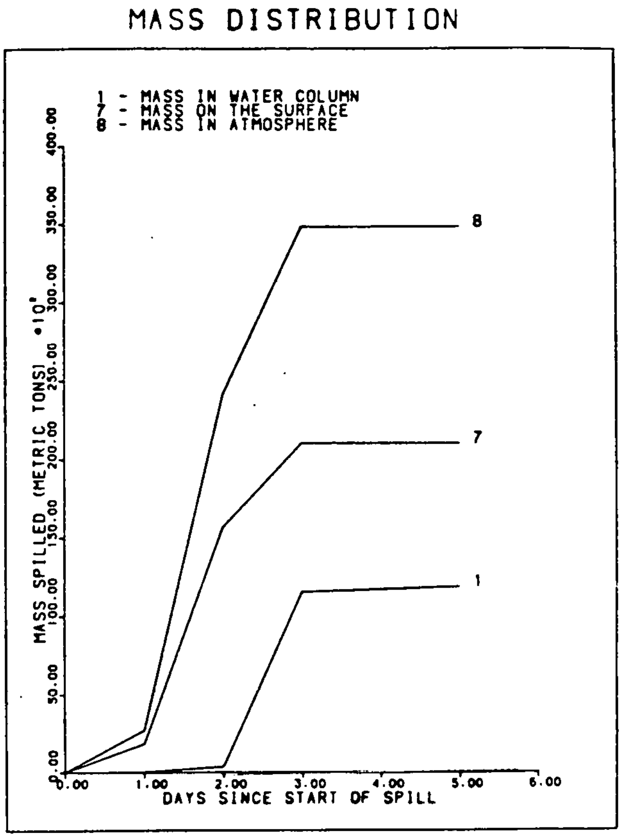


Figure 5.7 Mass Balance 50% Dispersed

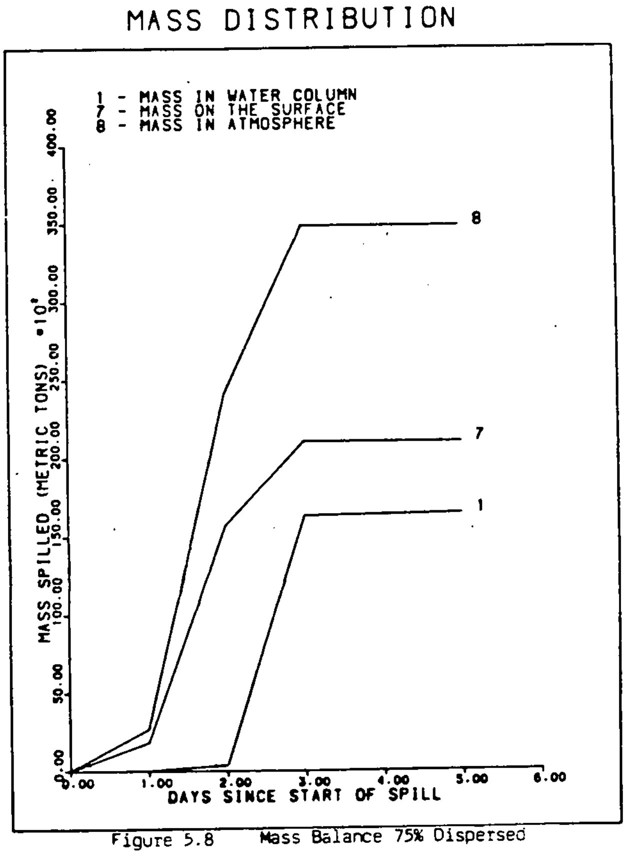


Figure 5.8 Mass Balance 75% Dispersed

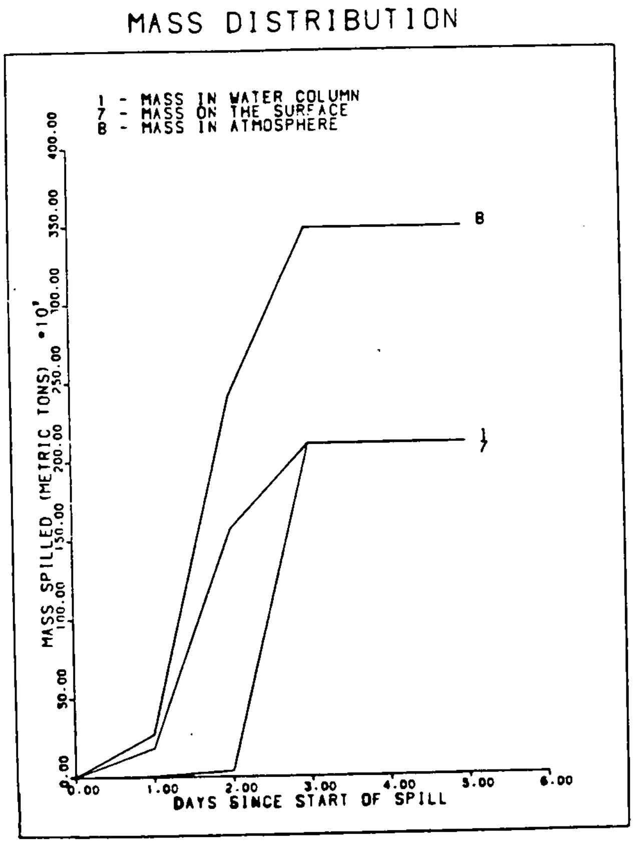


Figure 5.9 Mass Balance 100% Dispersed

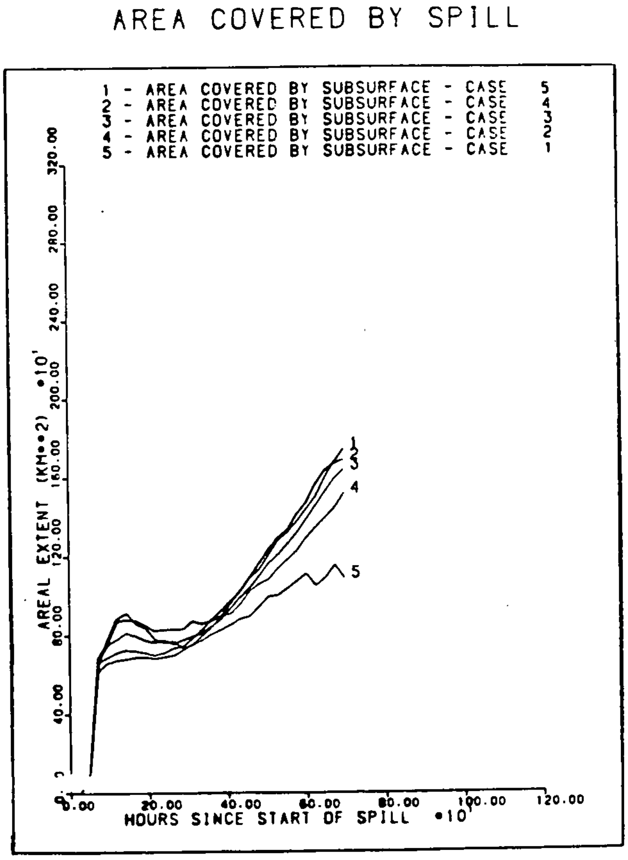


Figure 5.10 Areal Extent 50 ppb.

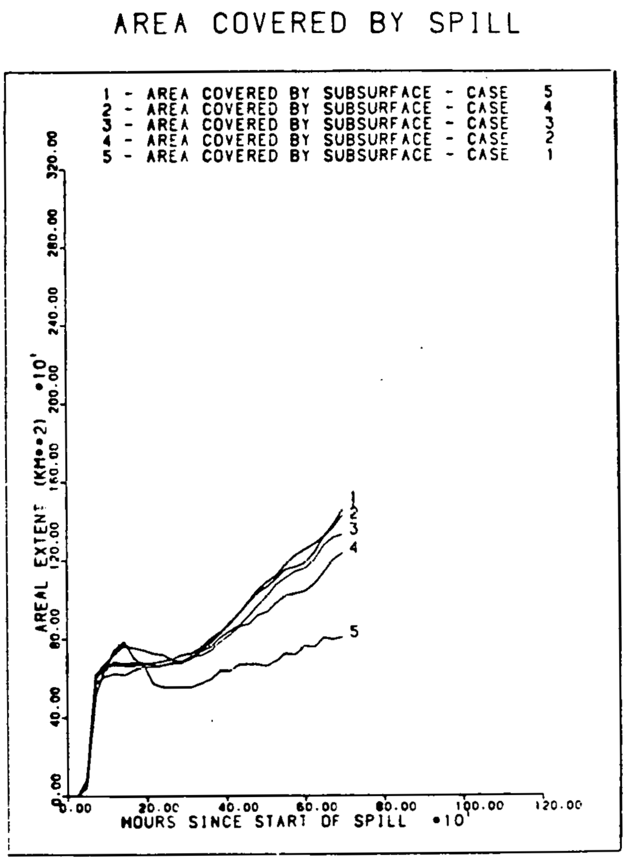


Figure 5.11 Areal Extent 100 ppb.

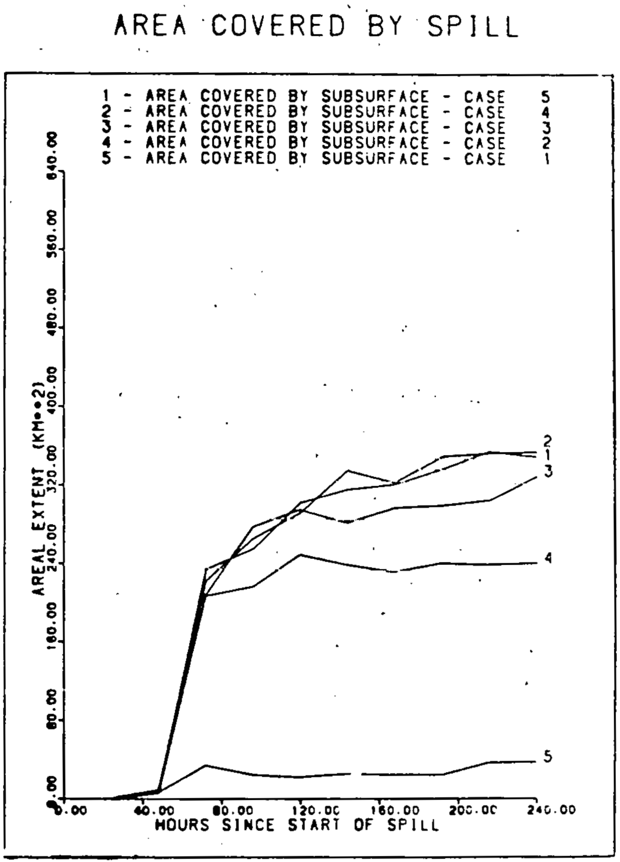


Figure 5.12 Areal Extent 1000 ppb. (10 days)

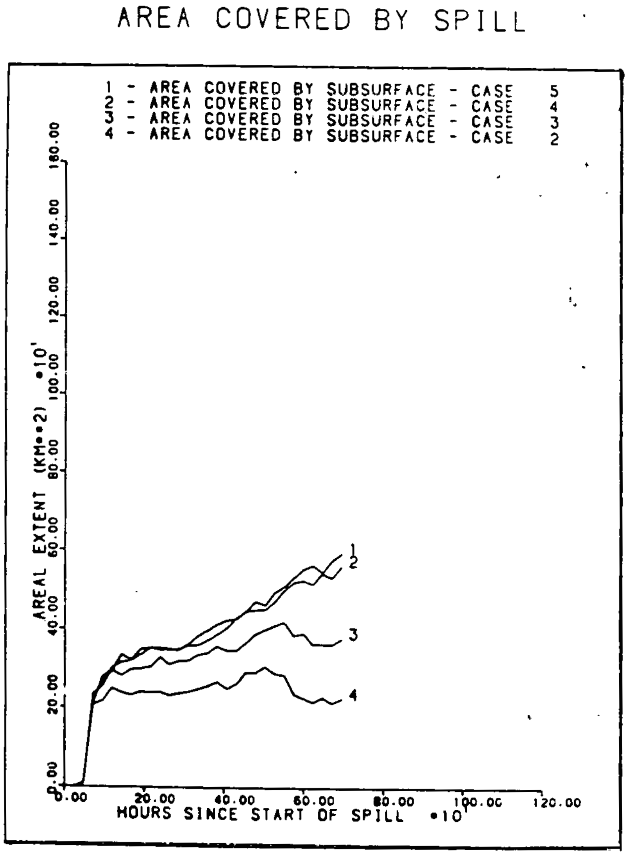


Figure 5.13 Areal Extent 1000 ppb. (31 days)

percent of the 100 percent dispersed case. As in the 50 ppb contour, the area of the 100 percent case is comparable to the other dispersed cases between 15 and 20 days after the spill for the 100 ppb contour. The 1000 ppb contours for all of the dispersed cases are very similar.

The other interesting feature of the areal extent curves is the decrease or leveling off of the area at approximately day 10 in most of the cases. This is due to the currents compressing the droplet cloud in the North-South direction. This is more noticeable in the 50 ppb contours and in the lower dispersed cases than in the higher contours and in the higher percent dispersed cases.

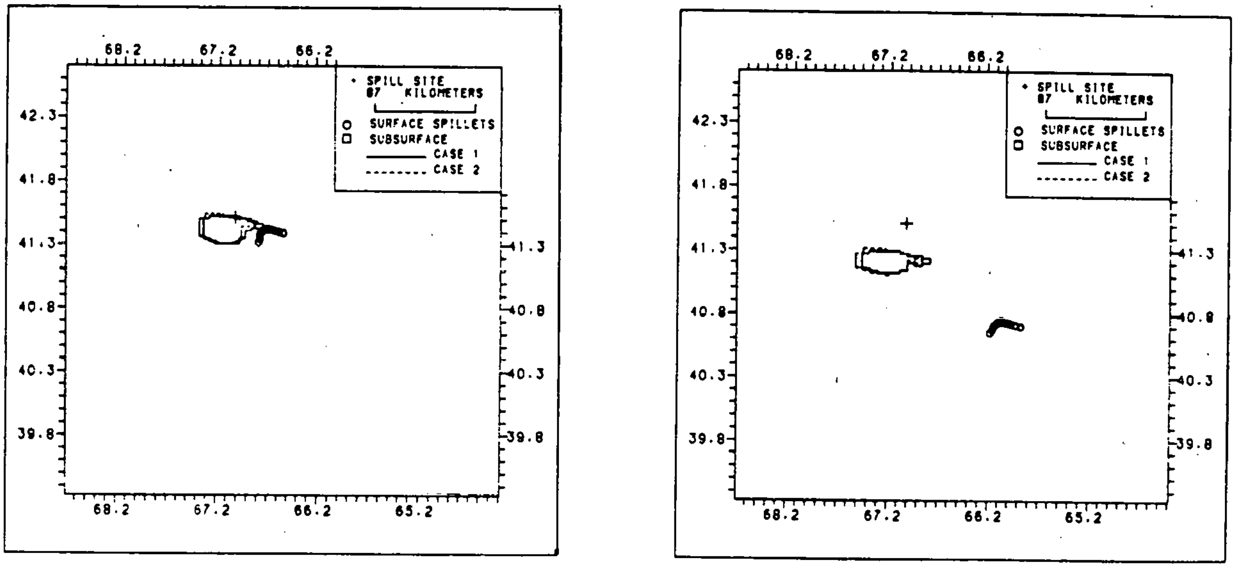
Charts including the contour lines and surface spills are included in Figures 5.14 through 5.24 for the 50 ppb, 100 ppb and the 1000 ppb lines. The non-dispersed case (case 1) is compared to cases 2 to 5 for the first two contours (Figures 5.14 to 5.17 for the 50 ppb contour and 5.18 to 5.21 for the 100 ppb contour) and the 25 percent dispersed case is compared to cases 3 to 5 in the 1000 ppb plots (Figures 5.22 to 5.24). In all of the views, the surface spillets have identical movements due to identical currents and winds for all of the scenarios. The wind blows from the west and shift to the north during the first five days resulting in the L-shaped pattern of the spillets. This causes the first spillet to move furthest to the east and the last spillet released to be to the south. The spillets move together to the southeast during the remaining time that the oil is tracked.

The movement and shape of the subsurface contours show some similar characteristics. The area covered by the non-dispersed case is larger than the other cases 5 days into the spill as was cited before. The compressive effect of the currents is shown clearly at day 10 for the 50 ppb outlines. The subsurface currents are generally southerly but the magnitude of the currents on the northern edge of the cloud are greater than those at the southern edge. This results in a collapse of the North-South dimension of the cloud as well as decreasing the areal coverage. As the cloud moves further south, the difference in currents is not as great and with the help of diffusion, the contour assumes a square shape at approximately day 15.

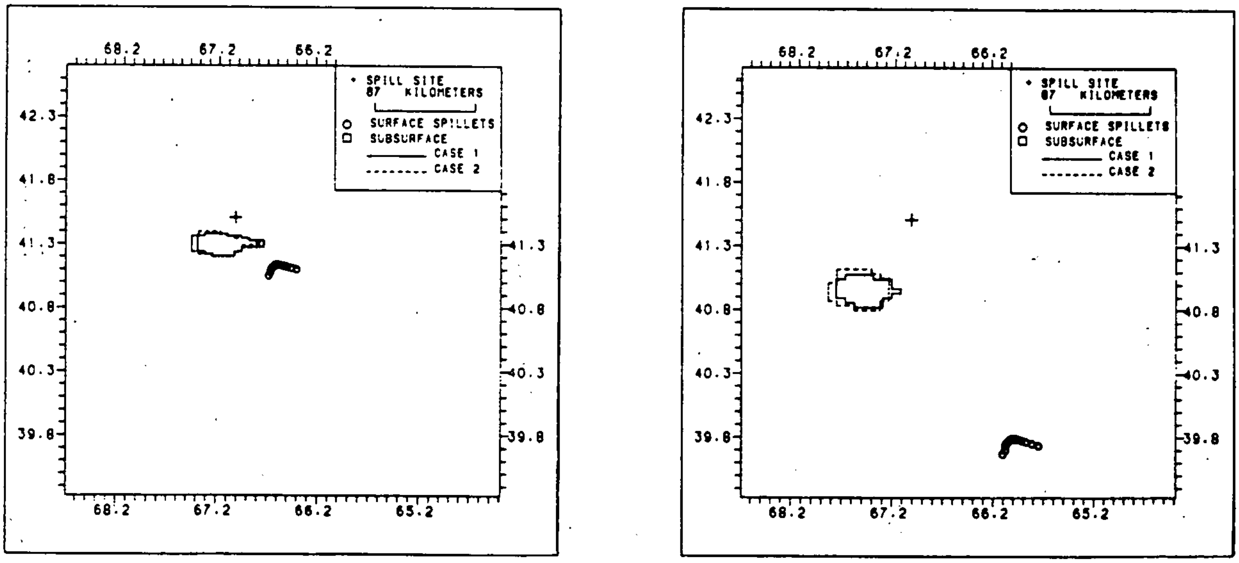
The plots for the 100 ppb contours show the same general behavior with the exception that the contours assume a more regular shape by day 10. The 1000 ppb contours are very similar as was the areal coverage.

5.5 Conclusions

An open ocean oil spill can be simulated using the model developed and different response strategies can be investigated. The movement of the spilled oil dependent on environmental variables is of importance at the beginning of the spill for cleanup or treatment. The efforts must begin before the oil weathers or spreads, both of which would reduce the efficiency of any efforts. The spillets in these runs are spread out over an area greater or equal to four kilometers after 3 days, thus making any treatment or cleanup attempt difficult. The surface area covered is approximately 10-20 percent of the area covered by the subsurface 50 ppb contour. The surface area overlayed by the higher dispersed cases is greatly reduced by as much as a factor of 10 due to entrained mass.


120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

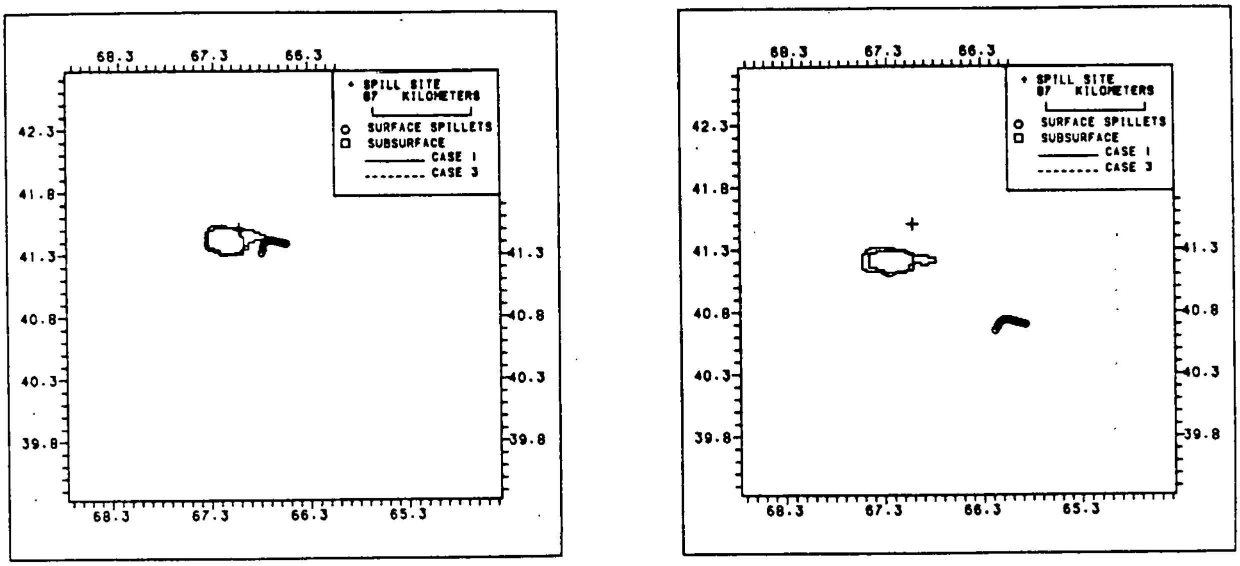

240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

Figure 5.14 Overhead Views 50 ppb. Case 1 vs. Case 2

120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

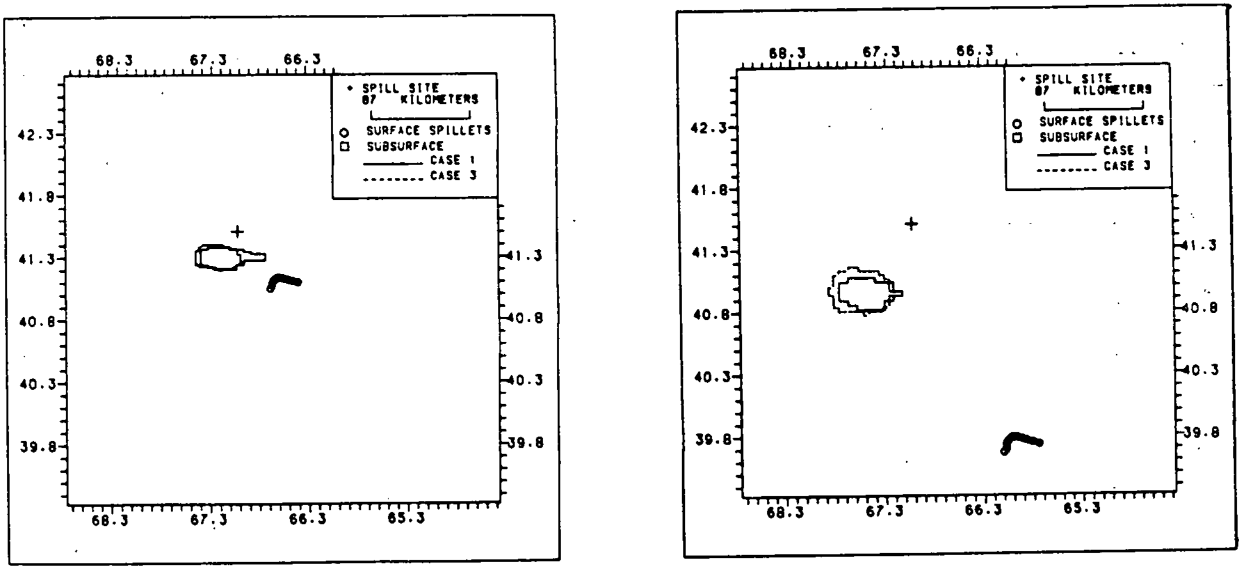
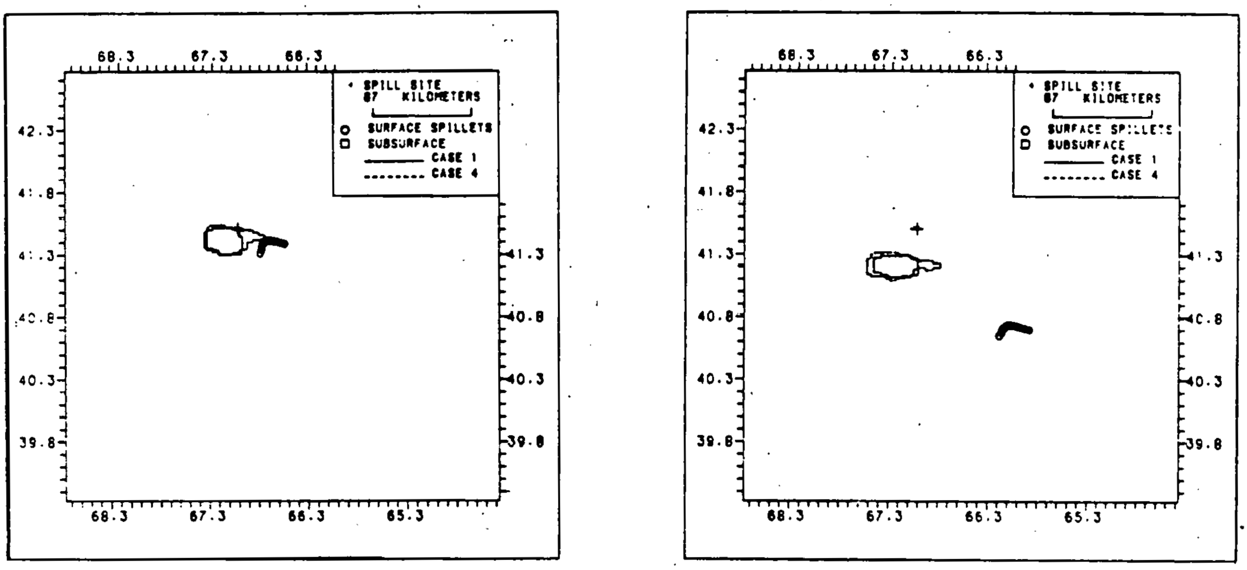
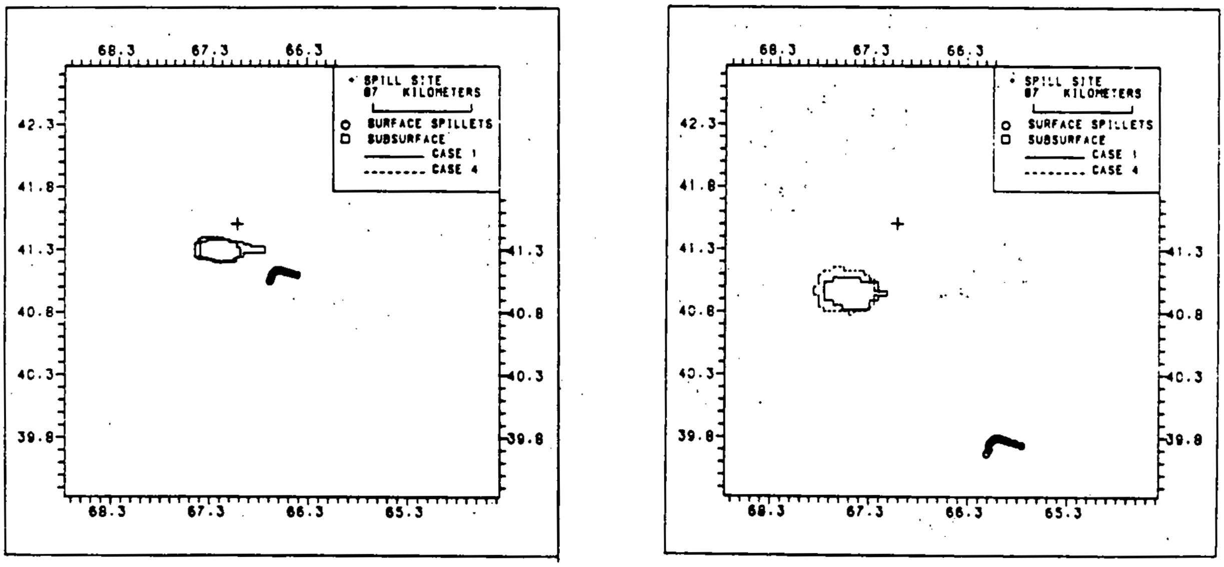


Figure 5.15 Overhead Views 50 ppb. Case 1 vs. Case 3



120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

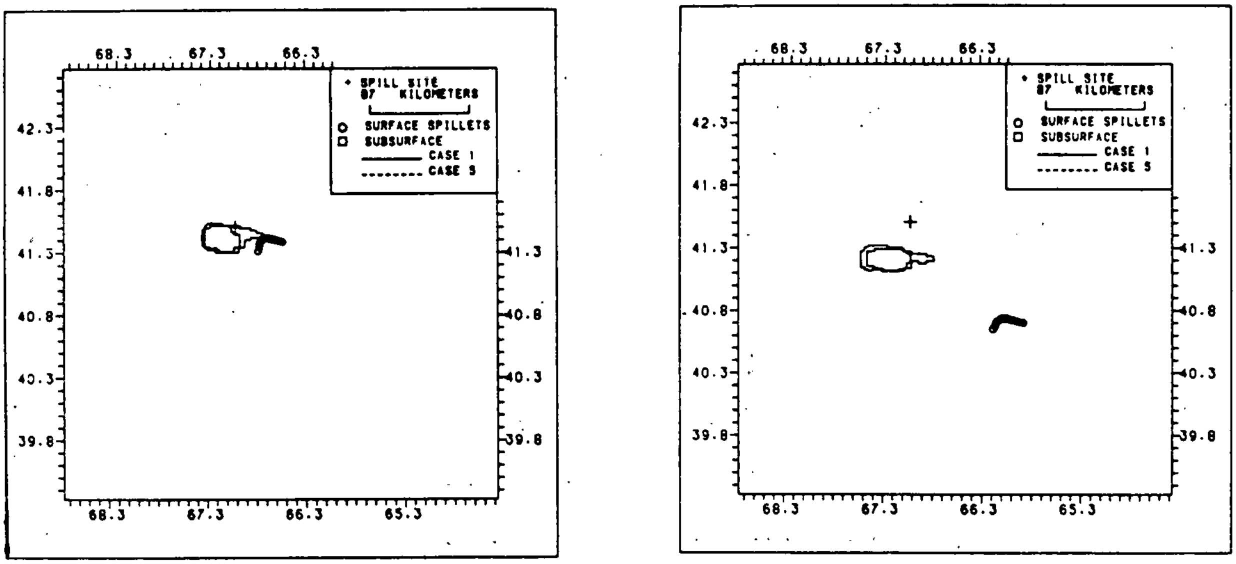
360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

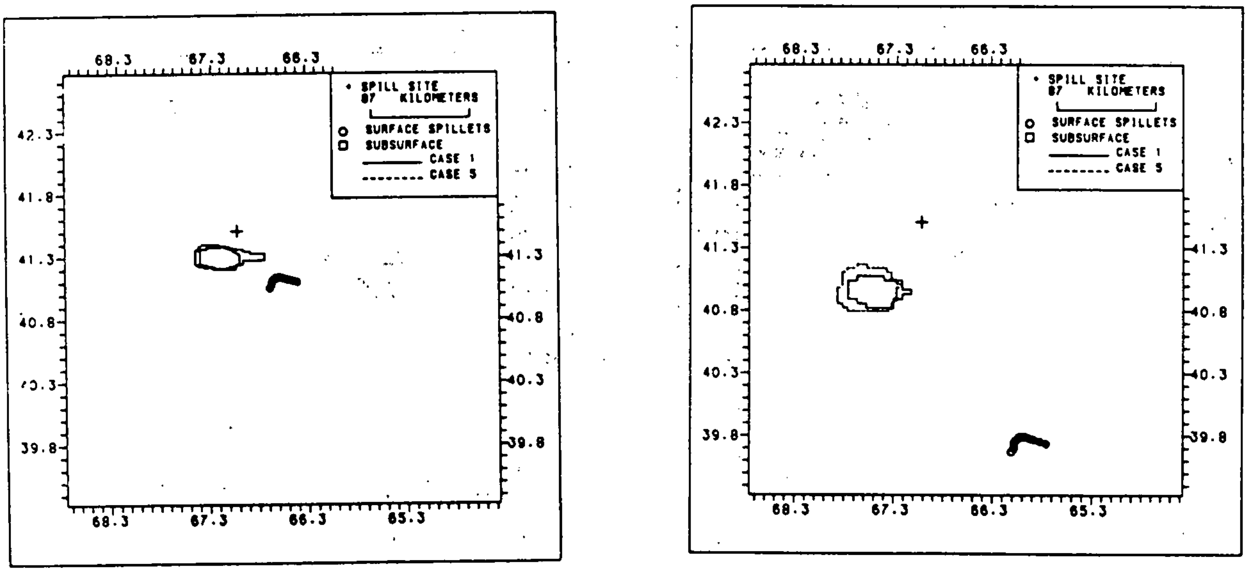
720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

Figure 5.16 Overhead Views 50 ppb. Case 1 vs. Case 4



120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



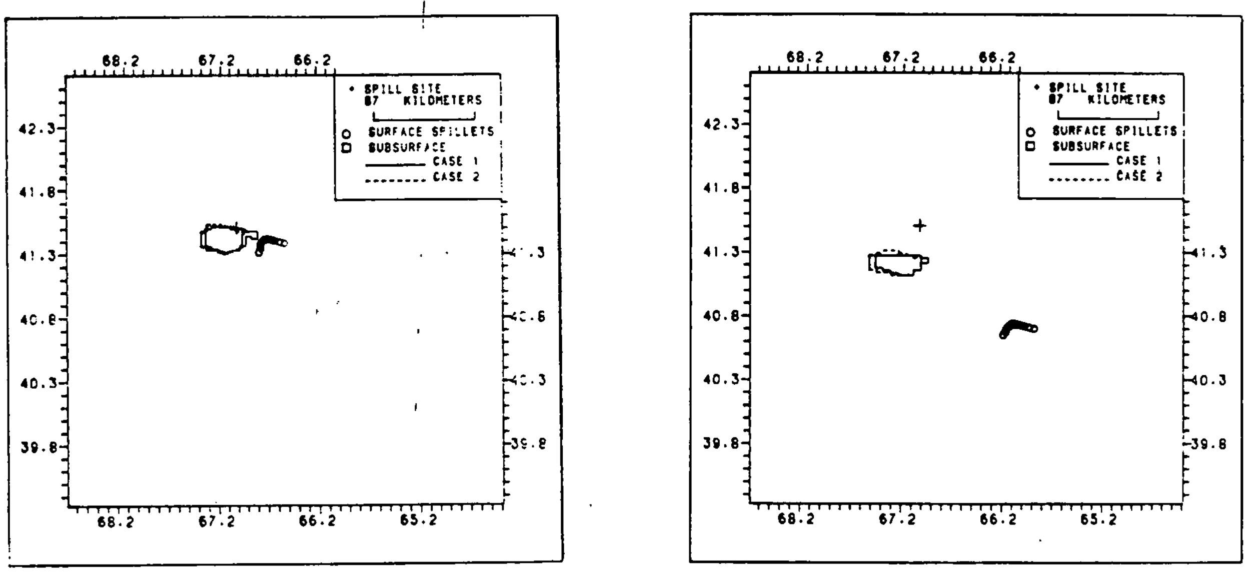
240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

Figure 5.17 Overhead Views 50 ppb. Case 1 vs. Case 5

120.0 HOURS AFTER START OF THE SPIL
MAP OF SPILLETS AND SUBSURFACE

360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

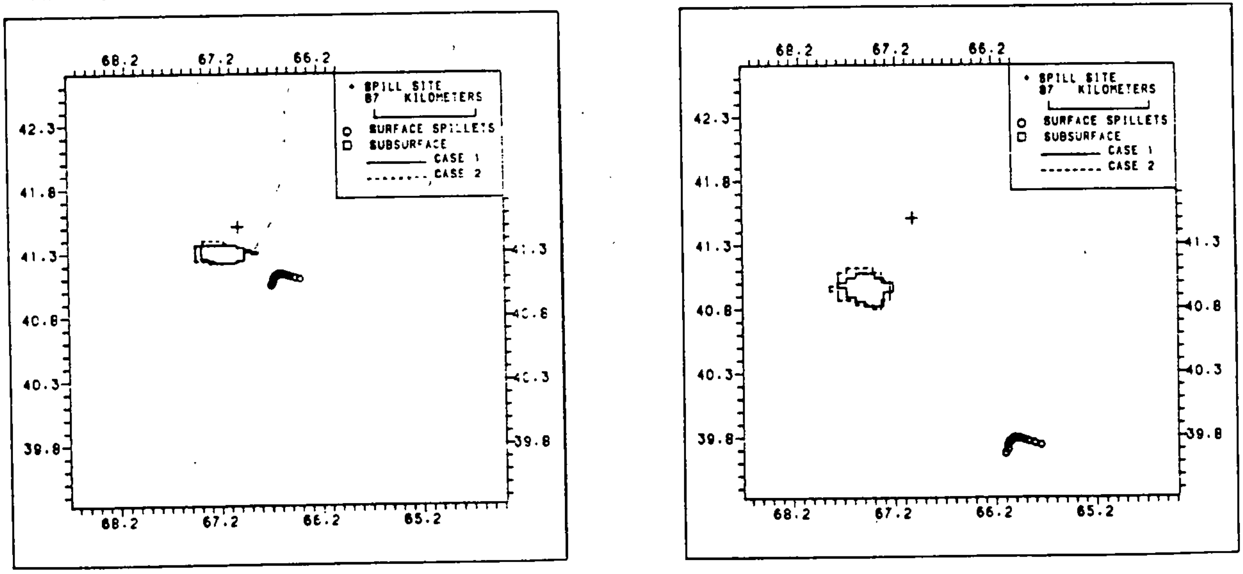
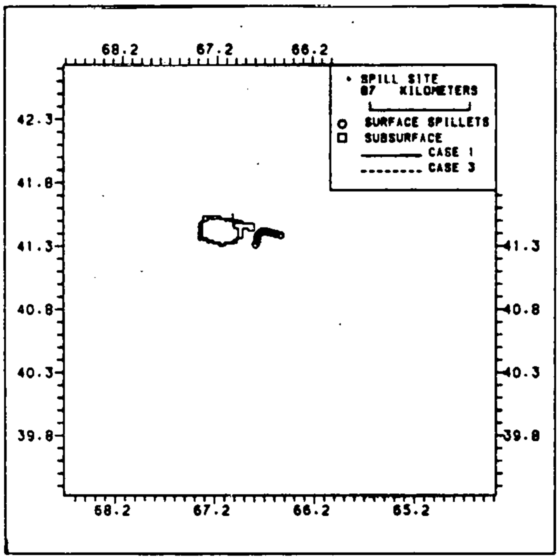
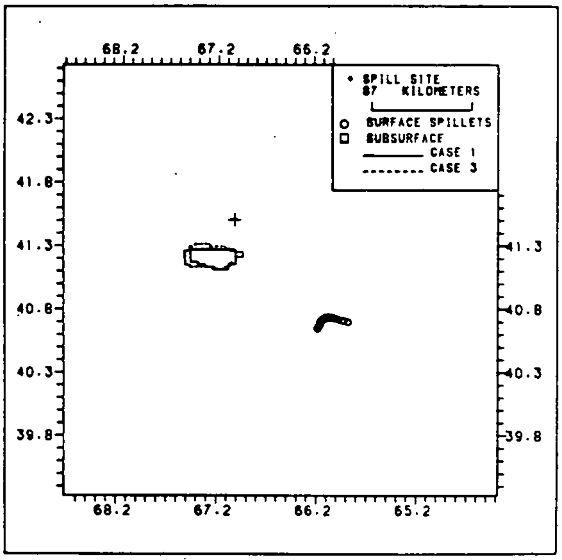


Figure 5.18 Overhead Views 100 ppb. Case 1 vs. Case 2

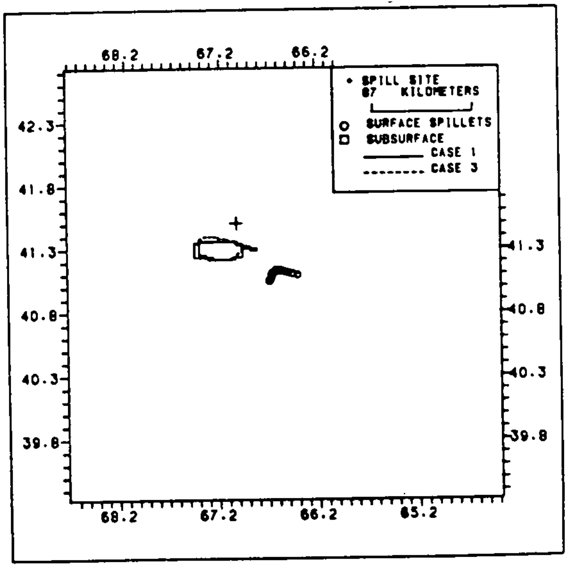
120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

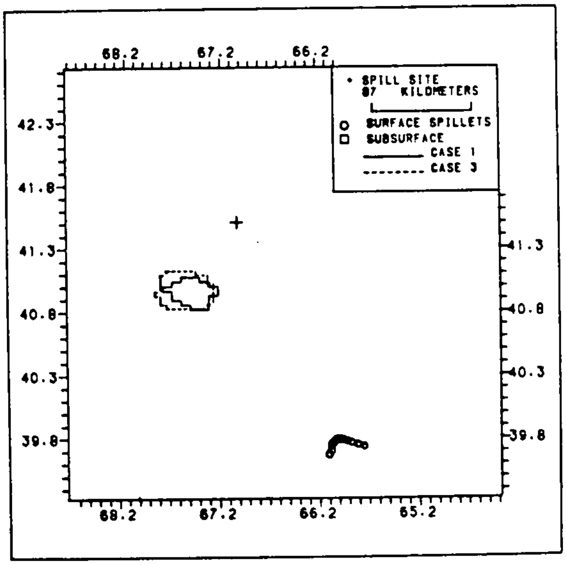
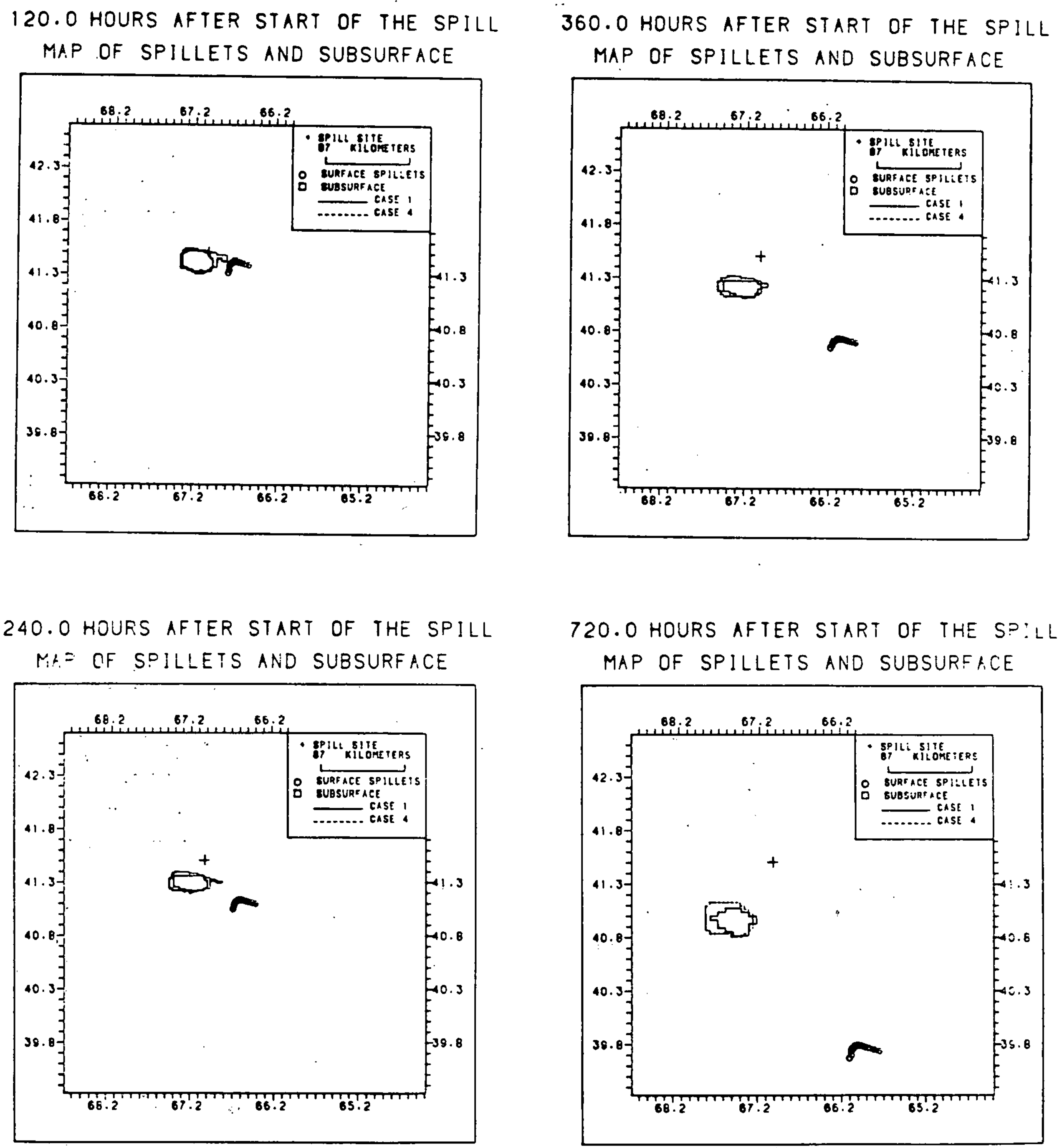


Figure 5.19 Overhead Views 100 ppb. Case 1 vs. Case 3



120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

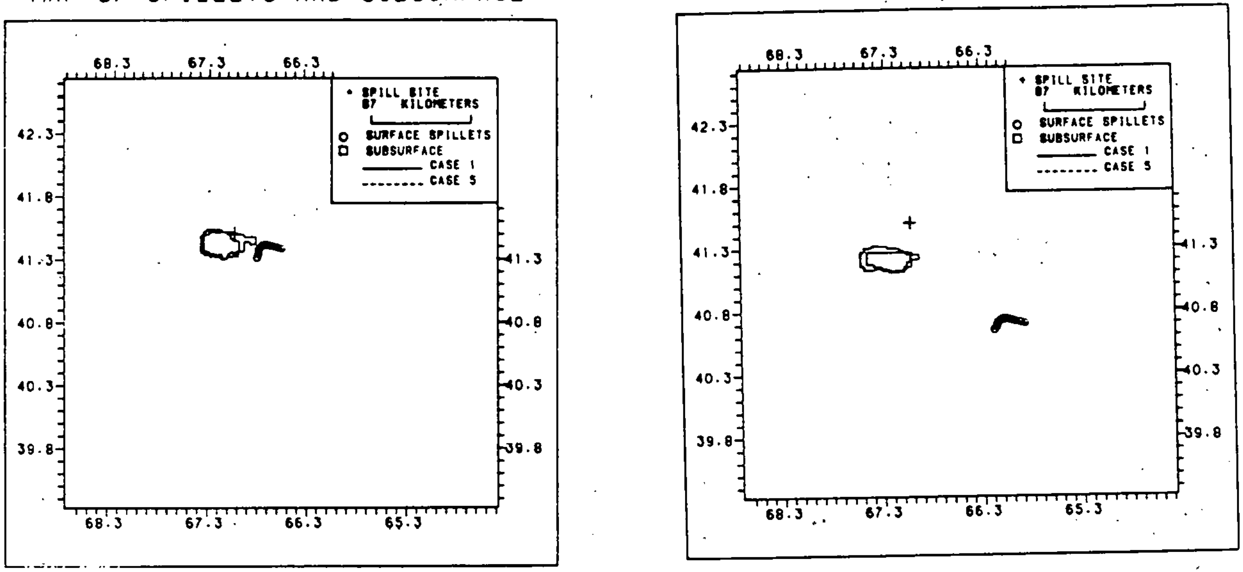
240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

Figure 5.20 Overhead Views 100 ppb. Case 1 vs. Case 4

120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

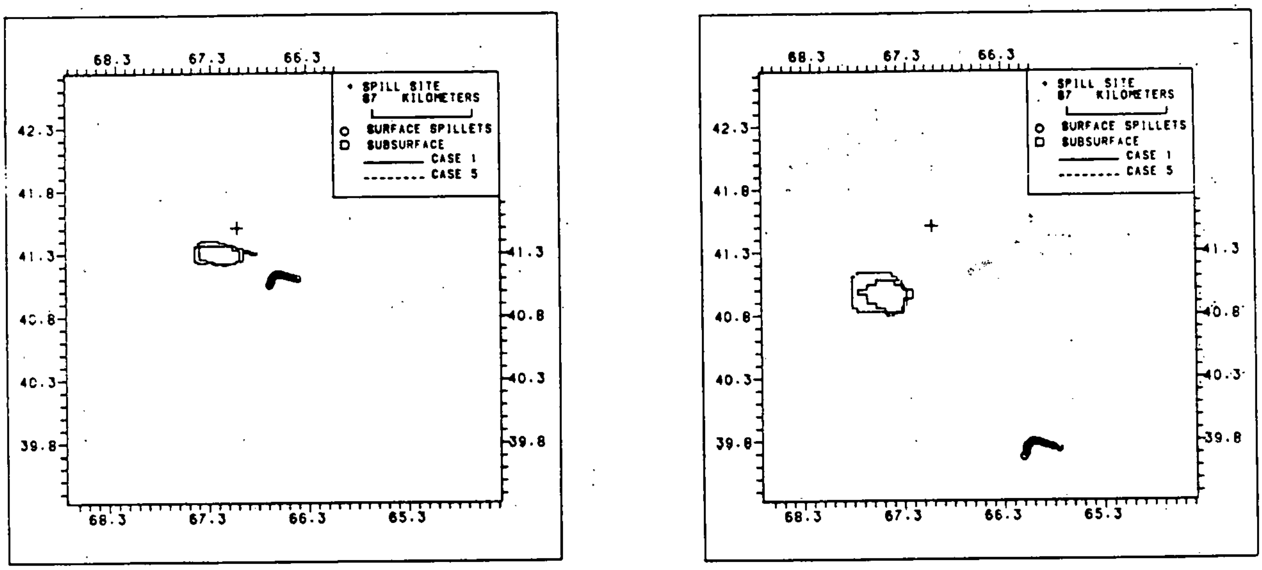
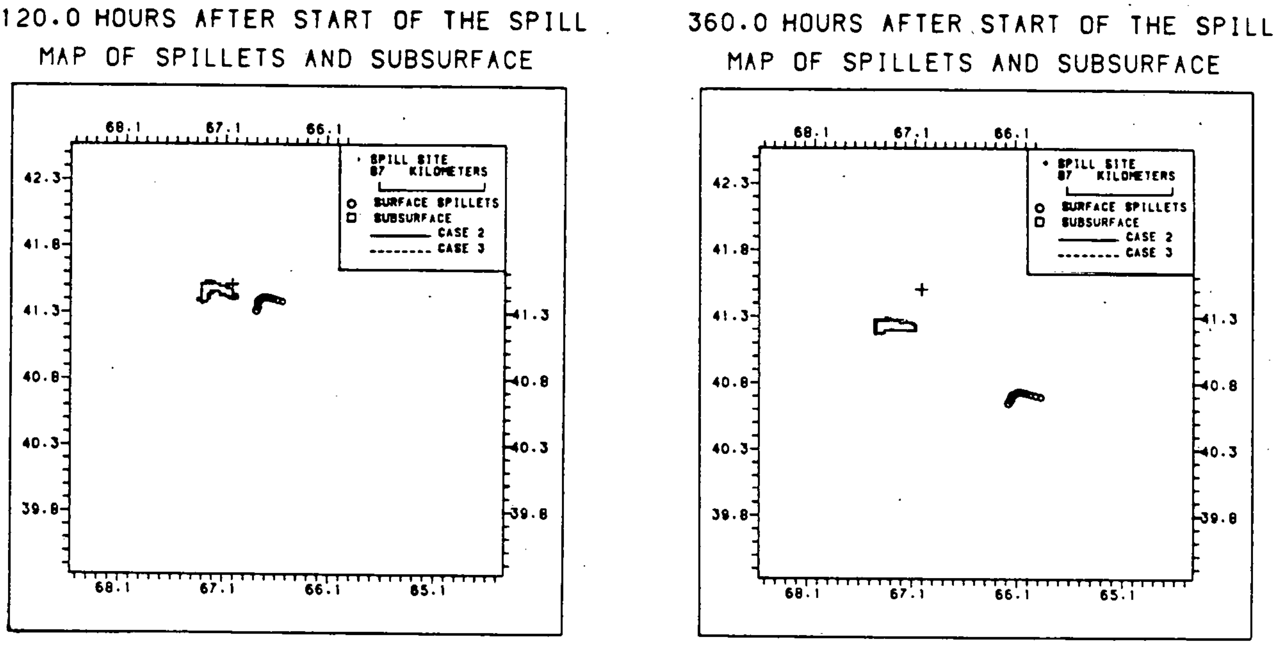
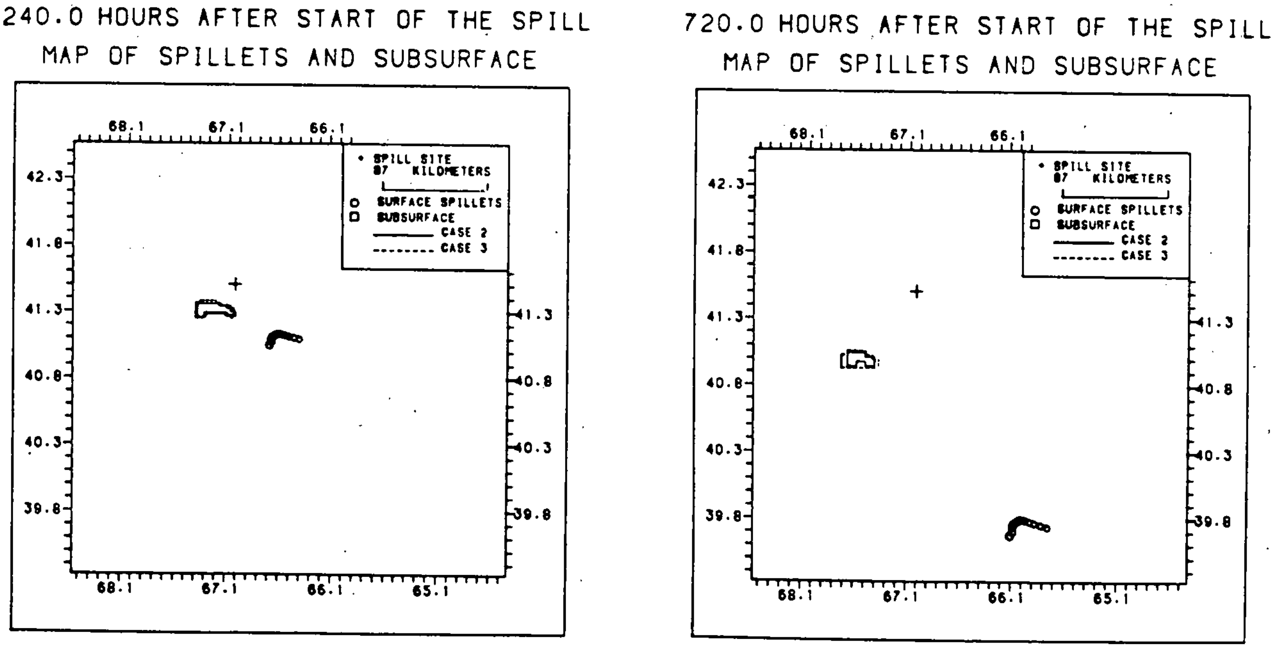


Figure 5.21 Overhead Views 100 ppb. Case 1 vs. Case 5



120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

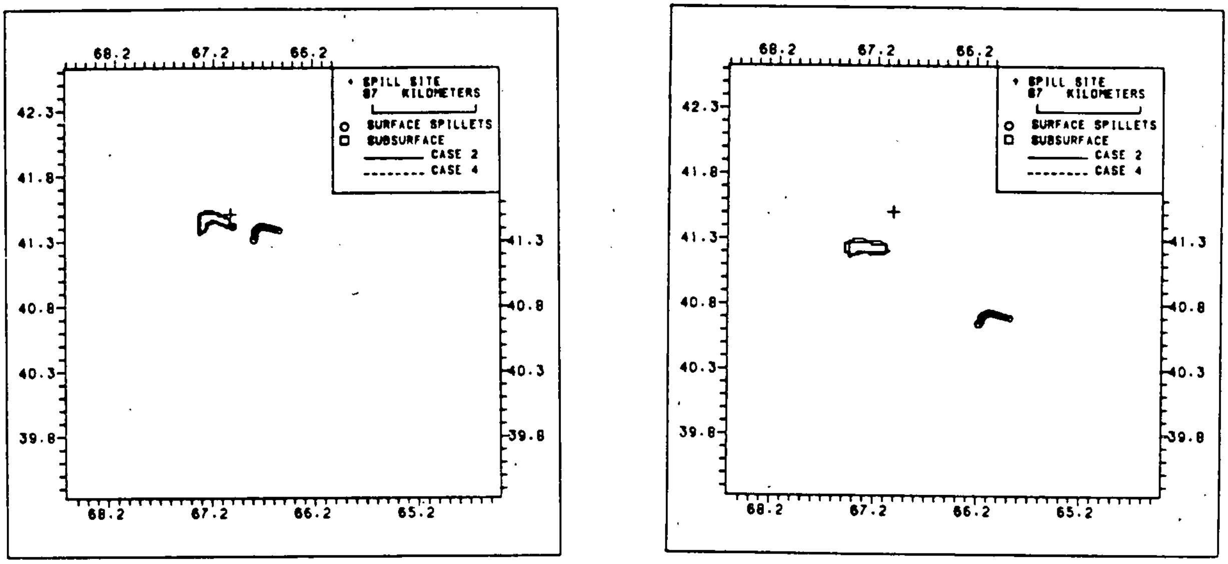
360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

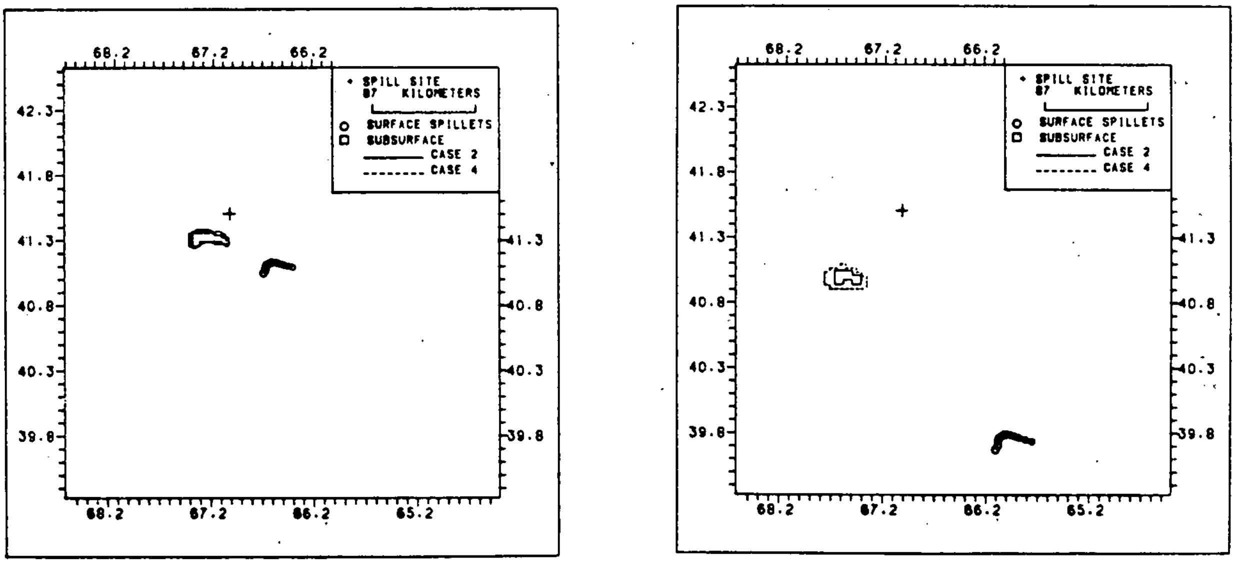
720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

Figure 5.22 Overhead Views 1000 ppb. Case 2 vs. Case 3



120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



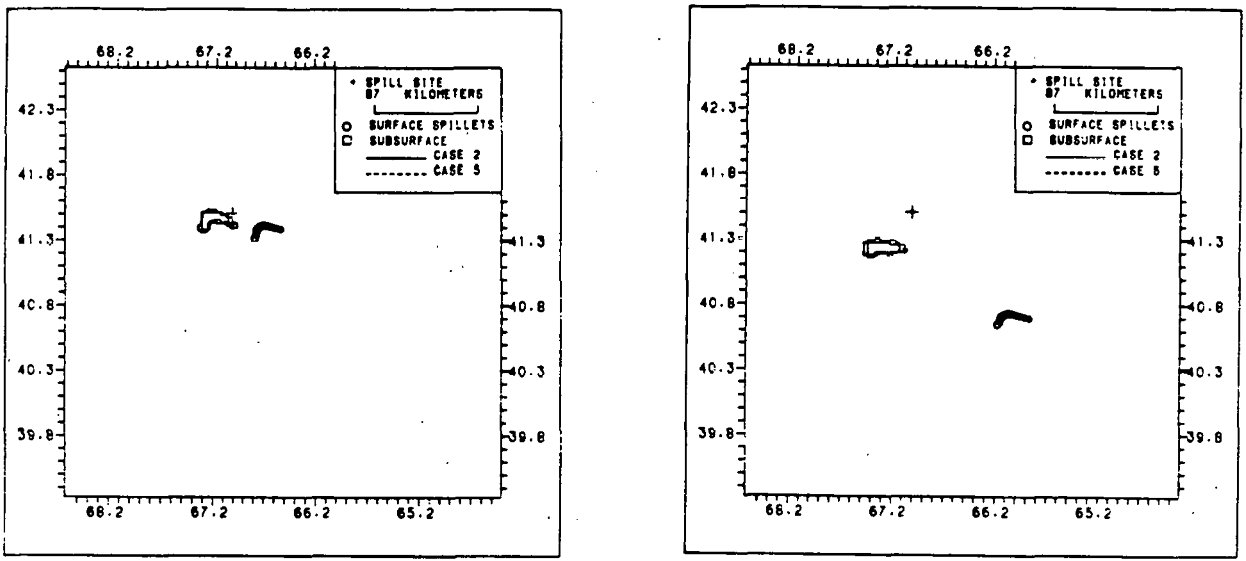
240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

Figure 5.23 Overhead Views 1000 ppb. Case 2 vs. Case 4

120.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

360.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE



240.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

720.0 HOURS AFTER START OF THE SPILL
MAP OF SPILLETS AND SUBSURFACE

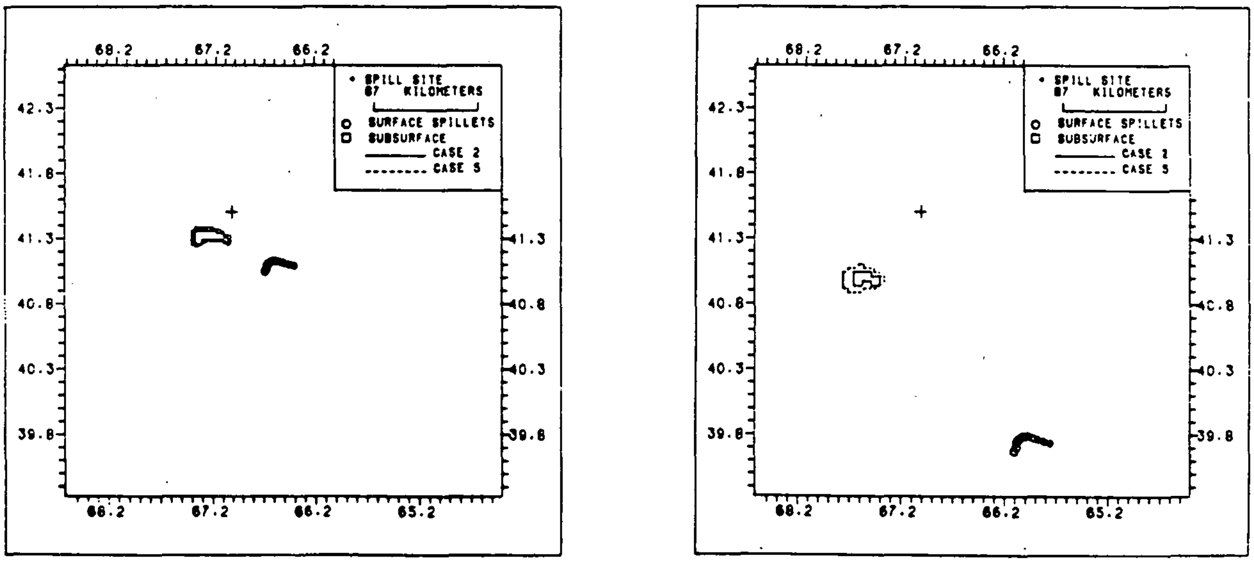


Figure 5.24 Overhead Views 1000 ppb. Case 2 vs. Case 5

The subsurface component of the spills can be compared with each other in order to determine the best strategy for the least impact on fish or fish larvae. The first aspect to consider is the timing of the treatment. In these scenarios, it can be seen that any delay in treating the spill will result in an increase in the area impacted. For coastal water scenarios, influenced to a greater extent by tidal currents, the entrained oil may return to the spill site and this aspect must be taken into consideration. The response time will most likely be even more important in this case than in the open ocean case.

The next question to consider is the percentage of oil to be dispersed. The plots of areal extent do not show the cumulative area covered but do indicate the area covered at each time step. The dispersed cases always cover more area by the end of the scenarios, but this is not true for the first 5 days for the lower concentration outlines (50 and 100 ppb). This may be of importance when toxicity is considered. The concentration for the non-dispersed case is at most one-quarter that of any of the dispersed cases. Since the spill is in a fish breeding ground, the dispersed cases are overlying the same area so the same impact will be felt for all five cases (see Figure 5.10). The higher concentration cuts, which will have more impact on the adult fish, are a result of a higher percentage dispersion (see Figure 5.13). Some larvae are thought to be affected by 50 ppb and thus lethal levels of hydrocarbon concentration may exist long after initial treatment.

It is evident from these simulated spills that local currents are of great importance as well as are the winds. Not so apparent are the effects of treatment. For example, early treatment although increasing the concentration in the water, may actually result in a smaller impacted area because of the decrease in area resulting from natural entrainment from surface spillets. On the other hand, the lower concentrations resulting from natural entrainment in the untreated case may not impact the fisheries as much because of the lower toxicity. This complicated interplay must be investigated in greater detail in the future where such variables as response time, toxicity, etc., are varied in an in-depth application of the oil spill fishery interaction model.

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6.0 A Fishery Oil Spill Interaction Model

Mark Reed

Malcolm L. Spaulding

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ABSTRACT

The oil spill - fisheries impact model has been used to simulate nine variations of an oil spill scenario on Georges Bank, producing a rough sensitivity analysis of system response. Following an overview of the model system, the results and implications of these simulations are discussed along with limitations of the approach used. It is suggested that the most significant unknowns in the system are the parameters governing recruitment dynamics in the fishery, toxicity threshold values and oil entrainment rates being of secondary importance in open ocean conditions.

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6.1 INTRODUCTION

Through the National Environmental Policy Act of 1976, the United States Government has given explicit recognition to the critical importance of maintaining and restoring the quality of the environment in a manner which promotes the general social and economic welfare of present and future human generations. This research represents an actualization of the intent of this policy, employing available technological capabilities to analyze interrelationships among a number of variables in an environmental problem of contemporary significance. Typically, as many questions have been raised as have been answered, but the primary goal, the creation of a modeling methodology capable of estimating the effects of marine pollution events on biological populations, has been realized. Although the development has evolved around a specifically defined system, the conceptual approach is biologically and spatially transferrable, with each model element being sufficiently independent to permit relatively facile modification when appropriate.

The specific problem addressed here concerns the degree of impact experienced by a given stock of fish subsequent to an offshore oil spill. Recent experience on both sides of the North Atlantic Ocean has clearly demonstrated the extent to which coastal ecological resources may be damaged by large petroleum spills. In the case of the Amoco Cadiz accident off the coast of France, for example, it appears that a majority of the impacts can be assessed through direct observations. In offshore situations such as the Argo Merchant wreck, the Bravo blowout in the North Sea, or the Ixtoc I blowout in the Gulf of Mexico, the ensuing ecological consequences are far less clear. Although the oil slick disappears from the ocean surface within a few weeks after cessation of release, the full post-spill legacy is uncertain. The virtual impossibility of actually measuring these effects necessitates the application of a modeling approach.

In any modeling effort, a necessary basic decision concerns the establishment of conceptual limits on the abstraction of the real system being considered. This decision is ideally made in such a manner as to optimize the quality of the final model output, subject to the constraints imposed on the project. Allotted model development time, financial support limitations, and the existence and availability of appropriate data are the most important of these constraining factors, and all came to bear on the definition of the model system selected here.

The initial intent in the present case was to estimate the environmental impact of oil spills at sea, and the effect on this impact of chemically treating a spill. The most objective measure of impact is one with final dimensions of dollars and cents, dictating that commercially exploited species be included in an explicit manner. Thus the cost of a spill under a variety of different treatment scenarios could be investigated, the quality of the model's output being evaluated according to the level of confidence associated with its predictions.

Although a reliable whole-ecosystems impact model may eventually be achievable, a review of related efforts (Reed et al., 1978), and an evaluation of currently available biological baseline data strongly suggested that pursuit of such a model in the time frame and funding level of this project task would be at the expense of output quality. The single species fishery model, a relatively well established art form supported by a healthy literature dating generally from the work of Verhulst in the nineteenth century and more specifically from Barenov's (1918) application of first order kinetics to a fish population, was selected as the simplest viable subset of the ecosystem approach. It was felt that sufficient uncertainties were evident in the problem without the addition of further conjectures and postulates regarding rates and processes of species interactions. The application of Okham's razor (see Hutchinson, 1978) in this case requires the identification of a position between employing too many parameters to justify from the adequacy of the data base, and too few to do justice to the system. Thus in adopting the principle of parsimony of parameters, permitting a tractable entry into the complexities of the problem, the advice of Lagrange is observed: seek simplicity, but distrust it. The potential magnification in complexity thus avoided is demonstrated in a paper by Andersen et al. (1977) describing a multispecies fishery model in which the simulation of 12 interacting species required the input of some 1600 separate parameters.

The selection of a physical area for the initial model application was relatively straightforward, since Georges Bank (Fig. 6.1), which has supported a thriving fishery for over a century, has recently become the focus of offshore continental shelf hydrocarbon exploration interests. The oil spill fishery interaction problem in this area is therefore potentially very real. Selection of the cod stock on the Bank followed from the data considerations discussed above, as well as the abundance of biological and modeling literature on the species. The previous reference further details this information.

6.2 MODEL OVERVIEW

Because the model has been described in detail elsewhere (Reed et al., 1978 , 1979a, 1979b) only a brief overview will be given here. The system is composed of three major interacting components: a fishery sector, an ocean transport sector, and an oil spill fates sector, as described below.

6.2.1 Fishery Model

As shown in Fig. 6.2, the population model cycles on a daily timestep when operating in conjunction with other system components. When operating alone, this timestep can be increased up to five days with little decrease in numerical accuracy, reducing computer time proportionately. The adult fishery model is constructed along well established lines (e.g. Beverton and Holt, 1957; Walters, 1969), whereas the egg and larval stages have been modeled using techniques drawn from other areas of mathematical ecology (Lotka, 1925 ; Pielou, 1969). The structure of the fishery model is shown schematically in Fig. 6.3.

The model has 17 adult age classes, enough to include all fish sampled in recent surveys (Heyerdahl et al, 1976). They increase in length and weight according to a published growth equation (Pentilla et al, 1976) for the Georges Bank stock. The i^{th} adult age-class is

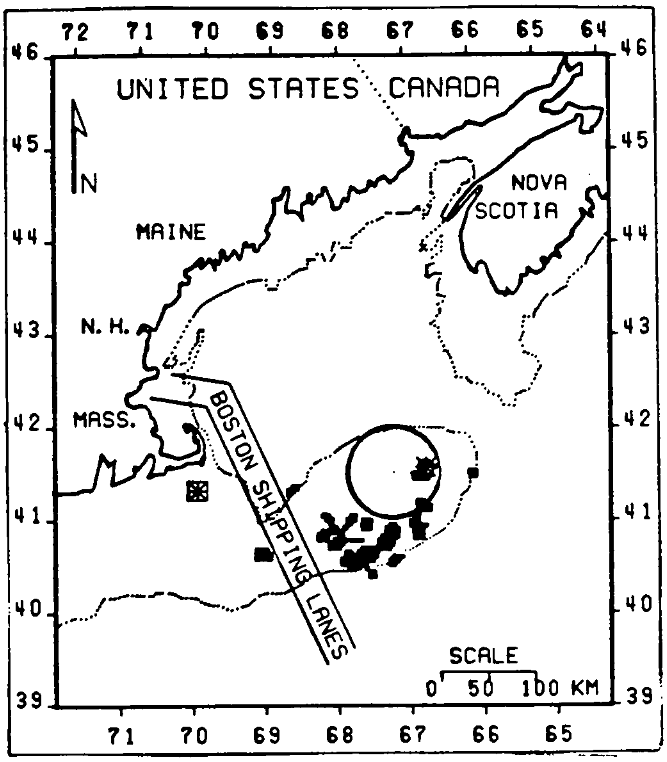


Figure 6.1 Map of Georges Bank, showing the 100 meter bathymetric contour, the spawning area (circle), oil exploration tracts (dark regions), commercial shipping lanes, wind data source (■), and the location of the simulated oil spill (⊠).

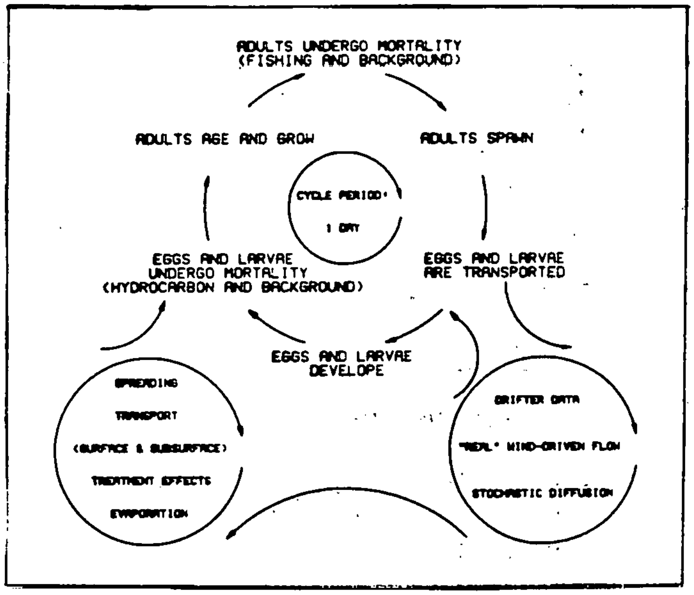


Figure 6.2 Model System Cycles, showing processes simulated in each sector. Arrows indicate information flow.

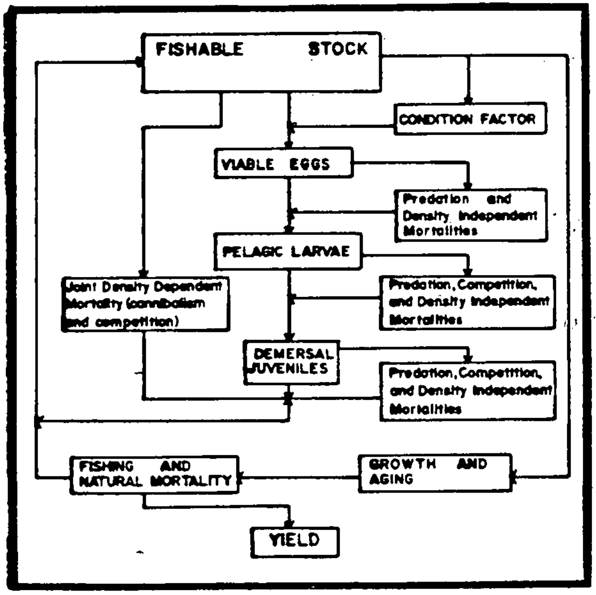


Figure 6.3 Process schematic for the fishery population model.

subject to a mortality equation following first order kinetics,

$$dN_i/dt = -(M_i + F_i)N_i, \tag{1}$$

in which M_i and F_i are natural and fishing mortality coefficients respectively, the former including all types not induced by the latter. Fishing mortality is assumed linearly proportional to standardized fishing efforts:

$$F_i = q\ S_i\ E(t) \tag{2}$$

Q is a species and stock dependent catchability coefficient (Gulland, 1977), S_i is net mesh selectivity for the i^{th} age-class, and E(t) is a measure of the fishing effort exerted on the stock during the time interval t.

The fecundity of cod appears well correlated with weight, although, as with all such characteristics, the relationship varies from one stock to another (Daan, 1973); Garrod, 1977; Bigelow et al., 1953; Nikolskii, 1965; Gulland, 1964). This literature suggests a value of 200 to 250 eggs per gram female, which conforms reasonably well to an estimate by Bigelow, et. al. of one million eggs per average female, although falling somewhat short of their estimated maximum of nine million.

Temporal distribution of spawning cod on Georges Bank remains something of an enigma, it being uncertain whether cod spawning activity is triggered by day length, temperature, or other environmental factors (F. Serchuck, National Marine Fisheries Service, Woods Hole, personal communication; Wise, 1961). Bigelow et al. (1953), Colton et al. (1977, 1978), and Walford (1938), support the observation that spawning occurs with varying degrees of intensity from November to late April, with a maximum occurring in March and a second smaller peak in the late Fall.

The model takes on spatial dimensions through the simulation of this activity. On any given day of the year, a percentage of the females of each sexually mature age class are assumed to release their eggs. (The fact that not all will be properly fertilized is accounted for in the density independent mortality parameter M_1 in Equation 3. Possible relations between age and time of spawning are not included). The total number of eggs available for spawning on that day is divided into a set number of groups, or sub-cohorts. Thus each particle in the transport model represents one sub-cohort of organisms in the population model. As simulated time progresses, each particle is transported, and represents a diminishing number of developing eggs, larvae, or post-larvae. When a sub-cohort reaches the demersal stage, it looses its explicit representation in space, while of course retaining its presence in the population model.

The major uncertainties in the biological sector of the model exist in the egg and larval mortality representations. These are formulated to require as few arbitrary parameters as possible, while simulating these stages in sufficient theoretical detail to resolve toxic effects which vary in magnitude from one developmental stage to the next. There are five first year stages represented in the model. These are an egg stage

(E), three planktonic larval and postlarval stages (L), and a demersal juvenile stage (J). The equations governing mortality during these various developmental periods are:

$$dE/dt = (M_1 + M_2*E)*E, \tag{3}$$

$$dL/dt = (M_3 + M_4*L)*L, \text{ and} \tag{4}$$

$$dJ/dt = (M_5 + M_6*J + M_7* \sum_{i=1}^{17} N_i*P_i)*J. \tag{5}$$

Equations (3) and (4) each include a density dependent and a density independent mortality term, whereas Equation (5) incorporates a set of adult-juvenile interaction terms as well. The theory upon which these equations are based derives from Lotka (1925), who employed the concept of a Taylor expansion about some hypothetical equilibrium value. Density dependent mortality of an intragroup nature, as associated with parameters M_1, M_4, and M_6, is intended to represent competition among individuals of the group for limited resources (e.g. food), or mortality due to predation by some species external to the explicit model formulations (e.g. herring). Density dependence between groups may result from competition for shared resources, or a parasitic (e.g. cannibalistic) relation. There is considerable evidence of cannibalism among Gadoids (see for example Daan, 1973, or Bigelow et al., 1953), and is a theoretically acceptable explanation for population control in Gadoids (Cushing et al., 1977). The third term in Equation (5) is designed to simulate this fact, the P_i being age-specific predation rates. Recent evidence reported by Ellertsen et al. (1979a) indicates that cannibalism amongst larval and postlarval Gadoids may contribute significantly to mortality, perhaps outweighing effects of food density. This process is not yet explicitly incorporated here. (Further discussion of these equations, their derivations, and an algorithm for the numerical solution of Equation (5) may be found in Reed and Spaulding, 1978.)

Sensitivity to the toxic action of hydrocarbons appears to result from a complex interaction among several variables (Malins, 1977):

(1) chemical composition of the oil,
(2) duration of exposure,
(3) concentration of soluble aromatics in the water,
(4) stage of development of the organism,
(5) physical condition of the organism, and
(6) species.

Along the same lines as suggested by Andersen et al. (1977), efforts have been made to utilize published bioassay data (Kunhold, 1970, 1977; Wilson, 1977) to partition density independent mortality parameters of cod during planktonic stages (Reed and Spaulding, 1978). Although the model is designed to keep account of the variables relevent to toxicity, difficulties of interpretation as well as uncertainty levels elsewhere in the system (e.g. oil entrainment rates, details of ocean transport estimates) have prompted the adoption of a threshold assumption: any eggs or larvae entering an area in which the concentration exceeds their respective threshold values are deleted from the system. In light of the fact that the presence of hydrocarbons in the water will adversely affect the food supply (Wolfe, 1977, Workshop...., (1975) as well as the larvae themselves, this appears reasonable, erring perhaps marginally on the environmentally conservative side.

Development during the first year is modeled in five stages: eggs, yolk-sac larvae, larvae adapting to free-feeding, adapted free-feeders, and bottom-dwelling juveniles. These stages were selected as those between which definite differences in susceptibility to hydrocarbon toxicity have been observed by Kunhold and Wilson. Egg hatching rates are well represented by a negative exponential curve, probably reflecting temperature dependent chemical interaction rates in egg development. Yolk-sac resorption requires from 4 to 12 days (Wise, 1961; Bigelow et al., 1953). Work being performed by Ellertsen et al. (1979b) suggests that food density may be significant in determining the duration of this stage, but for lack of any deterministic relation, eight days is used here. The larvae must then adapt to catching planktonic organisms, primarily copepod nauplii. Kunhold found the larvae most susceptible to hydrocarbon toxicity during this stage. According to Cushing et al. (1977), the Norwegian investigator H. Dannevig grew cod larvae from hatching to metamorphosis in 70 days, and it is believed that they seek bottom about a month later. These development rates are certainly variable with such things as temperature and food availability, but except for hatching rates, constant values have been used in the model due to lack of hard data.

Pre-recruit mortality parameters are notoriously difficult to evaluate, since what few values exist are usually derived from laboratory observations and do not reflect conditions in the open ocean. It is nonetheless desirable to use whatever our best estimates may be, to reduce the need for blind 'model tuning' in the final stages. Thus a value equivalent to 60% mortality has been used for the density independent rate for eggs (Laurence et al., 1976), and it is hypothesized that demersal juveniles die of natural causes (e.g. disease or starvation) at about twice the rate of the adults. The four remaining density dependent parameters were assigned values resulting from a series of steepest descent searches (Walters, 1969) using the sum of the squared differences between the modeled and the observed annual yields from 1932 to 1952. Several approximately equivalent local minima were found. Of these, most were rejected for biological reasons, such as the improbability of having 90% survival to the demersal stage. Of the remaining sets of mortality parameters which appeared acceptable from the modeling point of view, three were selected for further investigations. As shown in Fig. 6.4, these bracket the likely range of first year mortality curves.

Figure 6.5 shows a comparison of model behavior when operating under the first year mortality curves of Fig. 6.4. In each case, the model is initiated with an equilibrium population, and a perturbation is introduced by assuming the complete failure of the subsequent yearclass. It can be seen that the modeled stock fluctuations increase both in magnitude and duration as density dependent mortality emphasis shifts from intra-egg and intra-larval stages (Mode 1) to the adult-juvenile formulations (Mode 3). This behavior corresponds conceptually to a decreasing negative slope on the stock-recruit curve at the replacement point, as discussed by Allen et al. (1974). The biological explanation

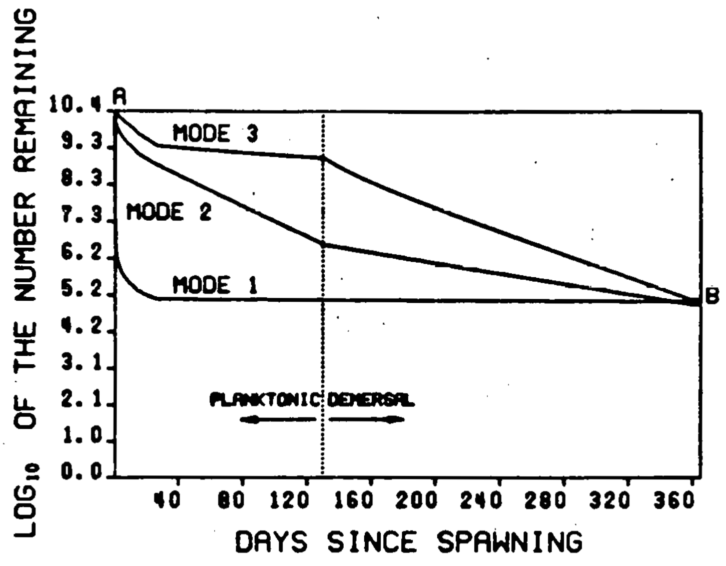


Figure 6.4 Three piecewise-continuous mortality curves for the first year of life. The curves result from three different sets of parameters in Equations 3, 4, and 5.

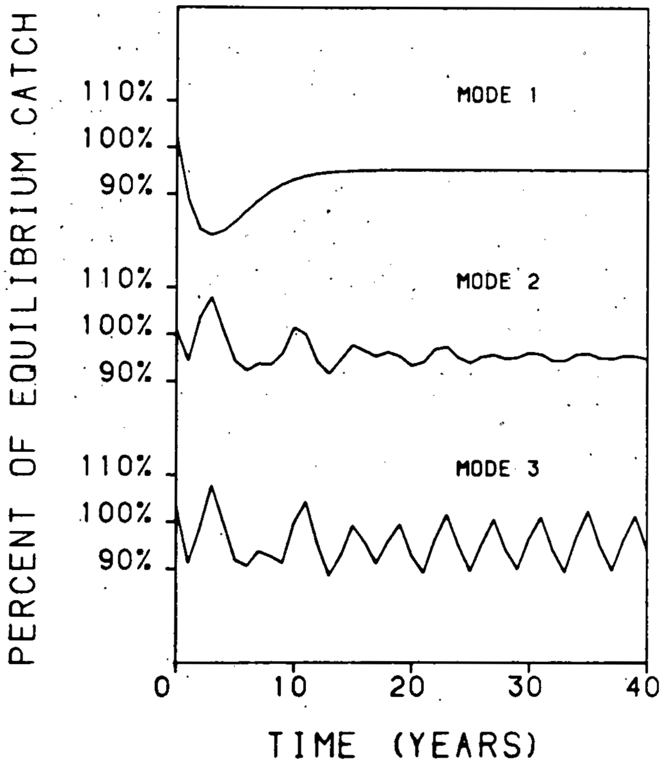


Figure 6.5 Comparison of modeled response to an arbitrary perturbation under the three nodes of Figure 4.

lies in the fact that increasing the relative importance of the adult juvenile interaction such that cannibalism (or resource competition) is the dominant controlling factor for population size causes the direct transferrence of oscillations in the parent stock to oscillations of the opposite sign in the associated O-Group. If the relationship becomes strong enough, the model becomes unstable.

Although the average error of the predicted yield is on the order of 20% of the average catch (Fig. 6.6), the model demonstrates a reasonable ability to follow the trends in the record (r=0.81). The model does not predict catch size with great accuracy, but the impact estimates required here will be the differences between predicted catches with and without a spill. While the actual predictions may be off by 20% or more, to the extent that the model follows the yield trends, these differences may only be in error by a few percent. The relative impact estimates themselves may be more accurate than the absolute yield estimates from which they derive.

6.2.2 The Ocean Transport Model

The marine transport model consists of three superimposed flow processes, each representing transport energy spanning a different portion of the energy spectrum. Although such separation neglects nonlinearities in the real system, this approach is adopted in lieu of a two or three dimensional numerical modeling effort involving the solution of the Navier-Stokes equations on a phase-space grid of sufficiently fine mesh to resolve the processes of interest. The available data base for verifications of larval fish distributions hardly warrants the time and effort necessary to produce such a model. The methods described here are on a level of approximation consistent with others in the physical sector of the model (e.g. spawning rates and locations), and appear to yield useful and credible transport estimates, as discussed below.

The low frequency seasonal circulation patterns have been deduced from oceanic drifter data gathered over approximately a decade (Bumpus et al., 1965). The resulting flow fields supply estimates of net transports on temporal scales of weeks and months, arising as the residual of tidal, meteorological, and river inflow events, as well as pressure forcing on the ocean boundaries of the modeled area. A triangular grid was constructed covering the area of interest (Fig. 6.7), and velocity components were assigned at each node. Linear interpolation is performed between seasonally adjacent data sets to supply smoothed daily input to the model. Advective velocities at a given point within a grid element are assigned by fitting a plane through the component values at each of the three surrounding nodes, thus spatially interpolating values at any internal point.

Intermediate frequencies of transport energy are input through wind forcing on time scales of a few hours to several days. Decoupling of this input from the long-term effects, it probably imparts to the real systems (Csanady, 1976) is achieved by first passing a digitized record of wind data for the time period of interest through a high pass filter with a corner frequency of one cycle every ten days. In this way, only energy associated with trends occurring over time periods less than ten days is retained in the record. This filtered wind record is then used as input to a simple two-dimensional model of the wind-driven surface

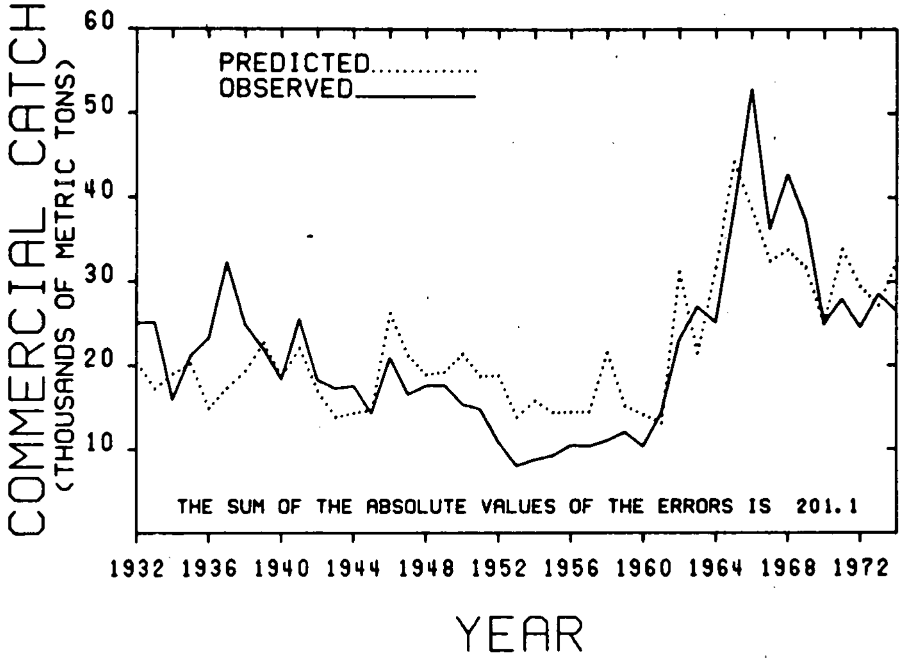


Figure 6.6 Modeled versus observed catch for Georges Bank cod.

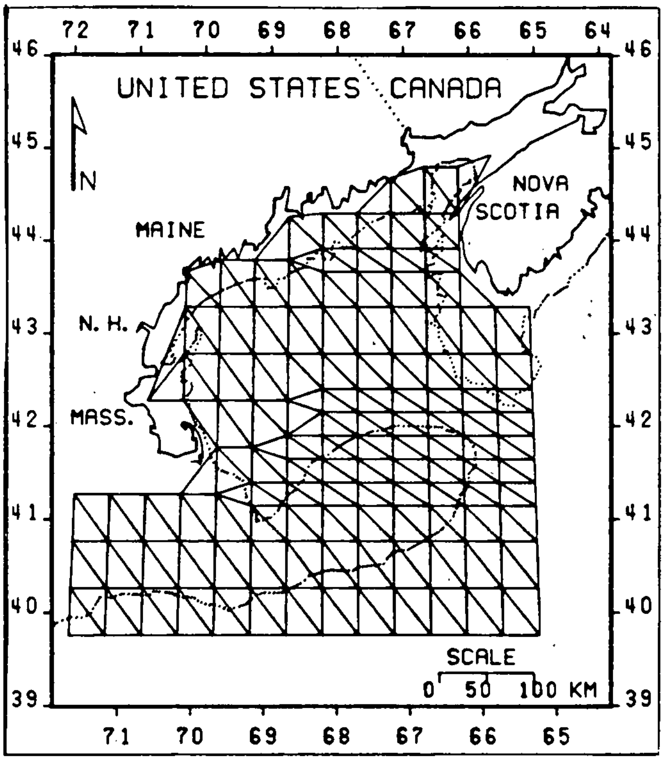


Figure 6.7 Triangular grid system for the ocean transport model.

layer. Because it does not appear elsewhere, the description of this sector of the model will be relatively detailed.

The complete Navier-Stokes equations describing the motion of an incompressible fluid continum may be averaged over H, the depth of the wind-driven layer. Because the area being modeled (Georges Bank) is far from any land boundaries, and because this wind driven depth will in general be small relative to the total depth, so that for coherent forcing periods below a few days only small return flows in the lower depths will be required to eliminate surface setup, the pressure gradient terms can be neglected. If the depth H is assumed constant for the duration of at least one sampling interval in the wind record (here three hours), then the convective acceleration terms can also be dropped from the equations. The usual quadratic forms of the wind stress terms can be replaced by linear approximations to preserve the validity of superposition. Data analyzed and reported by Kirwan et al. (1979) suggests that a linear law relating wind to wind drift current may be as good as the quadratic formulation for long terms (>5 days) estimates. Thus the wind stress at the surface in the x direction (positive to the east) is

$$\tau_x = \rho_a R_S U \tag{6}$$

and in the y direction (positive north) is

$$\tau_y = \rho_a R_S V \tag{7}$$

in which ρ_a is the air density, U and V are the wind velocities in the x and y (east and north) directions respectively, and R_S is an empirically derived constant. If a hypothetical stress at the bottom of the wind driven layer is similarly linearized, the equations of motion become

$$\frac{du}{dt} = fv + \frac{\rho_a R_S U}{\rho_w H} - \frac{R_H u}{H} \tag{8}$$

$$\frac{dv}{dt} = -fu + \frac{\rho_a R_S V}{\rho_w H} - \frac{R_H v}{H} \tag{9}$$

In Equations 8 and 9, U and V are the eastward and northward ocean current velocities averaged over the wind driven depth H, f is the Coriolis parameter, R_H is the linear stress coefficient at the depth H, and ρ_w is the density of sea water. Assuming the depth H to be constant over one sampling interval in the wind time record, this set of coupled ordinary differential equations has the simple solution.

$$u(t) = e^{-\left(\frac{R_H}{H}\right)t} \left[(u_o - u_\infty)\cos(ft) + (v_o - v_\infty)\sin(ft)\right] \tag{10}$$

$$v(t) = e^{-\left(\frac{R_H}{H}\right)t} \left[(v_o - v_\infty)\cos(ft) + (u_o - u_\infty)\sin(ft)\right] \tag{11}$$

wherein u and v are the orthogonal currents at the beginning of the time interval, and the asymptotic velocities for large times t are given by

$$u_\infty = \frac{\rho_a R_S}{\rho_w}\left[\frac{R_H U + HfV}{R_H^2 + H^2 f^2}\right] \tag{12}$$

$$v_\infty = \frac{\rho_a R_S}{\rho_w}\left[\frac{R_H V - HfU}{R_H^2 + H^2 f^2}\right] \tag{13}$$

Equations 10 and 11 describe circular motion with damping and an offset. The angle of the net transport to the right of the wind can be most easily calculated by aligning the axes such that U=0, giving

$$\Theta = \pi/2 - \arctan\left[R_H/Hf\right] \tag{14}$$

from which it can be seen that the transport will be 90 degrees to the right of the wind for zero bottom stress or infinite depth, in agreement with Ekman's classical analysis.

In reality, the mixed layer depth will be a function of wind speed and duration, sea state, and density stratification (Phillips, 1977; Liebovich, 1977; Kullenberg, 1976; Niiler, 1977). As pointed out by Gonella (1971) and Csanady (1972), the correct formulation for H as a function of time in very deep water would eliminate the necessity of the "interlayer stress" artifice (second term on the RHS of Equations 8 and 9). The resistance to surface stress in deep waters arises from a downward flux of momentum and internal dissipation, so the correct lower boundary condition is zero stress at the (variable) depth H. Because of the lack of agreement on vertical eddy viscosity formulations for the solution of this problem (see for example Huang, 1979), an arbitrary depth of 10 meters for a 3 hour response time has been selected as suggested by the literature overview summarized in Table 6.1. This depth includes the majority of cod eggs and larvae in the area, and unless oil actually sinks, it appears doubtful that any significant amount will penetrate deeper than this (McAuliffe, 1977).

Observer	Drift Layer Depth (meters)	Depth Averaged Current (as Percent of Wind Speed @ 10 m.)	Approx. Establish. Time (hrs)	Drift Angle (to the rt. of $\vec{W}$)	Comments
Nansen (1902)	-	~ 1%	-	20-40^0	observations of icebergs
Ekman (1905)	~ 50	$1.3\%/\sin^{1/2}\phi$	~10-20	90^0	theory
Smith (1931)	~ 20	< 1%	-	40^0	deep immersing iceberg
	~ 5	~ 1%	-	20^0	small iceberg
Csanady (1972)	9-18	2%	1-3	-10-60^0	Lake Huron observations
Csanady (1974)	10-20	-	3-8	-	theory
Murray (1974)	10	2%	3	10-90^0	near shore, shallow
Mellor et al (1975)	25	-	16	-	model compared w/ data
Niiler et al (1977)	10	-	1-2	-	theory and observation
Csanady (1976)	16	-	-	-	theory and observation
Gonella (1971)	10-15	1%	2-3	-	theory and observation
Madsen (1977)	25	1%	~ 3	10^0	modeled
Kondo et al (1979)	20	~ 1%	16	17^0	observed and modeled
Kirwan et al (1979)	surface	-	-	15^0	theory and observation

Table 6.1: Summary of Literature Estimates of Wind-Driven Flow Parameters

The most widely accepted formulation for the wind stress, supported by a large number of laboratory and field investigations, is a proportionality with the square of the wind speed multiplied by the density of the air. This is consistent with dimensional considerations, and corresponds to drag formulations for fluid flow around a solid body. One possible method of assigning a value to the parameter R_S would be to equate the energy input from atmosphere to ocean in the linear model with that prevailing under the quadratic stress formulation. This was not done because it would have amounted to forcing energy from lower frequencies into the domain of the filter applied to the wind record.

The problem has instead been approached in a simple statistical manner. An estimate of R_S in terms of the "correct" quadratic formulation,

$$\vec{\tau}_q = \rho_a C_d \left|\vec{W}\right| \vec{W} \tag{15}$$

results from a comparison with the linear expression

$$\vec{\tau}_\ell = \rho_a R_S \vec{W} \tag{16}$$

Equations 15 and 16 suggest that R_S, with dimensions of velocity, may be taken as a measure of the mean background wind velocity magnitude, and should, therefore, be derived explicitly for each specific wind record employed. The filtered wind record used here spans from September 1972 to September 1973, and has maximum and minimum magnitudes of 16.4 and 0.114 meters/sec. with a mean of 5.1 meters/sec. Using $c_D = 0.002$ (see for example Wilson, 1960, or Wu, 1969), this gives a value of $R = 0.01$ meters/sec.

Winant et al. (1979) statistically compared quadratic and linear formulations for the bottom stress in water depths of 30 to 40 meters, and were unable to determine which parameterization was more accurate, lending further support for the linearization imposed here. Their parameter estimates for R_H, varying from 0.04 to 0.2, are derived on the assumption that surface and bottom stress components are equal (i.e. at steady state conditions) and appear high. A second estimate of R_H can be determined by estimating the asymptotic magnitude of the depth averaged current as a function of wind speed from the literature (Table 6.1), and solving Equations 12 and 13 for R_H. Using $R_S = 0.01$ meters/sec., a density ratio of 0.00125, a depth of 10 meters, $f = 0.000097$ radians/sec, and solving the relation

$$(u_\infty^2 + v_\infty^2)^{\frac{1}{2}} = 0.01(U^2 + V^2)^{\frac{1}{2}} \tag{17}$$

by substituting for u_∞ and v_∞ from Equations 12 and 13 gives $R_H = 0.001$. These values imply an asymptotic drift transport angle of 44 degrees to the right of the wind, attained within ± 2% after 7 hours.

The behavior of the model for other values of the parameters is shown in Figs. 6.8-10. Empirical validation of such a model is necessarily subjective, not only because vertically uniform slab flow is an extreme simplification of actual wind-driven ocean current profiles, but also

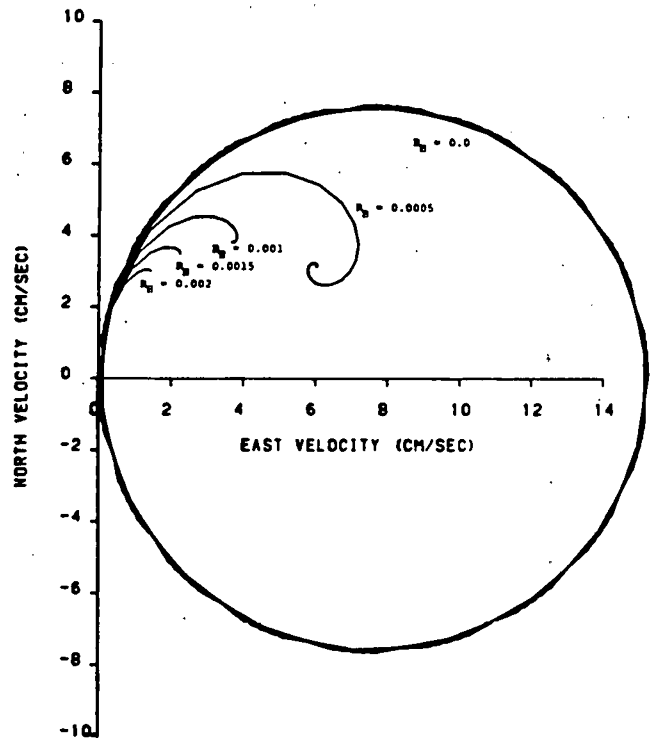


Figure 6.8 Response of the wind drift equations (Equations 10 and 11) for several values of the linearized interlayer stress R_H.

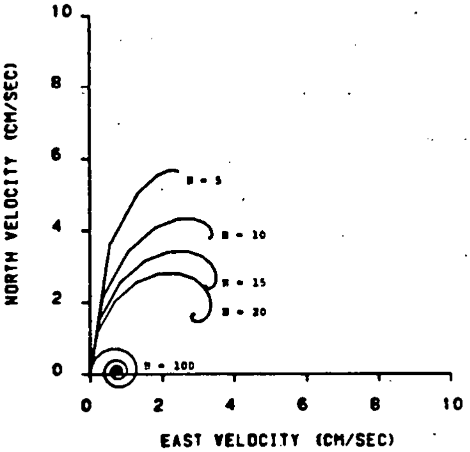


Figure 6.9 Response of Equations 10 and 11 for various drift layer depths (meters).

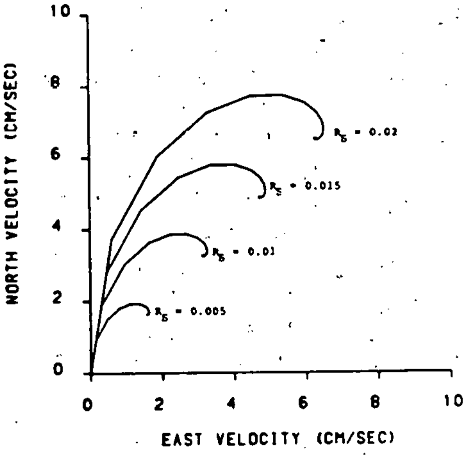


Figure 6.10 Response of Equations 10 and 11 for several values of the linearized surface stress coefficient R_S (in/sec).

because documented observations of atmosphere-ocean momentum interactions are themselves so variable. The studies summarized in Table 6.1 suggest that, for an establishment time of 3 hours, plausible attributes of the wind drift current are a depth of 10 meters, a vertically averaged speed of $^{o}1\%$ that of the wind, and a drift angle of 20 to 60 degrees. If the observations by Smith (1931) of drifting icebergs can be taken as reflecting vertically averaged drift angles and speeds, then 30 degrees might be a reasonable intermediate value. For the parameter values used here (r_S = 0.01 m/sec; R_H = 0.001 m/sec; H = 10 meters) the linear model predicts a drift angle about 30 degrees to the right of the wind after 3 hours, and a speed $^{o}1\%$ that of the wind.

The third transport process in the model is dispersion, assumed to result from energy input at frequencies greater than and equal to that of the tides, as well as energy cascaded into this frequency range through dissipation processes in the real system. Dispersion is modeled as a random walk process occurring with a mean velocity magnitude

$$V = \sqrt{6D/dt}, \tag{18}$$

(see Appendix A), in which dt is the simulation timestep, and D is the diffusivity, taken from an oceanic diffusion diagram (Okubo, 1974).

In summary, the transport of ichthioplankton and entrained oil is simulated through the juxtaposition of a random walk diffusion process, a wind-driven velocity component responding to an actual time series preprocessed through a high pass filter, and a drifter-inferred seasonally varying aspect.

Validation of the fishery cum ocean transport model has been described in the references already cited, but is discussed briefly here to clarify the significance of results, and to emphasize the importance of longterm methodical data acquisition programs to the success of ecological impact modeling endeavors. The basis for the validation methodology proposed here is a space-time history of larval fish concentration data. Unfortunately, such data is extremely expensive to acquire, and National Marine Fisheries Service data for larval cod on Georges Bank exists only for December and February, so that spring verification is not possible. (A data set for March, 1976 may soon become available.) The length of the record (four years) is insufficient to warrant actual statistical comparison of model results with the data. Qualitative comparisons (Figs. 6.11-14) suggest that the model performs reasonably well. If the data record were longer, an average distribution with variance could be derived, and a confidence interval could be placed on the model predictions. In addition, one could begin to consider the environmental factors relating to specific distributions, thus revealing which of these factors when included in the model would most improve performance.

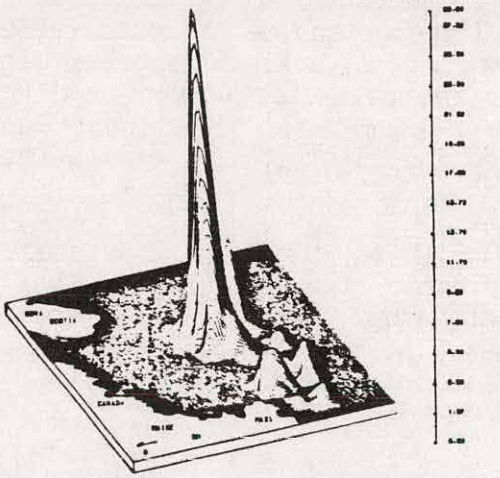


Figure 6.11 Observed Larval cod distribution for December, 1974. The larvae southeast of Massachusetts are associated with the Southern New England Cod Stock (Wise, 1963) not modeled here.

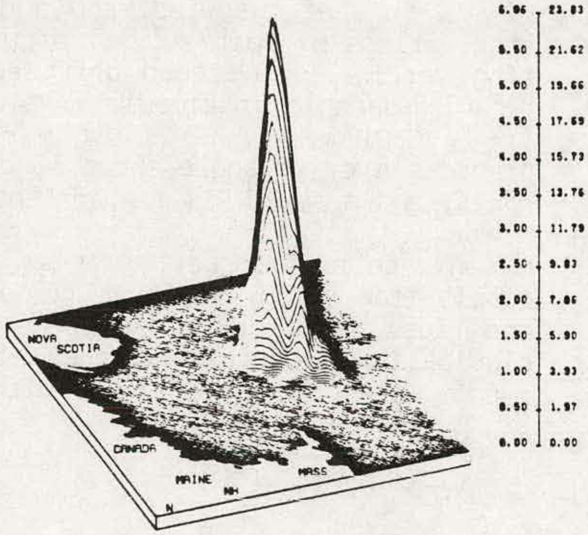


Figure 6.12 Modeled larval cod distribution for December 15.

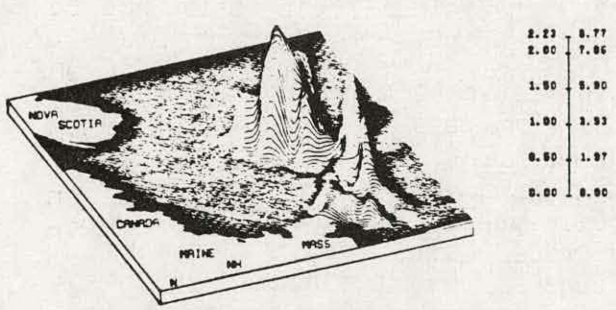


Figure 6.13 Observed larval cod distribution for February, 1975. (See caption, Fig. 11).

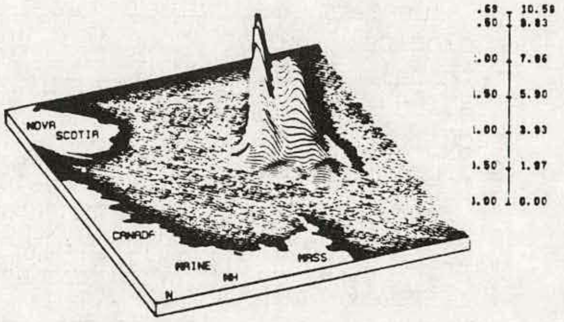


Figure 6.14 Modeled larval cod distribution for February 15.

6.2.3 THE OIL SPILL FATES MODEL

This sector of the impact model is described elsewhere in this report, and will, therefore, not be discussed in detail here. The interconnection between the oil spill and fishery models is accomplished through storage of the oil spill output data sets on disc or tape, for access as needed by the toxic impacts section.

6.3 RESULTS OF SIMULATIONS

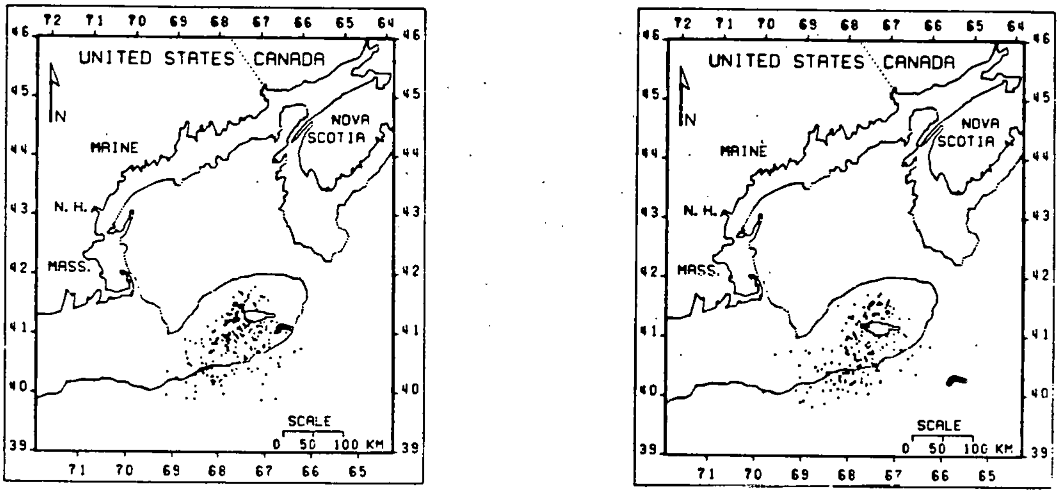
Model sensitivity to three types of parameters has been investigated. Because field data limitations and model complexity preclude the derivation of confidence intervals on the predictions, it is felt that the best indicator of reliability will be a demonstration of the relative importance of key assumptions in the system. The usual gradient approach to sensitivity (e.g. Brylinsky, 1972) is useful when the values of parameters are known with confidence intervals of, say, ± 15%. Then local rates of change due to small variations are significant. If actual parameter values may range over more than one order of magnitude, however, a set of widely spaced point values on the response surface is more revealing. This latter approach is used here.

A two-day, 34,840 metric ton oil spill, occurring on December 15, has been simulated for this sensitivity analysis. Figs. 6.15-18 show four snapshots of the interaction among the eggs and larvae, the surface slick, and the subsurface distribution of hydrocarbons within the 50 ppb contour. Further details are presented in the oil spill modeling report section. Impact predictions have been compared under three theoretically acceptable piecewise-smooth larval mortality curves (Fig. 6.4), three threshold toxicity values of 50,100, and 1000 parts per billion (ppb) and three dispersant application scenarios in which 0%, 50%, and 100% of the oil is chemically treated. The results of these model runs are shown in Tables 6.2, 6.3, and 6.4.

Decreasing impact is associated with increasing larval resistance to oil toxicity (increasing threshold values), with decreasing entrainment, and with increasing mortality mode. This latter fact results from an increase in the amount of compensatory mortality in modes 2 and 3 (Fig. 6.4) in the post-planktonic stages, relative to mode 1. Thus for a given treatment scenario and toxicity threshold, although the same number of eggs and larvae are lost from the system due to the spill, the effect on recruitment, and ultimately yield, is considerably different, as reflected in the relative losses associated with each mode.

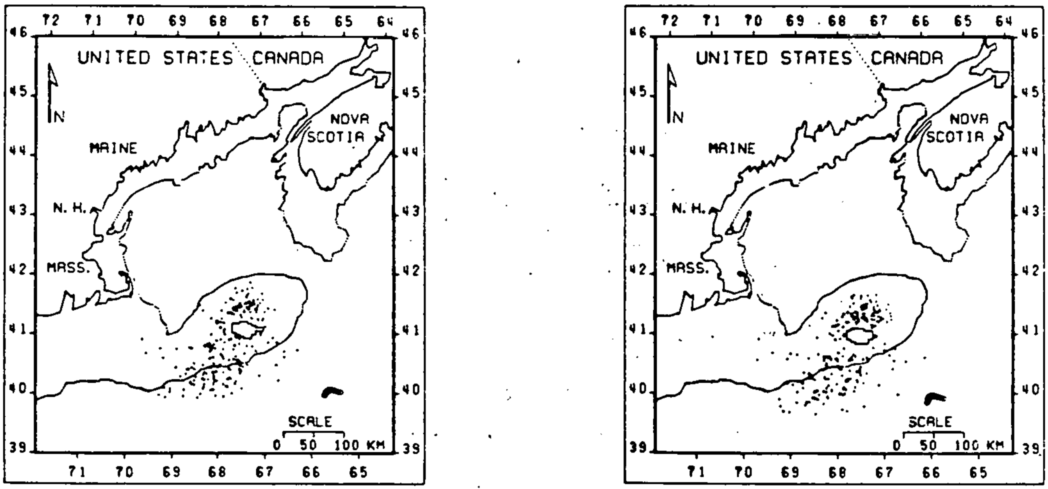
Not surprisingly, none of the scenarios modeled here supports the application of dispersants as a means of mitigating impact on the fishery. Microbial degradation, which is rate dependent on both temperature and interfacial area (Traxler et al., 1977), a process not included in the oil spill fates model at this time, could alter this outcome somewhat, although to what extent is uncertain (Gibson, 1977).

One of the more significant findings here is that the natural mortality regime for the population is more important than either threshold toxicity values or the percent of oil being dispersed into the water column. The importance of determining appropriate mortality regimes and



10 DAYS AFTER THE OILSPILL
(JULIAN DAY 360)

20 DAYS AFTER THE OILSPILL
(JULIAN DAY 5)



25 DAYS AFTER THE OILSPILL
(JULIAN DAY 10)

30 DAYS AFTER THE OILSPILL
(JULIAN DAY 15)

Figure 6.15-18 Four "snapshots" of the oil spill, eggs, and larvae during the simulation. The crescent-shaped group of circles is the surface slick, and the rectangular region is the subsurface 50 ppb contour.

Percent Chemical Treatment

Threshold Toxicity	0%	50%	100%
50 ppb	1.4	1.8	2.4
100 ppb	1.1	1.4	1.5
1000 ppb	0.3	1.0	1.2

Mortality Mode 1

Percent Chemical Treatment

Threshold Toxicity	0%	50%	100%
50 ppb	0.4	0.6	0.8
100 ppb	0.3	0.5	0.7
1000 ppb	0.0	0.1	0.2

Mortality Mode 2

Percent Chemical Treatment

Threshold Toxicity	0%	50%	100%
50 ppb	0.1	0.3	0.4
100 ppb	0.1	0.2	0.4
1000 ppb	0.0	0.0	0.1

Mortality Mode 3

Tables 6.2, 6.3, and 6.4: Effects of Variations Among 3 Sets of Parameters on Modeled Results. Mortality Modes refer to Curves of Figure 4. Tables entries are in thousands of metric tons lost to the Fishery. ($1 million 1 thousand MT) toxicity threshold values is manifest from these results. Suppose for example that an oil spill on Georges Bank were to be driven towards the islands of Nantucket and Martha's Vineyard, rather than out to sea. If mode 2 or 3 proved a good approximation to the governing mortality rates for the population, and a threshold value of 1000 ppb appeared credible for the oil at hand, treatment with dispersants before the oil reached shore would greatly decrease the aesthetic impact at little cost to the fishery. (As a "best guess" however, the most likely description of cod egg, larval, and post larval mortality on Georges Bank is a curve somewhere between modes 1 and 2, with a threshold toxicity of about 100 ppb.)

Certain limitations of the model must be stated in accompaniment to this conclusion. The most important is that only one element of the ecological complex in question is being modeled, a basic assumption being that overall biological patterns will not be disrupted by the spill. If treatment with dispersants or possible sinking of the oil resulted in contamination of the sediment on the spawning ground, this assumption would certainly be violated. The basic philosophy of causality in evolution implies that fish spawn in space and time in such a way as to optimize the probability of survival of the offspring in the long term, so that forced shifts in these patterns would presumably prove detrimental to the stock. Modeling such phenomena would require hypothesizing stock responses to extended spawning interruptions, which would fall little short of blind conjecture. Similarly, any major impact on another element of the food web could result in significant feeding shifts throughout the ecological system. An impact model of this type is, therefore, limited in its usefulness to situations involving only small population perturbations.

The magnitudes of the impacts estimated here range between 0% and 10% of the annual maximum sustainable yeild of approximately 25,000 metric tons, or up to $2.5 million in reduced income to the fishing fleet. Simulation of a 30 day oil well blowout (Reed et al., 1979b) shows impacts four times as large, so that the specific scenario is of considerable importance. Furthermore, it must be remembered that the vast majority of the commercially important species in the area, including cod, haddock, pollock, hake, herring, flounder, mackerel, lobster, crab, and scallop have pelagic eggs and/or larvae. Depending on the specific biological patterns associated with each of these species, the total cost of a spill in terms of reduction in catch could greatly exceed these values.

In summary, the simulations described here suggest that the most significant set of unknown parameters in the model system is that relating to mortality rates and processes during the first year of life. The amount of dispersant applied to the spill and the toxicity of the oil appear to be of secondary importance in deep offshore waters. (It is somewhat ironic that the most important and desirable information needed for further model improvement is also the most difficult and expensive to obtain.) As is often the case with complex simulations, the strength of the underlying data base limits the real usefulness of the output. In the case at hand, further advances in marine fisheries impact assessment of this type require a concerted ichthyoplankton data acquisition program, systematic in both space and time. Although expensive, it appears that basic progress in this field will be largely dependent on the planning and implementation of such programs.

7.0 Chemical Analysis of Oil Spills

Chris W. Brown

Mark Ahmadjian

Patricia Lynch

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7.1 Introduction

The overall objective of the project is to assess the environmental impact of a chemically treated vs. an untreated oil spill. The primary objective of the chemistry group has been to determine the amounts and compositions of petroleum chemicals in the atmosphere, surface waters, water column and sediments, resulting from a treated and untreated spill. To meet this objective, it was necessary for the group to develop sample collecting, extraction, and chemical analysis methods. In addition, extensive development and testing of computer software was undertaken to collect and massage the analytical data. Laboratory experiments were designed and executed to aid in the development of these analytical techniques. Results from the laboratory studies determined the techniques which would be applied to the analysis of the meso scale experiments and eventually to any "real world" spills of opportunity.

7.2 Analytical Procedures:

7.2.1 Choice of Oil/Dispersant System

(A) Oil: The choice of oil for the study was based on several factors:

a) availability of sufficient quantities for testing,
b) availability of the compositional data on the oil,
c) presence of sufficient percentages of the spectrum of representative components, e.g., aromatics, paraffinics, cycloparaffins,
d) ability to handle oil easily at ambient temperatures.

Based on these prerequisites, it was decided that one of the two API reference crudes, South Louisiana or Kuwait, be used for the experiments. Initially, these two oils were used in laboratory tests and eventually Kuwait Crude was used for the bulk of the laboratory work and for the meso-scale experiments. In addition, as a result of two "real world" spills, bunker C oil from the Argo Merchant and a No. 2 fuel from the Buzzards Bay Spill were used in some of these studies.

(B) Dispersant:

The program objectives of the chemistry study did not include a performance testing of chemical dispersants. It was decided that a study using one well chosen dispersant and extensively testing its use with a limited number of oils would prove to be more informative and complete, vis-a-vis, the project objective, than would using multiple dispersants with these oils.

The choice of dispersants was based on several factors:

a) product should be one of the major products on the market,
b) dispersant should have low toxicity,
c) dispersant should have application on wide spectrum of oil types,
d) dispersant should be easily applied and require minimal mixing energy.

Based on the above criteria, six products were considered (Table 7.2.1). Of these, Corexit 9527, a self-mixing dispersant, was chosen for the study.

7.2.2 Infrared Analytical Procedures

(A) Water Column
a) Quantitative

i) Choice of solvent system - infrared analysis of the petroleum hydrocarbons extracted from the water column were analyzed quantitatively as well as qualitatively. It was desirable therefore, to have one solvent which could be used as an extracting solvent and allow for the subsequent infrareo analyses without having to remove the sample from the solvent. Carbon disulfide was chosen since it can be used as an extracting solvent and has infrared spectral "windows" at 2930 cm^{-1} to allow for quantitation of the hydrocarbon band and also has windows between 1355 and 655 cm^{-1} to allow for measurement of the spectrum in the infrared "fingerprint" region (used for qualitative analysis) (1). Since the infrared cells, extraction and separation techniques required for analysis of chemically treated oil spills with this solvent were nonexistent, this lab designed and tested methods to allow us to perform infrared analyses of these samples.

The solvent was reagent grade and redistilled in glass immediately prior to use.

ii) Infrared instrumentaion - analysis was performed on a Beckman 4260 Infrared Spectrometer interfaced to a Data General NOVA 3/12 Minicomputer.

iii) Design of Cell: A large portion of time was devoted to the design of 6 mm liquid cells. Cells are not normally manufactured at this pathlength and volume and cannot hold the very volatile samples and solvent we normally use. Figure 7.2.1 shows the schematic of the cell we chose. The holders were designed to contain a 6 mm spacer sandwiched between two AgCl windows. The design and material of the spacer was varied and tested as follows:

1) Teflon spacers - two Teflon spacers were machined to matching thickness (6 mm). Injection ports were located on the side of the spacer, and angled as shown as "a" in Figure 7.2.1. Teflon plugs were used to seal the ports. Two major difficulties were encountered with this design:

a) The softness of the Teflon made it impossible to machine two spacers to an exact, uniform thickness. As a result, it was necessary to hand lap the two spacers to exact thickness. This was time consuming and tedious.

b) The CS_2 slowly leaked through the side ports of the spacers.

2) Stainless Steel - two stainless steel spacers were machined to matching thickness (6 mm). Injection ports were located on the side of the spacers. Teflon plugs were used to seal the ports. The hardness of

TABLE 7.2.1 Dispersants Considered for Study

Product	Type Oil Dispersed	Toxicity	Mixing Requirements
TEOC777	Light Crudes at Sea	N/A*	Fine Mist
SURFLO-OW-1	Crude at Sea	Non-toxic	Spray/Agitate by Boat
BP1100WD	Oil at Sea only	Conforms to UK standards	Spray/seawater mix/boat
BP1100X	Oil at Sea or on beach	"	"
Corexit 7664	no limitations	"low"	Spray/Agitate by boat
Corexit 9527	no limitations	"low"	None required

*N/A-none available

All information was taken from company product brochures.

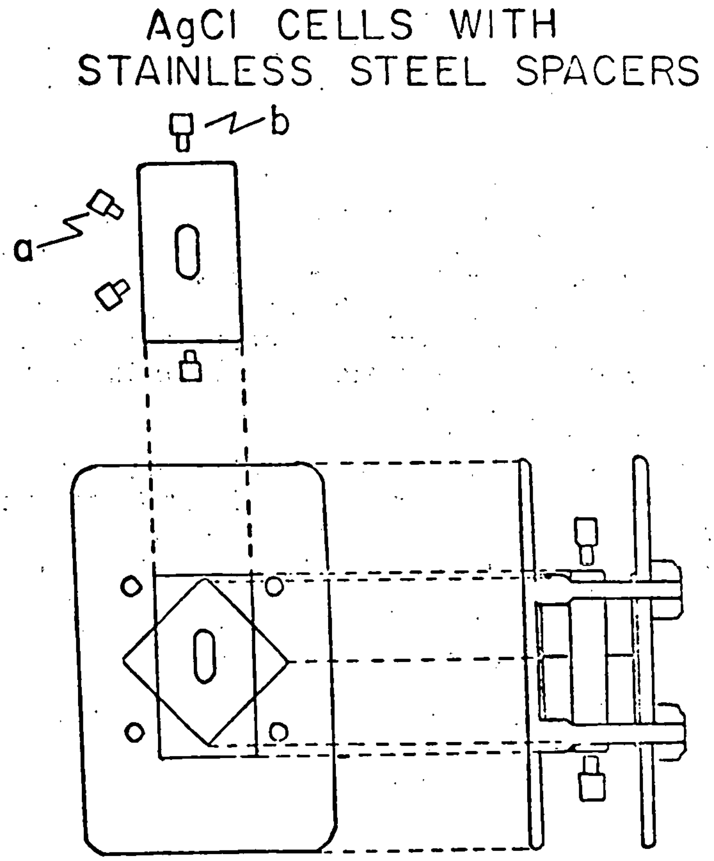


Figure 7.2.1 AgCl Cells with Stainless Steel Spacers

the stainless steel allowed for machining of the two spacers to exact thickness and, unlike the Teflon, no further polishing was necessary. However, the ports still leaked.

(3) Stainless Steel - two stainless steel spacers were machined to matching thickness. The port positions were moved from the sides to the top and bottom, as "b" in Figure 7.2.1. This prevented leakage. The cells presently in use are those designed with ports located on the top and bottom of the spacer.

iv) Extraction Efficiencies

To determine the extraction procedure and the amount of solvent that would yield a relatively high extraction efficiency, four procedures were tested, using carbon disulfide as the extracting solvent. In each experiment, one liter of sea water collected from a previously determined clean site was spiked with a known amount of sample and poured into a 2000 ml separatory funnel. The organics were then extracted as follows:

a) Ten mls. of CS_2 were added to the water and the sample was agitated for 5 minutes. The bottom organic layer was transferred to a 25 ml volumetric and brought to volume with additional solvent.

b) Ten mls. of CS_2 were added to the sample in 5 ml portions with extraction after each addition. The 5 ml portions were combined in a 25 ml volumetric and brought to volume with additional solvent.

c) Fifteen mls of extracting solvent were added to the sample in 10 and 5 ml aliquots, with extraction after each addition. The aliquots were combined as described above.

d) Thirty mls. of extracting solvent were added in 15 ml aliquots, with extraction after each addition. Combination of sample and volume adjustments were made as described above.

The amount of extracted hydrocarbon in each sample was determined by measurement of the absorbance of the 2930 cm^{-1} band.

These four procedures were tested with Kuwait Crude, Corexit 9527 dispersant and a 5:1 mixture of Kuwait Crude and Corexit 9527. Results are shown in Table 7.2.2. As can be seen, method "d" yields the highest efficiency. All extractions are now performed according to this method.

v) Analytical Protocol

In the initial phases of the project, the feasibility of chemically separating the oil from the dispersant prior to infrared analysis was studied. The dispersant is a mixture of polar hydrocarbons, whereas the oil is a mixture of nonpolar and polar hydrocarbons (the nonpolar compounds being present in the higher percentage). Therefore, Thin Layer and Column Chromatography were used with various solvent systems in an attempt to isolate the oil from a mixture of oil and dispersant. Several pure solvents and solvent systems were tested for their resolution capabilities. The best results were obtained with a system of a 1:1 mixture of $CHCL_3:CCl_4$. However, even with this system, a complete separation

Table 7.2.2. Results from Extraction Efficiency Experiments

Procedure	Efficiency		
	Kuwait Crude	Corexit 9527	Kuw/Corex
a) 10 ml 1st ext. 0 ml 2nd ext. 10 ml total	40.5%	8.7%	28.8%
b) 5 ml 1st ext. 5 ml 2nd ext. 10 ml total	31.0%	10.3%	21.8%
c) 10 ml 1st ext. 5 ml 2nd ext. 15 ml total	31.8%	11.1%	46.6%
d) 15 ml 1st ext. 15 ml 2nd ext. 30 ml total	64.8%	22.0%	65.2%

of the oil from the dispersant could not be realized. Because of this and of the time required to perform this separation, it was decided that development of computer techniques to effect spectral separation of these two components would be more promising (see Section 12.5).

The amount of hydrocarbons present in a sample was determined by placing 0.5 ml of the sample solution into the sample cell. The matched reference cell was filled with CS_2 and both were placed in the infrared spectrometer. Since the cells were of identical pathlength, the CS_2 absorbed the same amount of light from both sample and reference beams, effectively eliminating the bands due to the solvent and allowing the measurement of the absorbance band for hydrocarbons at 2930 cm^{-1}. The absorbance of the 2930 cm^{-1} band was calibrated using solutions of known concentrations of the oil, oil/dispersant and dispersant respectively, and concentration vs. absorbance curves were plotted. The concentration of the unknown was then determined from the appropriate curve.

b) Qualitative - Spectral measurement

Following quantitative analysis, the total sample is concentrated to approximately 1 ml by slowly evaporating the solvent. Again, about 0.5 ml of this solution is placed in the sample cell, pure CS_2 is placed in the reference cell. Both are placed in the instrument and the infrared "fingerprint" of the sample is measured by scanning the 1355-655 cm^{-1} region of the spectrum.

(B) Air
a) Charcoal Tubes

i) Laboratory

The vapors above treated and untreated simulated oil spills were collected by pumping air above the slick through activated charcoal cartridges. A flow meter was connected between the cartridges and a pump to measure flow rate. Three systems were used for collecting vapors:

1) the apparatus shown in Figure 7.2.2.
2) the apparatus shown in Figure 7.2.2 without the charcoal filter.
3) the apparatus shown in Figure 7.2.3.

Prior to the extraction of the charcoal an internal standard, n-C_{20} (eicosane), was added to the solvent. Carbon disulfide was used for extraction. Thus, its area and height can be easily determined. The concentration of the standard was about 50 ppm. Before the extraction, the solvent and the charcoal were cooled in liquid nitrogen and then mixed together. This was done to prevent losses of vapors due to heat of extraction (1). Extraction time was 30 minutes. Infrared spectra were measured using the 6mm cells described above. Carbon disulfide was used as a solvent for the IR measurements.

ii) Meso scale

Two tanks, 6.2 meters tall and 0.9 meters in diameter, located about 50 meters from the Narragansett Bay, were used for the meso-scale experiments. The tanks were filled with approximately 2000 liters of sea water pumped from the ocean. Kuwait crude oil was added to the north and south tanks, and Corexit 9527 was then added to the south tank.

The surface was mixed by stirring with glass rods. Air samples were collected immediately after the spill. Air samples were collected and treated similarly to the air samples taken in the laboratory experiments. Figure 7.2.4 shows the system used for collecting the air samples in meso-scale experiments. The funnels through which the air was pumped were placed at about 2.5 cm above the water surface.

Extraction of samples from the charcoal tubes and infrared analysis of the samples were performed as described above.

b) Long-path Gas Cell

The purpose of this study was to determine the feasibility of direct IR monitoring of vapors of oil and its various light hydrocarbon components. Fundamental problems are quickly encountered when trying to obtain an IR spectrum of a complex mixture such as crude oil. Overlapping bands and non-linear responses make quantitative accuracy questionable in such cases, and this was one of the major problems addressed. Work was largely done with synthetic mixtures of light hydrocarbon gases to simplify the study. Problems of sample handling and transfer were also addressed. A simple laboratory system was set up for the routine analysis of vapors from liquid hydrocarbon samples, along with special handling apparatus for other situations (artificial weathering, etc.). Finally, a simple, very small-scale spill simulation tank was set up.

Spectra were measured on a Beckman 4260 infrared spectrophotometer with a Wilks 20-m Variable Path Gas Cell mounted in the sample beam. A beam attenuator was placed in the reference beam and the sample compartment was continuously flushed with dry N_2 gas to minimize atmospheric interferences.

Figure 7.2.5 shows a simple schematic of the 20 m gas cell. The IR sample beam is directed up into the cell, multiply-reflected along the length of the cell, and directed back out and into the instrument. By

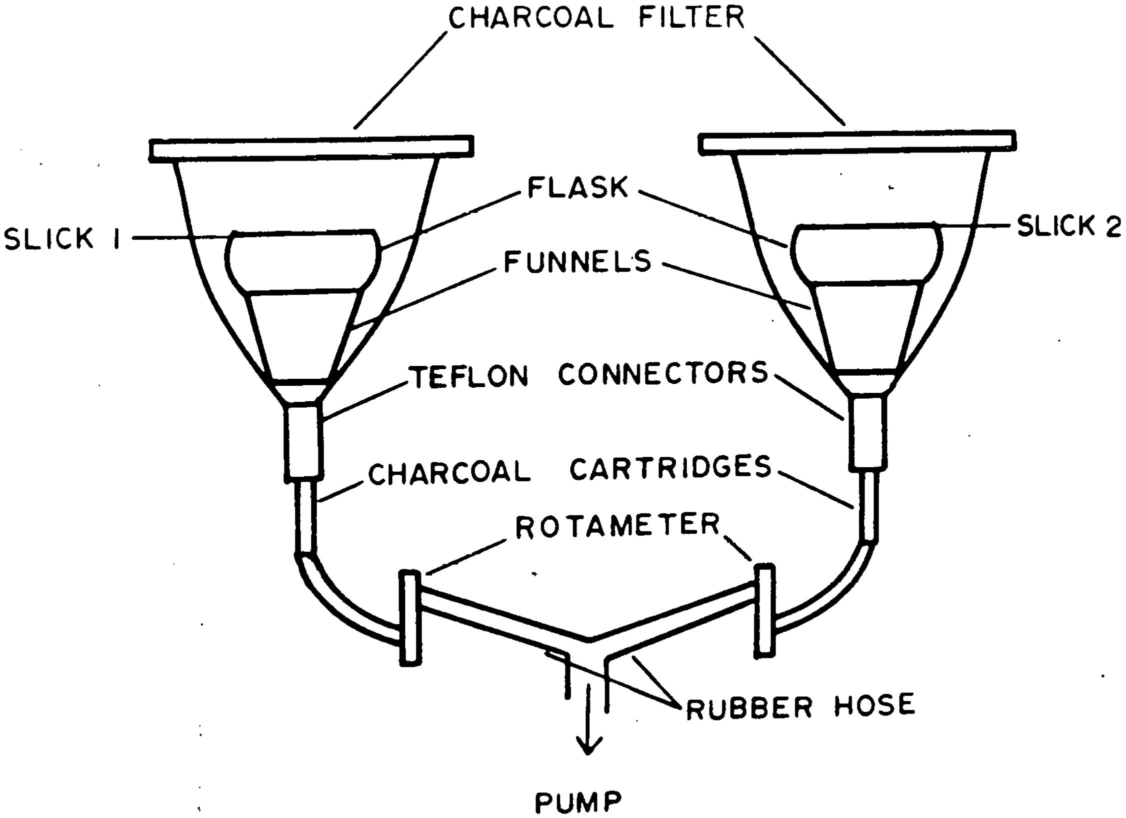


Figure 7.2.2 Air Flow Sampling Probe for Laboratory

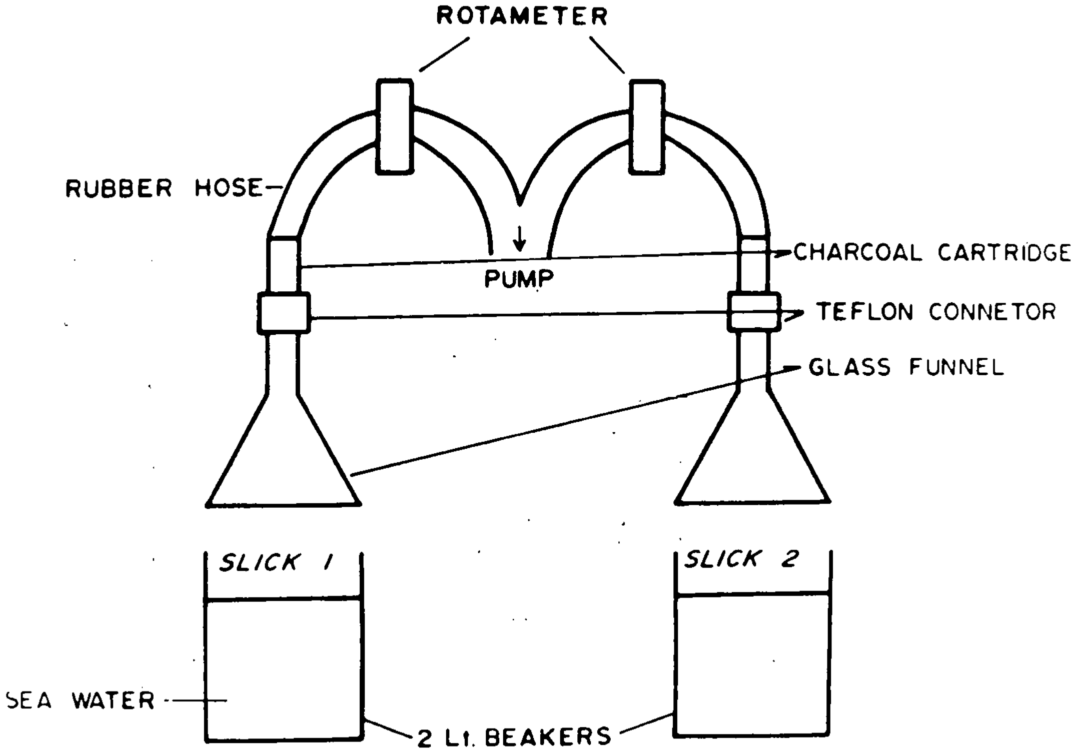


Figure 7.2.3 Test with Prefiltering for Laboratory Experiment

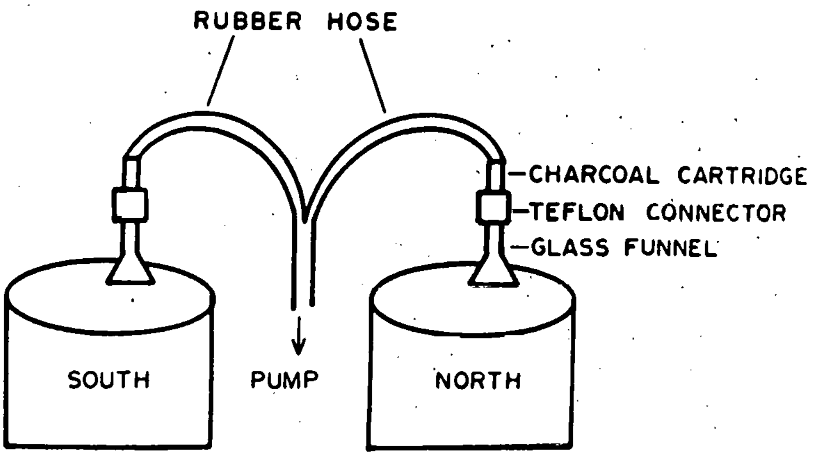


Figure 7.2.4 Test with Prefiltering for Meso Scale Tank

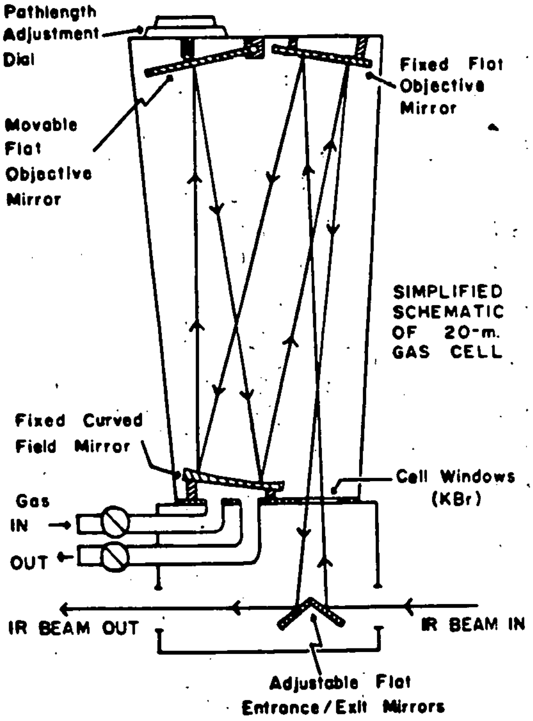


Figure 7.2.5 Schematic of the IR 20 meter Gas Cell

varying the angle of one mirror with a simple vernier dial, the number of reflections and, therefore, the pathlength in the cell, can be varied. The pathlength can be set from 0.75 to 21.75 m, in increments of 1.5 m. The longer pathlengths are often necessary when working with low concentrations or weakly absorbing species. Two gas connections, with valves, allow for a flow-thru operation of the cell. The cell is about 0.4 m long, with a volume of 5.5 liters.

Figure 7.2.6 shows a diagram of the experimental setup. The apparatus can be used in several ways. For quantitative studies of pure gases, dry N_2 was pumped through the cell to flush the system. The 4-way valve was then turned to isolate the pump and gas cell (in a closed loop) and a sample of gas was injected through the septum with a gas syringe. Repeated injections of a gas into this flowing loop could be made while monitoring a wavelength of interest on the IR, until the desired concentration was reached. Likewise, sequential injections of different gases could be made to produce a synthetic mixture of known composition. Injections were made with Series A gas syringes from Precision Sampling, Inc. Syringes were filled from lecture bottles via a stainless steel outflow tube.

For sampling vapors from crude oil or from a simulated oil spill, the vapor is pumped once through the cell and out the exhaust. In the case of a spill, a glass funnel suspended over the spill is connected to the input. For pure oil samples, a sampler such as in Figure 7.2.7 can be used to isolate the vapors. All pump parts, valves and connections are 316 stainless steel, and tubing connections are made with TFE. The gas cell itself is Teflon lined.

Data measurement was generally carried out with the IR interfaced to the Data General NOVA 3/12 computer. Programs developed in the lab allow for acquisition and storage of data, spectral smoothing, addition or subtraction and graphic display of spectra on a CRT or plotter. This allows for improvement and enhancement of spectral display, and exact comparisons of very similar spectra. Also, spectra of pure gases can be added in the computer to produce an artificial mixture, for comparison with a real sample.

Most work with pure light hydrocarbons was done from 3250-2750 cm^{-1} in the region of the C-H stretching frequency. Some work with heavier hydrocarbons was done in the fingerprint region from 1000-500 cm^{-1}. Light hydrocarbons used were methane, ethane and propane, while benzene and toluene were used as heavier aromatic hydrocarbons. Data for the computer was acquired at 1/10 cm^{-1} increments over 500 cm^{-1}, giving 5000 data points. Spectra of larger regions were also measured at 1 cm^{-1} resolution. Typical IR conditions were 50 cm^{-1}/min, 1.5 cm^{-1} resolution; pathlength from 0.75 to 21.75 meters.

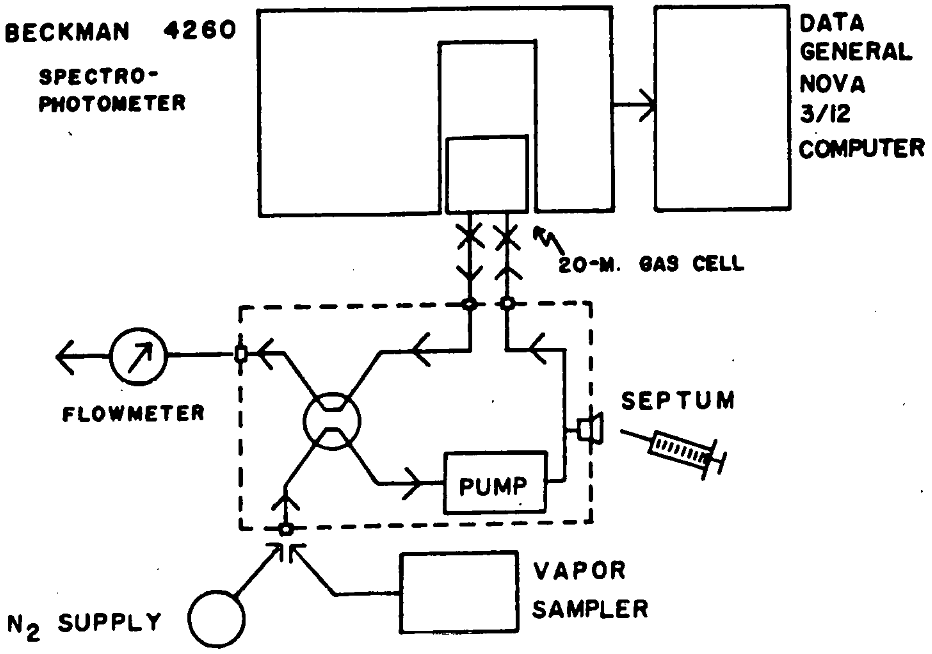


Figure 7.2.6 Diagram of IR System

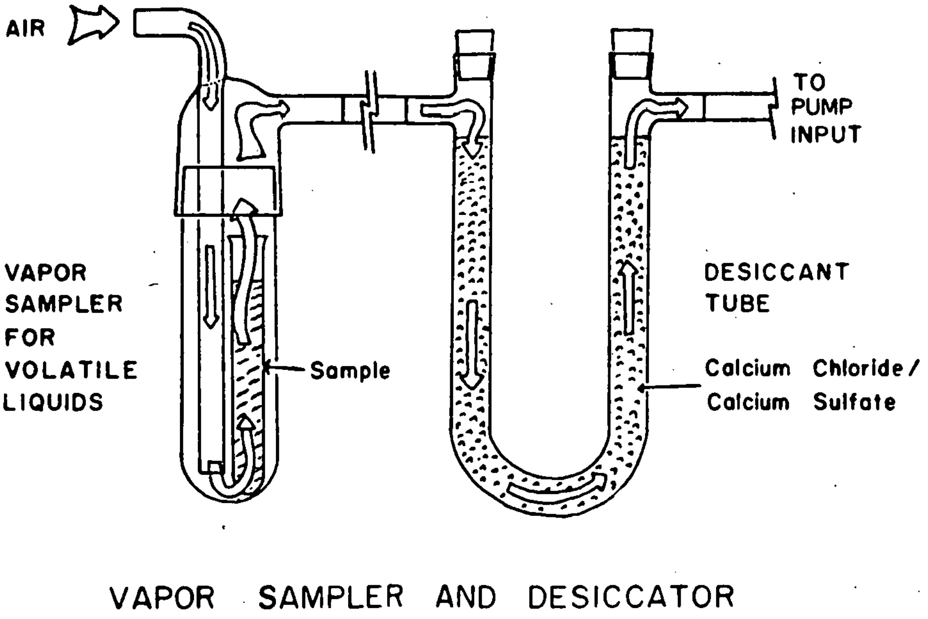


Figure 7.2.7 Vapor Sampler and Desiccator

7.2.3 G.C. Analytical Techniques

Qualitative/Quantitative Procedure

(A) Water Column

After infrared analysis was completed, the CS_2 was completely removed from each of the extracts by evaporation and the residue was taken up in 2µ liters of hexane.

The samples were then analyzed by Gas Chromatography (GC) on either a Hewlett Packard Model 5710A or a Perkin Elmer Sigma 2, both equipped with flame ionization detection and 10-m by 3-mm column packed with SP2250 (temperature programmed at 8 degrees C/MIN).

(B) Air Analysis

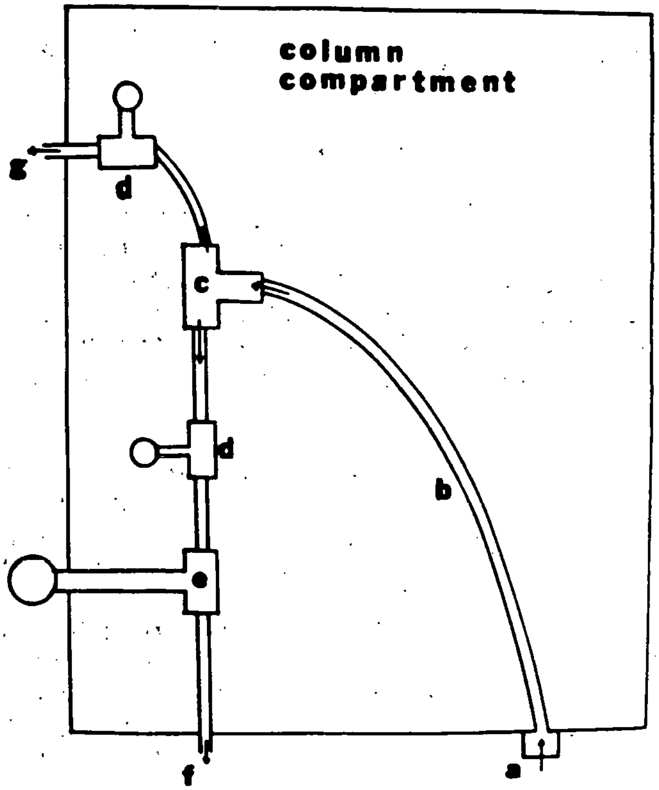
a) Separation on GC followed by IR - prior to extraction of the sample impregnated charcoal. an internal standard, n C_{20} (eicosane) was added to the solvent, CS_2. Eicosane was chosen since its GC peak does not overlap any of the GC peaks of the sample, thus its area and height can be easily determined. The concentration of the standard was about 50 ppm. Gas chromatograms were measured using a Hewlett-Packard Model 700. The GC was modified for collecting fractions. The GC is equipped with a 10 ft., 1/8 in. column of 10% SP2250 on 100/120 Supelcoport and a flame ionization detector (FID). The detector destroys the eluents, therefore, it was necessary to split the effluent prior to the detector. A Swagelok union T was inserted between the column and the detector (inside the oven) to split the flow valve. A stop-flow valve was placed between the splitter and the FID detector. Another stop-flow valve and a fine metering valve (Nupro 4BM) was installed between the splitter and the device. The splitter and all three valves were located in the oven, however, the metering valve could be controlled externally. A schematic of the oven compartment is shown in Figure 7.2.8.

After the two valves on the collection side of the splitter, the effluent exits the oven compartment through a temperature controlled heated jacket to the "merry-go-round" device shown in Figure 7.2.9. This device was made in-house of Teflon; the eluent enters the device through the center and is directed at a right angle to the front where it enters one of the 20 possible holes containing a charcoal cartridge.

To collect a number of fractions, the GC eluents were monitored by the FID detector (10% going to detector, 90% to the collection device). When the recorder indicates that a GC fraction was starting to elude the column, the collection device is manually moved to a position containing the desired charcoal cartridge. The eluent was collected and the device was rotated to another position for collecting the next fraction.

The possibility of a single component concentration exceeding the breakthrough level of a charcoal cartridge was investigated for a number of components by attaching a second cartridge to the exit of the first cartridge. The components could not be detected in the solutions of the desorbed cartridges; thus. it was concluded that under typical GC conditions the breakthrough level would not be exceeded.

Figure 7.2.8 GC Column Arrangement in Oven



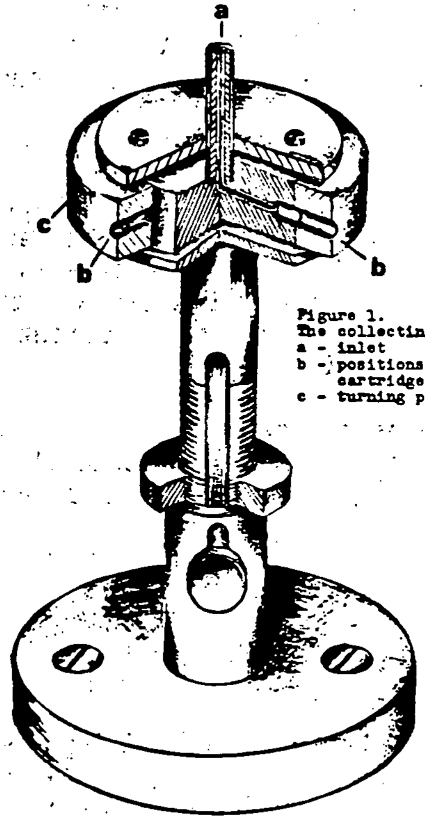


Figure 1.
The collecting device.
a - inlet
b - positions of charcoal cartridges
c - turning part

Figure 7.2.9 Device for Collecting Gas Samples

h) IR analysis, followed by GC of total sample - subsequent to infrared analysis of the charcoal extract. gas chromatograms were measured on either the Hewlett Packard 700 or the Hewlett Packaro 5710A, both previously described.

7.2.4 GC-Mass Spec Analytical Procedures

The GC/MS/CS system was developed in order to analyze water extract samples for aromatic hydrocarbon compounds. The MS is of the chemical ionization (CI) variety and is ideally suited for aromatic compounds. The nucleophilic nature of these compounds increases the reaction cross section and enhances the sensitivity. Also the nature of the Cl process yields a strong molecular ion peak and, therefore, is readily interpretable.

CI is a phenomenon resulting from ion-molecule interactions and requires gas mixture pressures on the order of one Torr in the MS ion source. The composition of the gas is such that the reagent gas, in this case CH_4, is present at a much higher concentration than the sample. Primary ionization occurs in the reagent gas because of its great excess through electron impact ionization. These reagent ions then react with reagent gas in second order processes to produce stable ions characteristic of each gas (for CH_5+ and C_2H_5+). These reagent ions are stabilized as a plasma in the ion source and there are no further reactions of these characteristic reagent ions with the reagent gas.

When a reagent ion encounters a sample molecule, one of several chemical interactions may occur. These include transfer of a proton, a hydride ion, another ion fragment, or a charge. One important advantage in CI as opposed to electronic impact (EI) is that the average energy transferred to the sample molecule by the reagent ion is much less than that transferred by EI ionization and this leads to only a small amount of fragmentation and, therefore, a large molecular ion peak.

A chemical ionization system can be readily interfaced with a gas chromatograph. Because the source operates at high pressures, sample separations can be eliminated and the entire effluent from the GC can be introduced into the ion source. Because of the vast amounts of data produced by a GC/MS system, a dedicated computer system for control and data acquisition is a necessity.

The objectives were as follows:
a. Assemble the MS system with its associated vacuum system, cooling systems, electrical and electronic system and sample handling systems.

b. Interface a gas chromatograph to the sample inlet of the MS and determine the optimum columns and conditions for operations.

c. Interface the GC/MS to a computer system and develop the necessary hardware and software to support such a system.

A HP-5710A gas chromatograph with capillary column pneumatics was used to separate the extract mixtures prior to MS analysis. A J Scientific SP--2250 glass capillary column was finally chosen as the most versatile and efficient column for the separation of a low to medium mass aromatic hydrogen. Temperature programming was from 90° to 270° C at 4 C/min. The carrier gas was helium. The injector was automatically purged 45 seconds after injection.

The MS was a Biospect/Finnegan with a CI source and a quadrapole mass separator. A complete MS scan from 50 to 400 amu was performed three times per second ano this data was stored by computer. The scan rate was controlled by the computer through a DAC. The rate could also be manually controlled by the operator. The GC effluent was introduced directly into the MS source through a heated glass lined tube. The solvent peak was not vented to the atmosphere, rather the source filament was turned off while the solvent was passing into the MS. This was easily monitored via the source pressure gauge.

The computer system was a Data General Corp. NOVA3/12 with 64K word memory, foreground/background and memory map protection, 10M byte cartridge disk system, 16 channel 12 bit ADC, 2 channel 12 bit DAC, 16 channel digital I/O, CRT, TTY, and a plotter. The software used was DGC Fortran IV and DGC Nova assembly language. The Fortran was used mainly for data management, processing, and display. The assembly language was used for data acquisition and instrument control.

Figure 7.2.10 is a typical mass spectrum scan of a several component mixture containing PAH. The identified compounds are toluene, phenanthrene, anthracene, fluoranthrene, pyrene, triphenylene, benzanthracene and chrysene. This spectrum was obtained using the solids probe and was used as a calibration scan.

Figure 7.2.11 is a total ion plot showing the reconstructed gas chromatogram for an n-paraffin calibration mixture.

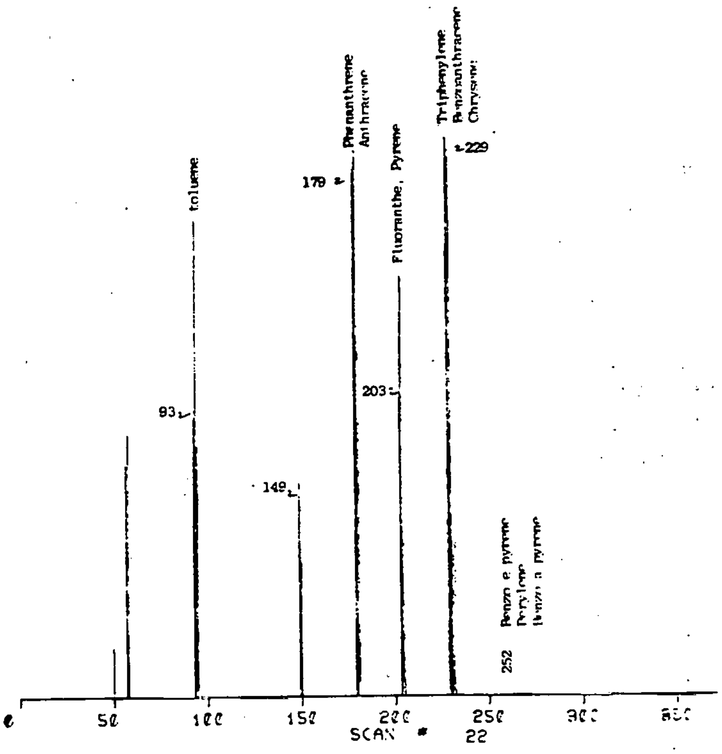
Figures 7.2.12 and 13 show the total ion plot and subsequent mass spectrum for a sample of dimethyl-naphthalene in hexane. As can be seen from the total ion plot, a compound is indicated by a GC peak at 390th scan. The mass spectrum of scan 390 indicates a molecular ion mass of 157 amu which corresponds to the dimethyl-naphthlene.

Figure 7.2.14 shows the total ion plot-reconstructed gas chromatogram for the aromatic fraction of a fuel oil. Naphthalene, methyl naphthalenes, dimethyl-naphthalenes, tri-methyl naphthalene and phenanthrene can be clearly and unambiguously identified.

Figure 7.2.15 shows the total ion plot of deasphalted Kuwait Crude oil in hexane. Benzene, xylene, naphthalene, methyl-naphthalene and dimethyl-naphthlene can be identified along with the n-paraffins.

Figure 7.2.16 shows the total ion plot for a water extract from the south tank top after one hour. Xylene, naphthalene, methyl-naphthalene, and dimethyl-naphthalene along with n-paraffins were detected.

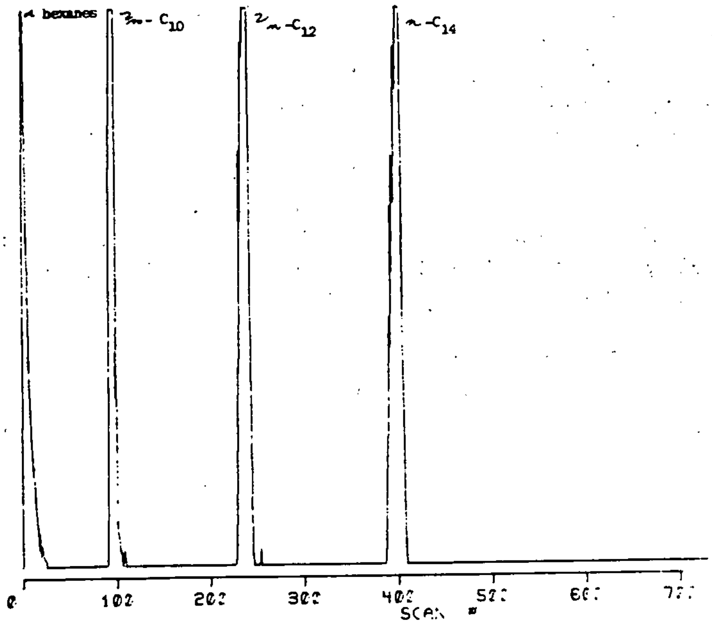
Figure 7.2.17 shows the total ion plot for a water extract from the South tank top after 24 hours. Naphthalene, methyl-naphthalene, dimethyl naphthalene along with n-parraffins were detected.



PAHSTD
Solids Probe
28 Nov. '78

calibration off by + 1

Figure 7.2.10 Typical Mass Spectrum of a Several Component Mixture Containing P, A. H.

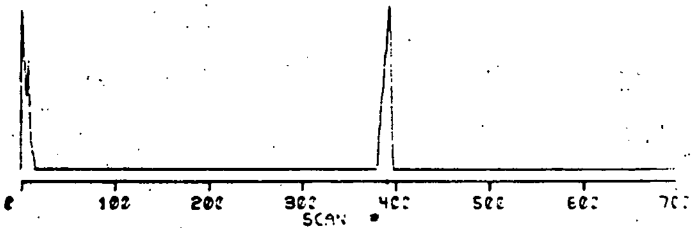


1 ml $C_{10}C_{12}C_{14}$ in hexane
11 Oct. '78

Totion : 1 Y
50 lower limit

90 to 270°C @ 8° C/min
20 psi SP-210^0 glass capillary
C H_4 @ ~ 1000 milliliter @ source

Figure 7.2.11 Total ion plot showing the reconstructed Gas Chromatogram for an n Paraffin Calibration Mixture



Dimethnap (Dimethyl-naphthalene)

13 Oct. '76

Totion : 1 X

50 filters
700 scans

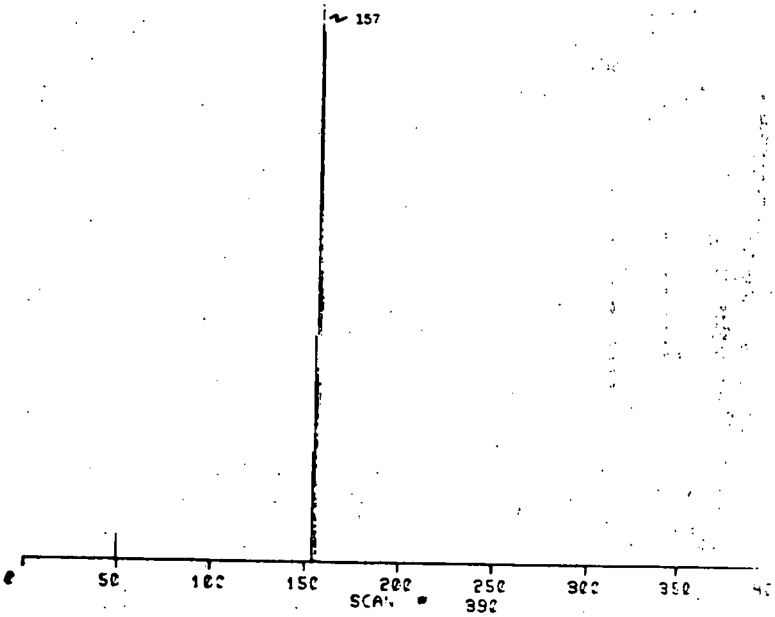
CH_4 @ ~ 1000 milliliter @ source

90 to 270°C @ 8°C/min.

capillary column SP-2100

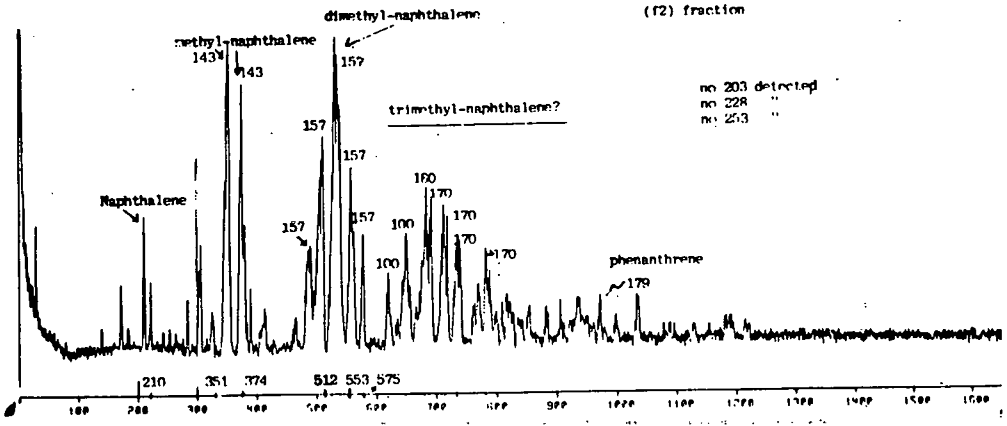
25 psi

Figure 7.2.12 Total Ion Plot for the Sample of Dimethyl-napthalene in Hexane



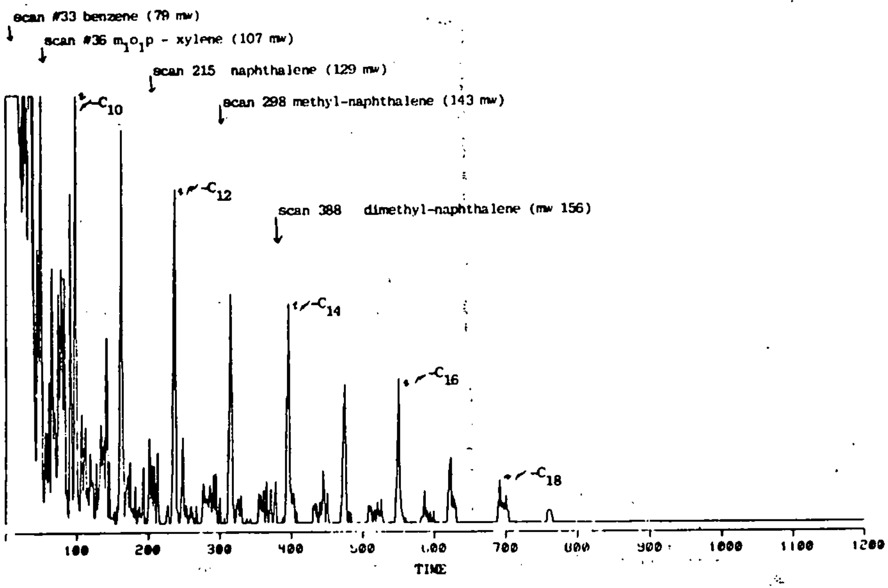
Dimethyl-napthalene

Figure 7.2.13 Mass Spectrum of Scan 390



6 Feb. '79
50 limit on Iotion
1 " limit on ms displays

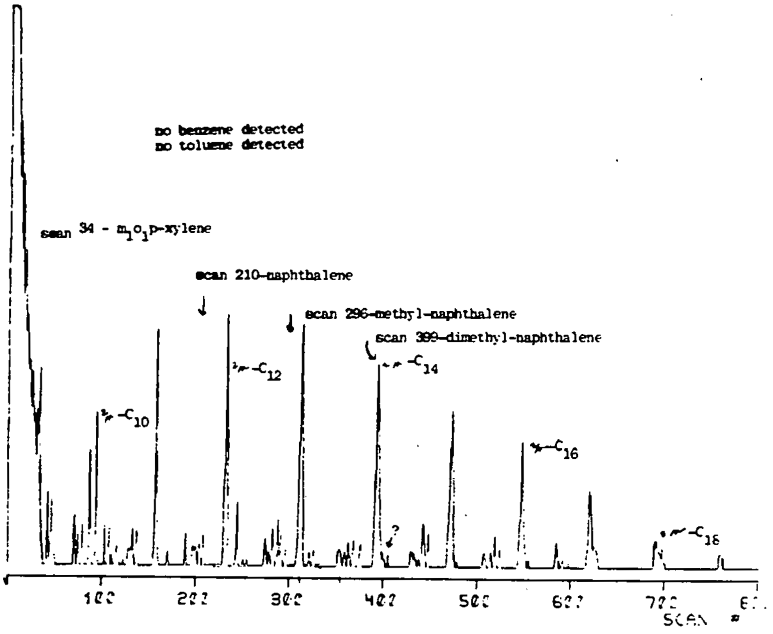
Figure 7.2.14 Total ion Plot Reconstructed - GC for Aromatic Fraction of Fuel Oil



Kuwait (Deasphalten In Hexane) 16 Oct. '78
Totion : 1 X
50 filters

90 to 270°C @ 8°C/min.
25 psi SP-2100 glass capillary
CH_4 @ ~ 1000 milliliter @ source

Figure 7.2.15 Total ion Plot of Deasphalted Kuwait Crude Oil and Hexane

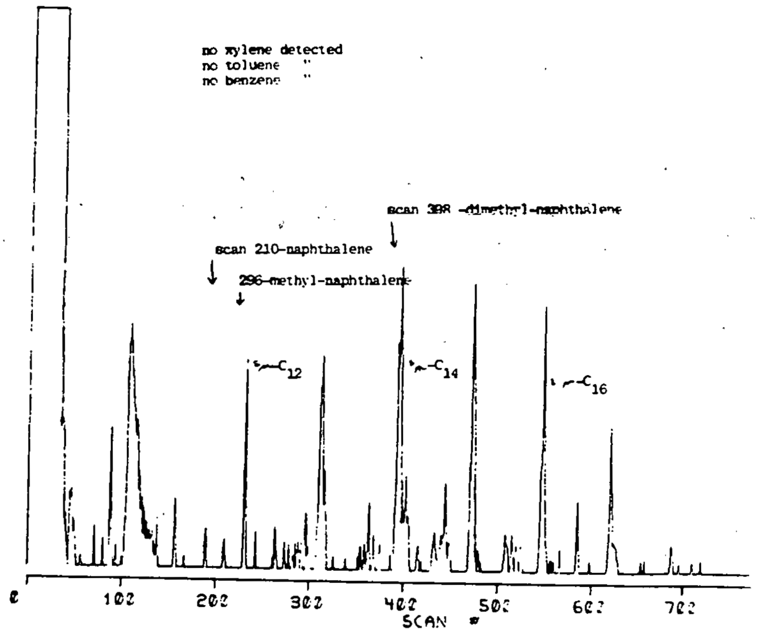


STOP 1 (8/16/78)
Totion : 1 X
50 filters
1499 scans

10 Oct. '78

90 to 270°C @ 8°C/min.
25 psi SP-2100 glass capillary
CH_4 @ ~ 1000 milliliter @ source

Figure 7.2.16 Total ion Plot for a Water Extract from the South Tank after one hour



STOP 24
TOTION 1X
40 filters

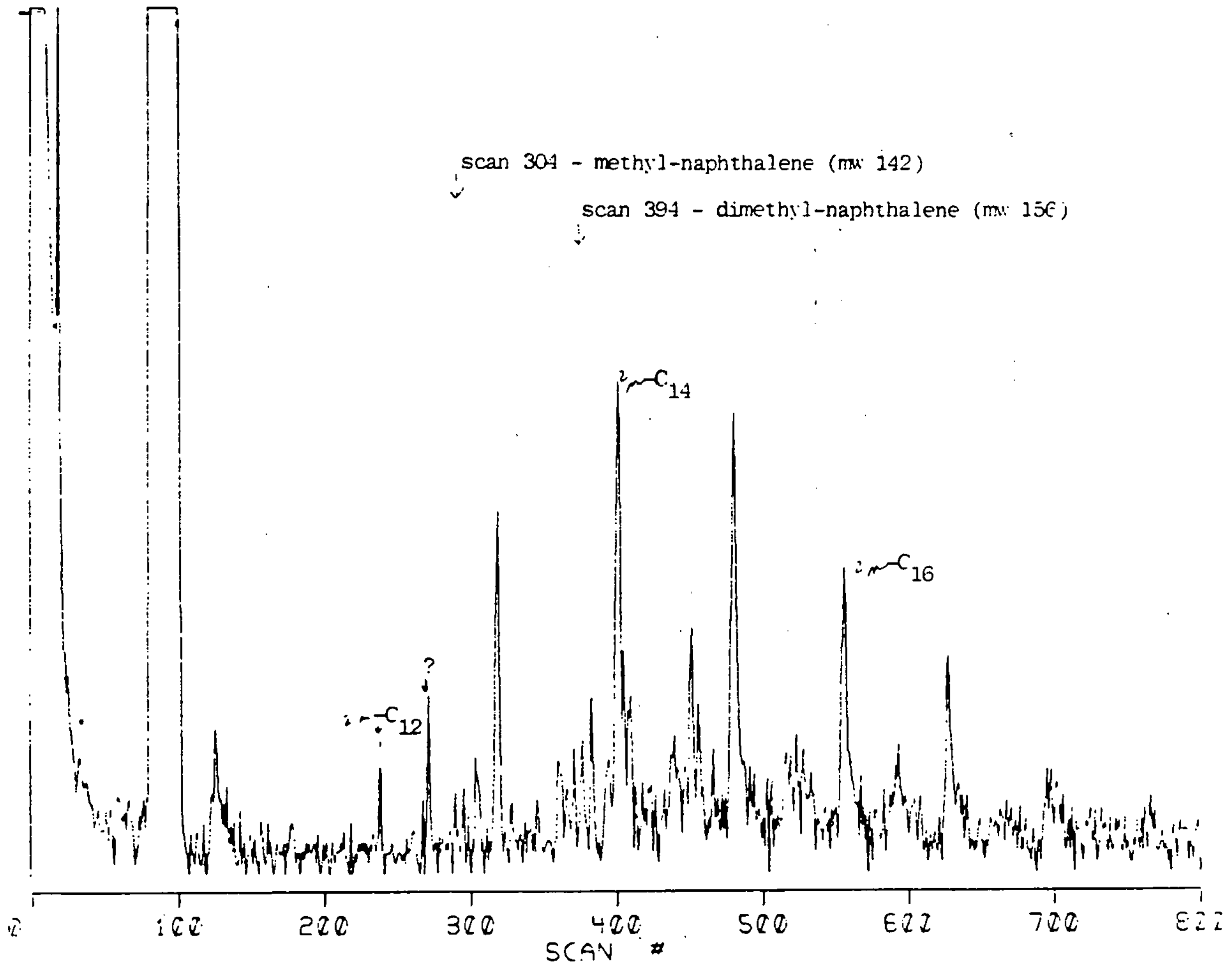
12 Oct. '78

90 to 270°C @ 8°C/min.
SP-2100 capillary column

Figure 7.2.17 Total ion Plot for a Water Extract from the South Tank after 24 hours

Figure 7.2.18 shows the total ion plot for a water extract from the south tank mid after 24 hours. Methyl-naphthalene, dimethyl-naphthalene, along with n-paraffins were detected.

no benzene detected
no xylene detected
no naphthalene detected



SMID 24 18 Oct. '78

TOTION 3 X
15 filters

90 to 270°C @ 8°C/min.
SP-2100 capillary column

Figure 7.2.18 Total ion plot for Water Extract from the middle of South Tank after 24 hours

7.3 Laboratory Experiments:

The laboratory experiments were intended to:

1) test the available methodology

2) develop new methods

3) be used as cursory analyses of the oil/dispersant system to provide an overview of the analytical problems that would be encountered and the results that may be anticipated in the meso-scale and "real world" environments.

For these experiments, untreated and chemically treated spills were manufactured in laboratory scale test tanks and in larger, outdoor tanks. The oils used in the experiment were API Kuwait Crude, API South Louisiana Crude; the No. 6 oil involved in the Argo Merchant Spill (Dec., 1976), and the No. 2 oil from the Buzzards Bay Spill (Jan., 1977).

7.3.1 Water Column

(A) Methodology:

Effect of dispersant on Kuwait Crude and S. Louisiana Crude: Four fiberglass containers were filled with 28 liters of Narragansett Bay sea water. Vertical agitation of the water was provided by the vertical motion of Al paddles hinged to the bottom of each container and attached to a motor via a nylon string. Ten ml. of each oil were placed in two test tanks and 10 ml. oil/2ml dispersant were placed in two other test tanks. Qualitative results on the second laboratory experiment are given in Table 7.3.1. The total relative amounts of petroleum entering the water is about the same for the two oils. A large amount of phthalic acid esters (phthalates) were found in the Kuwait test tank after 24 hrs., the source of which could not be traced.

(B) True solubility of petroleum chemicals:

For this series of experiments, "artificial sea water" was used and was prepared by adding a specified amount of Instant Ocean (Aquarium System, Inc., Ohio) to distilled water. Oil was added to the surface of the water contained in a large glass carboy. The water was gently agitated with a slowly moving magnetic stirrer for the duration of the experiment.

The results for two different initial concentrations of So. La. Crude are given in Figure 7.3.1. Two 1 liter water samples were collected prior to each experiment (controls or C), two subsurface samples at 1 hour, and two at 24 hours. One 1 liter sample from each time period was analyzed without filtering and the other was filtered through a 0.45 mm Millipore filter prior to analysis. The filtering was performed in order

Table 7.3.1

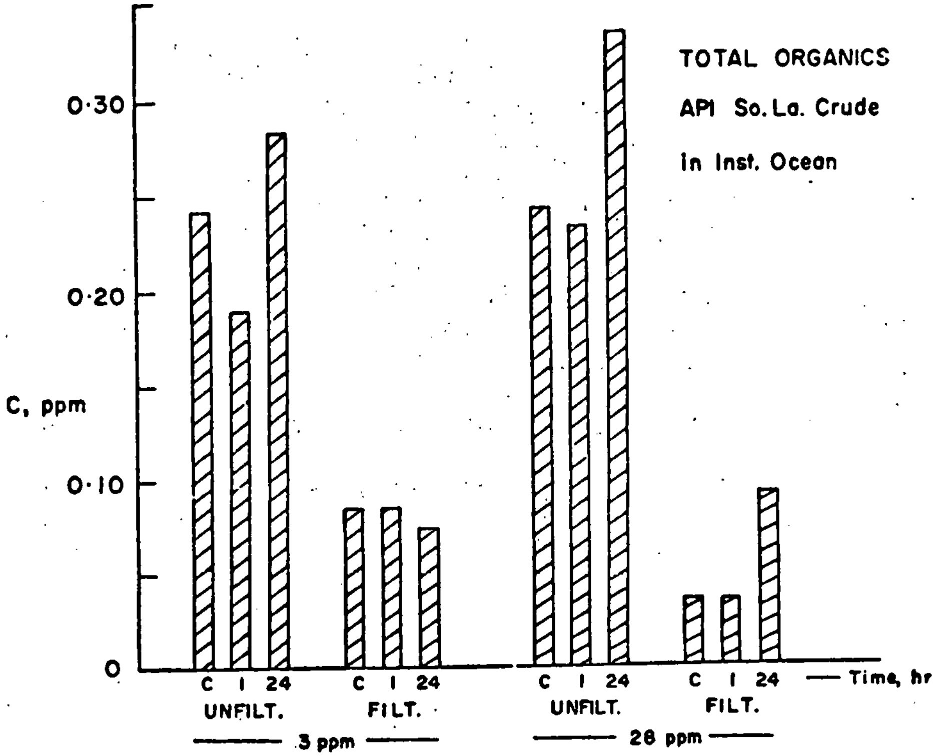
Qualitative Results of 2nd Laboratory Experiment

	Relative Amounts of Oil Present[a]	
	Time	
Test System	1 hour	24 hours
Kuwait Crude	1	High in Phthalates (some oil)
Kuwait/Disp.	3	7[b]
So. La. Crude	1	2
So. La. Crude	3	7

[a] Estimated from IR spectra

[b] After separation by column chromatography

Figure 7.3.1 Total extractable Organics from Laboratory Experiment on South Louisiana Crude Oil with Initial Concentrations of 6 and 28 ppm.



to remove dispersed droplets; however, the control also contained considerable amounts of filterable particles.

Starting with 3 ppm of the crude oil (e.g., 15 mg of oil added to the surface of 5L. of water) we observed an overall increase in total organics after 24 hours; however, after filtering, the controls, 1 and 24 hour samples contained (within experimental error) the same amounts of extractable organics. In the experiment with an initial concentration of 28 ppm, the total organics in the unfiltered water increased by 0.094 ppm and those in the filtered water by 0.056 ppm after 24 hours in the filtered water. These two experiments indicate that the relative amounts of soluble organics in oil is low; however, directly beneath a slick, soluble compounds can be found as is indicated in the 28 ppm experiment.

We performed the same experiment with the No. 6 oil from the Argo Merchant spill. In this case 6.2 ppm of the oil were added to the artificial sea water; the results are presented in Figure 7.3.2. Again, the amount of oil entering the water was small; the amount of total extractable organics in the filtered water increased by 0.020 ppm after 24 hours.

The same experiment was performed with the No. 2 fuel oil from the Buzzards Bay spill. The results are presented in Figure 7.3.3. The initial concentration of 24.7 ppm is similar to the second So. La. Crude oil experiment and the results are similar. There was an increase in the total organics in the unfiltered water after 1 and 24 hours. Furthermore, the true solubles increased by 0.035 ppm after 24 hours in the filtered water.

Another useful result can be obtained from Figures 7.3.1-7.3.3 and that is the high concentration of extractable organics in the control sample of the artificial sea water (Instant Ocean). Typical values for extractable organics in the Atlantic Ocean are from 0.010 to 0.100 ppm, whereas the control sample of the artificial sea water contained 0.200 ppm. Qualitatively, we found a relatively high concentration of phthalates and polymers in the control samples.

(C) Outdoor experiments:

In the laboratory experiments designed to measure hydrocarbons in the water column from untreated and treated spills, the amount of oil used was just enough to give a slick of 0.05 mm thickness. However, even with dispersant only a very small fraction of the oil stayed in the water column. We felt that this was due to the small volume of water in the containers. Thus, we performed two experiments in larger test tanks using the aquarium facilities at the Narragansett Bay Campus.

Three 55 gallon fiberglassed drums were fitted with the paddle system described above to provide agitation. Each drum was filled with 190 l. of sea water on 10/26/76, and the following added:

1) Kuwait Crude, 155 ml (70 ppm)
2) Kuwait Crude/Corexit 9527, 15.5/3.1 ml
3) Corexit 9527, 3.1 ml

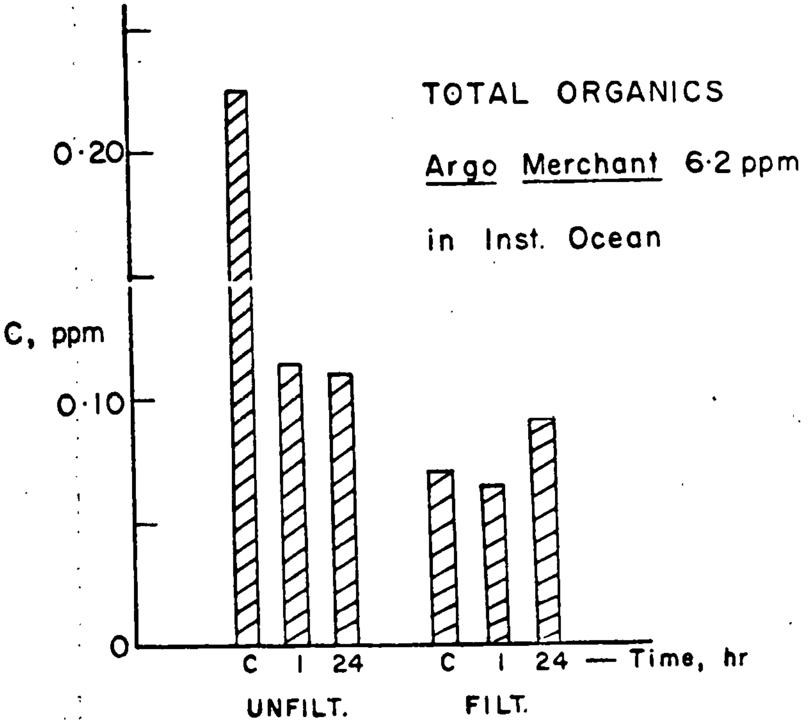


Figure 7.3.2 Total Extractable Organics from Laboratory Experiment on the No. 6 Fuel Oil from the Argo Merchant Spill.

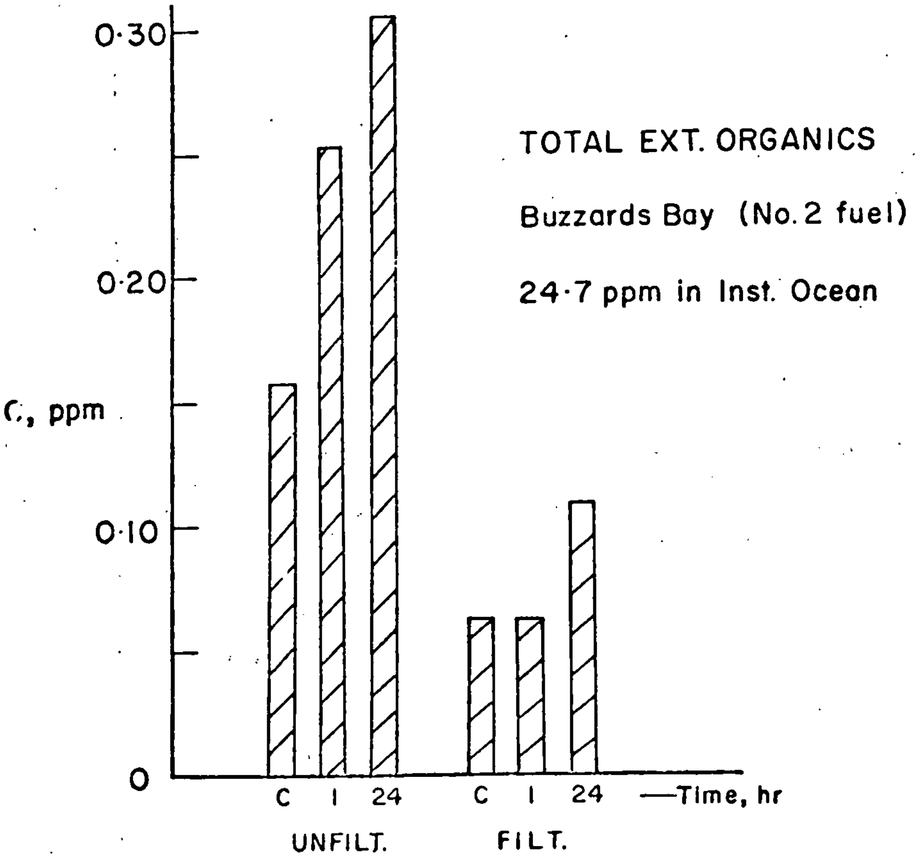


Figure 7.3.3 Total Extractable Organics from Laboratory Experiments on the No. 2 Fuel Oil from the Argo Merchant Spill

The dispersant and oil were thoroughly mixed with sea water in a 1 liter bottle prior to adding to drum #2. A 2 liter water sample was collected while filling the drums and this was used as a control. Samples (2,1) from each drum were collected at 2 and 25 hours at a depth 20 cm from the bottom. The samples were analyzed without adding an internal standard for GC analysis in order to determine the amount of internal standard needed in later experiments. Qualitative results by infrared spectroscopy indicated that an extremely small amount of oil entered the water column when the dispersant was not used.

The above experiment was repeated on 11/11/76 and all samples analyzed for total hydrocarbons, n-paraffins, other resolved components, unresolved hydrocarbons, and amount of dispersants using gas chromatography. The test tanks contained the same amount of water, oil and dispersant as the above experiment. The results of the chemical analysis are given in Table 7.3.2. The control sample contained a total of 10 g/liter of hydrocarbons. The water in the test tank having only the Kuwait Crude contained 108.4 g/liter after 2 hours, and 158.2 g/liter at 25 hours, whereas the test tank containing oil and dispersant had 646.5 g/liter after 2 hours and 20 g/liter after 25 hours. The latter value is much lower than anticipated, and we have no explanation for it at the present time.

In addition to collecting water samples, surface slick samples were also collected during experiments 1 and 2, and their infrared spectra measured. The infrared spectral fingerprints of seven samples were compared using the log-ratio method (1). In this method, the absorptivities for 18 bands in the fingerprint region are ratioed, logs of the ratios calculated and these log-ratios normalized to eliminate differences in sample thickness. Then the number of ratios within 10% of the average ratio are listed. If two samples are identical, all 18 ratios would be equal to the average; thus, the number of ratios within 10% of the average indicates the similarity between samples.

In the present case, spectra of the following samples were compared:

Kuwait = Kuwait Crude

K/D2 = Kuwait/Dispersant in H_2O column after 2 hours.

K/D24 = Kuwait/Dispersant in H_2O column after 24 hours.

Surf 1 K = Kuwait on surface after experiment 1.

Surf 2 K = Kuwait on surface after experiment 2.

Surf 1 K/D = Kuwait/Disp on surface after experiment 1.

Surf 2 K/D = Kuwait/Disp on surface after experiment 2.

The results given in Table 7.3.3 provide some useful comparisons. The fingerprints of the oil in the water column, K/D2 and K/D24, are considerably different from that of the Kuwait crude. The surface oil in the first experiment, Surf 1 K/D, is also very different from the Kuwait oil. In the first experiment, the oil, dispersant and water were

Table 7.3.2

Chemical Analysis by Gas Chromatography of
2nd Aquarium Experiment (11/11/76)

		g/liter of water				
Test Tank	Time	n-paraffins	other resolved components	unresolved envelope	total hydrocarbons	dispersant
Kuwait oil	2 hrs	6.7	16.2	85.5	108.4	—
	25 hrs	13.2	10	135	158.2	—
Kuwait Oil &	2 hrs	97.5	60	489	646.5	240*
Dispersant	25 hrs	--			-20	320
Dispersant	2 hrs	--			-60	300
	25 hrs	--			-25	80
Control	0 hrs	--			-10	—

*based on the area of the GC peak of one component; thus, the amounts listed for the the dispersants are only relative values.

Table 7.3.3

Comparison of Infrared Spectra of Kuwait, Water

Column and Surface Samples from Aquarium Experiments.

Number of ratios within 10% of average are listed.

	Kuwait	K/D^2	K/D^a	Surf$_1$K	Surf$_1$K/D	Surf$_2$K	Surf$_2$K/D
Kuwait	18	7	3	11	5	11	11
K/D$_2$		18	9	10	7	9	8
K/D$_{24}$			18	6	10	8	3
Surf$_1$K				18	2	16	18
Surf$_1$K/D					18	12	7
Surf$_2$K						18	11
Surf$_2$K/D							18

[a] Experiment 1; both samples were separated by TLC

thoroughly mixed in a 1 liter bottle prior to adding to the test tank. The second experiment, oil, and oil/dispersant were added to the test tanks, and then agitated with a stirring rod; thus, both surface samples compared better with the Kuwait oil.

7.3.2 Air Column

1 Charcoal Tubes

(A) Methodology

1) To analyze the air above simulated spills for hydrocarbons, the laboratory apparatus for collecting volatiles is shown in Figure 7.3.4. Initially, water is placed in the central flask and air is pumped through a charcoal filter, around the central flask, and through one of the charcoal cartridges (which becomes the control). Then oil is placed on the water in the central flask, air is pumped through the system, and the hydrocarbons are collected in the second charcoal cartridge.

After the experiment, the two charcoal canisters are extracted with CS_2. Infrared spectra and gas chromatograms of the solutions are measured; both giving qualitative and quantitative analyses.

The first set of experiments was performed on the No. 2 fuel from the Buzzards Bay spill. One hundred and fifty ml. of artificial sea water were placed in the central container and air was pumped through one of the cartridges for 1 hour; this was used as the control. Then 0.1 g of oil was added to the surface of the water and air pumped through the second cartridge for one hour. After the experiment, water from beneath the surface was extracted and analyzed. The gas chromatograms of the cargo oil, the air sample and the water sample are shown in Figure 7.3.5. For this oil, the "separation point" for the chemicals going into the atmosphere from the chemicals going into the water column is the normal paraffin n-C_{14}; the lighter molecules go into the air and the heavier into the water. Later in this report, these laboratory results are compared to the field experiments on this oil (Section 7.6).

2) Following this preliminary experiment, the more sophisticated laboratory apparatus in Figure 7.2.2 (Section 7.2.28) was constructed. When systems 1 and 2 were used, 1 ml of Kuwait crude oil was added to the surface of 150 ml. of sea water in one flask and 1.2 ml of a mixture of 5:1 (v/v) Kuwait crude oil and Corexit 9527 dispersant, were added to 150 ml of sea water in the other flask. The surface and the water were not mixed.

When system 3 was used (Fig. 7.2.6), 2 ml of Kuwait crude oil were added to the surface of 800 ml of sea water in each of the beakers, 0.4 ml of Corexit were then added dropwise to one of the beakers. The beakers were shaken immediately after the dispersant was added for a few seconds. This caused the water in the beaker containing the oil and dispersant to darken. In a few experiments, the system was continuously mixed by magnetic stirrers. Identical magnetic stirrers were used in both beakers and the stirring rate was approximately the same.

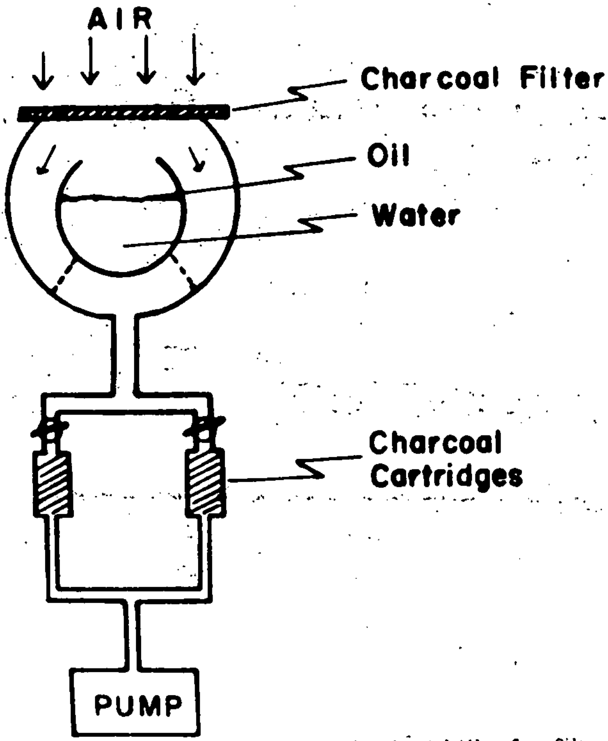


Figure 7.3.4 Laboratory Apparatus for Collecting Volatiles from Oil Slicks

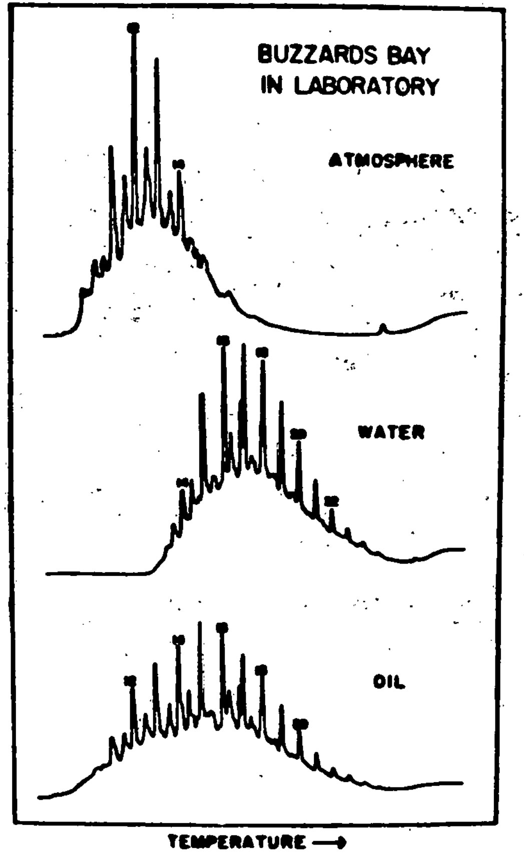


Figure 7.3.5 Gas Chromatograms from the Laboratory Experiment on the No. 2 Fuel Oil from the Buzzards Bay Spill

Air samples were taken simultaneously from both the treated and untreated slicks. In experiments when flow rates were measured, they did not differ by more than 10. Air samples were collected periodically after the spills. Experiments were conducted using 3 different flow rates of 0.2, 1.5 and 4.3 l/min.

Since air samples taken above treated and untreated spills were compared to evaluate the effects of the dispersant, it was important to determine error limits by comparing two identical oil samples. Oil was added to flasks 1 and 2 of systems A, B, and C; air samples were taken from both parts simultaneously and their gas chromatograms were compared. The results of such experiments indicate those differences which are significant when a dispersant is used. The conditions for these experiments are listed in Table 7.3.4.

Three different types of experiments were performed to determine the effects of using dispersants:

a) Using apparatus 1 and 2, oil and oil + dispersant were added and the surface was not mixed.

b) Using apparatus 3, oil was added and then the dispersant was added dropwise. The beakers were shaken for a few seconds after adding the oil and the dispersant.

c) Same as 2 with continuous stirring by magnetic stirrers. Table 7.3.5 lists all experiments performed in the laboratory on evaporation of oil vs. oil + dispersant.

In experiment 6, surface samples were taken at times 1.5 and 4 hours after the spill. In experiment 11, surface samples were collected with a spatula and dried with calcium chloride. Hexane was added to deasphalt the oil. The samples were then centrifuged to remove the calcium chloride and the asphalt precipitate.

IR spectra were measured using 6 mm (pathlength) cells with silver chloride windows and teflon or stainless steel spacers. Carbon disulfide was used as a solvent for the IR measurements.

Another type of experiment was performed. A random mixture of pentane, hexane, octane, nonane, decane, dodecane, tetradecane, o-xylene, p-xylene, m-xylene, toluene and benzene was prepared. About 1 ml of the mixture was added to 150 ml of sea water and 1 ml of the mixture and 0.2 ml Corexit were added to another flask with 150 ml of sea water. Vapors were collected using apparatus A; the flow rate was about 0.2 l/min and the water was not mixed. The same experiment was performed using apparatus B and the flasks were shaken after adding the mixtures. A flow rate of 3.4 liters/min was used for this experiment.

(B) Experimental Results

(i) Oil vs. oil on water-evaporation experiments

Experiments 1-5, as mentioned in the above section, were performed in order to find the experimental errors of systems 1, 2, and 3 and to

Table 7.3.4

Flow Rates and Sample Times for Laboratory Experiments 1-5

Exp #	Water Temp. OC	Time Taken	System	Flow Rates oil 1	Flow Rates oil 2
1	19	0-0.5	A	1.56	1.56
		0.5-1.5	A	1.44	1.40
		1.5-4	A	1.24	1.40
2	19	0.5-1.5	B	1.56	1.56
3	19	0-0.5	B	1.52	1.52
		0.5-1.5	B	1.56	1.56
4	18	0-0.5	C	2.00	2.10
		0.5-1.5	C	1.76	1.84
5	18	0-0.5	C	4.30	4.30
		0.5-1.5	C	4.30	4.30

Remarks:
Time - hours after the spill.
Flow rates are in lit/min.
In experiment 2, did not pump during 0-0.5 hours.
In experiment 4, distance between funnel and beaker 2.5 cm.
In experiment 5, distance between funnel and beaker 1.5 cm.
and there was 1200 ml sea water in the beakers.

Table 7.3.5

Flow Rates and Sample Times for Laboratory Experiments 6-16

P	Water Temp.	Time Taken	System	Flow Rate		Mixing
	oC			oil	oil/disp	
6	20	0-1.5	A	< 0.2	< 0.2	no
		1.5-4	A	< 0.2	< 0.2	
7	20	0-1.5	A	< 0.2	< 0.2	
		0.5-4	A	< 0.2	< 0.2	
8	20	0-1.5	A	< 0.2	< 0.2	no
		1.5-4	A	< 0.2	< 0.2	
9	20	0-1.5	A	< 0.2	< 0.2	no
		1.5-4	A	< 0.2	< 0.2	
10	17	0-0.5	A	< 0.2	< 0.2	no
		0.5-1.5	A	< 0.2	< 0.2	
		1.5-4	A	< 0.2	< 0.2	
		4-7	A	< 0.2	< 0.2	
		7-12	A	< 0.2	< 0.2	
		12-23	A	< 0.2	< 0.2	
		23-31	A	< 0.2	< 0.2	
11	17	0-0.5	A	1.44	1.44	no
		0.5-1.5	A	1.44	1.44	
		1.5-4	A	1.36	1.24	
		4-7	A	1.56	1.56	
		7-12	A	1.44	1.56	
		12-24.5	A	1.52	1.52	
		24-5-31	A	1.52	1.52	
12	16	0-0.5	B	4.24	4.28	no
		0.5-1.5	B	4.04	4.32	
		1.5-4	B	4.28	4.04	
13	16	0-0.5	C	1.60	1.60	yes
		0.5-1.5	C	1.60	1.60	
		1.5-4	C	1.60	1.60	
		4-7	C	1.60	1.60	
		7-23.25	C	1.60	1.60	
		23.25-29	C	1.60	1.60	
14	15	0-0.5	C	1.60	1.60	yes
		0.5-1.5	C	1.60	1.60	
		1.5-4	C	1.60	1.60	
15	18	0-0.5	C	1.60	1.60	const.
		0.5-1.5	C	1.60	1.60	
		1.5-4	C	1.60	1.60	
16	18	0-0.5	C	1.60	1.60	const.
		0.5-1.5	C	1.60	1.60	
		1.5-4	C	1.60	1.60	
		4-7	C	1.60	1.60	

Remarks:

Flow rates are in lit/min.

Time is in hours after the spill.

Const. = constant mixing during the entire experiment.

determine if differences between the evaporation of oil and oil + dispersant slicks are due to the dispersant or to the experimental conditions and procedures. When both parts of the system contained only oil, differences in the evaporation rates could be caused by differences in flow rates, or differences in the crude filters used in system A. Since only the GC peaks of the normal alkanes were definitely identified and their GC peaks are the most intense, they were used to compare the two samples. Each sample, i.e., the one taken above part 1 and the one taken above part 2, contained the same amount of internal standard (n-C_{20}). The relative heights of the GC peaks of each normal alkane to the height of n-C_{20} were calculated and plotted as a function of the carbon number of that certain n-alkane. The plots for experiment No. 1 for the samples collected during 0-0.5, 0.5-1.5 and 1.5-4 hrs. after the oil addition are shown in Figure 7.3.6. The evaporation rates of oil components from the slick were ordered according to their vapor pressures, i.e., heptane, octane, etc. Usually after 0.5 hrs., these graphs have maxima which change with time towards the heavier n-alkanes. For example, in experiment 1 (slick 1) the sample taken during 0.5-1.5 hrs. had a maximum at n-C_9, whereas in the sample taken at 1.5-4 hrs. the maximum moved to n-C_{10}.

The ratio HC_x/HC_{20} (x=7,8,.....), where HC_x is the GC peak height of a normal alkane with x carbons and HC_{20} is the GC peak height of n-C_{20}, is proportional to the amount of n-C_x that evaporated. This ratio for a particular n-alkane in two air samples taken under the same conditions can be compared, i.e., the ratio HC_8/HC_{20} in air samples taken during the same time and in the same experiment above slick 1 and slick 2. This comparison was justified since the collection efficiency, extraction efficiency, detector response, GC conditions (temperature and flow rate) and the amount of standard added to both samples were the same. The envelope formed by these plots indicates when a certain n-alkane starts to evaporate and when its evaporation process is over. The differences in the shape of the envelopes of two samples taken during the same time and conditions indicate differences in the evaporation process of the light components from the slick. For experiments 1-5, the more similar the shapes of the envelopes of the two samples taken simultaneously, the better, i.e., it means that the system is good for determining the effects of dispersants on the evaporation.

Figure 7.3.6 shows the envelopes obtained for experiment 1. When system A was used, there was a difference in the position of the maximum in the samples of 0.5-1.5 and 1.5-4 hrs. The evaporation rates of the two identical slicks were different. Slick No. 1 had a faster rate. It could be that the crude filters were not exactly identical and have caused the differences. Experiments 2 and 3 were performed using apparatus B which is similar to apparatus A, with the filters removed. Results of these experiments are illustrated in Figure 7.3.7. The envelopes obtained for slicks 1 and 2 at 0.5-1.5 had the same shape. The evaporation process was faster when the filters were removed and the maximum of the envelope was at n-C_{10} for both slicks in experiments 2 and 3, whereas in experiment 1, it was at n-C_8 for slick 2 and at n-C_9 for slick 1. Collection efficiency decreased from experiment 1 to experiments 2 and 3. This could be due to the removal of the filters. When they covered the apparatus, they could have interfered in the escape of vapors into the room atmosphere, so less was lost and more was collected;

Figure 7.3.6 Evaporation Profiles from Oil Slicks - Experiment 1

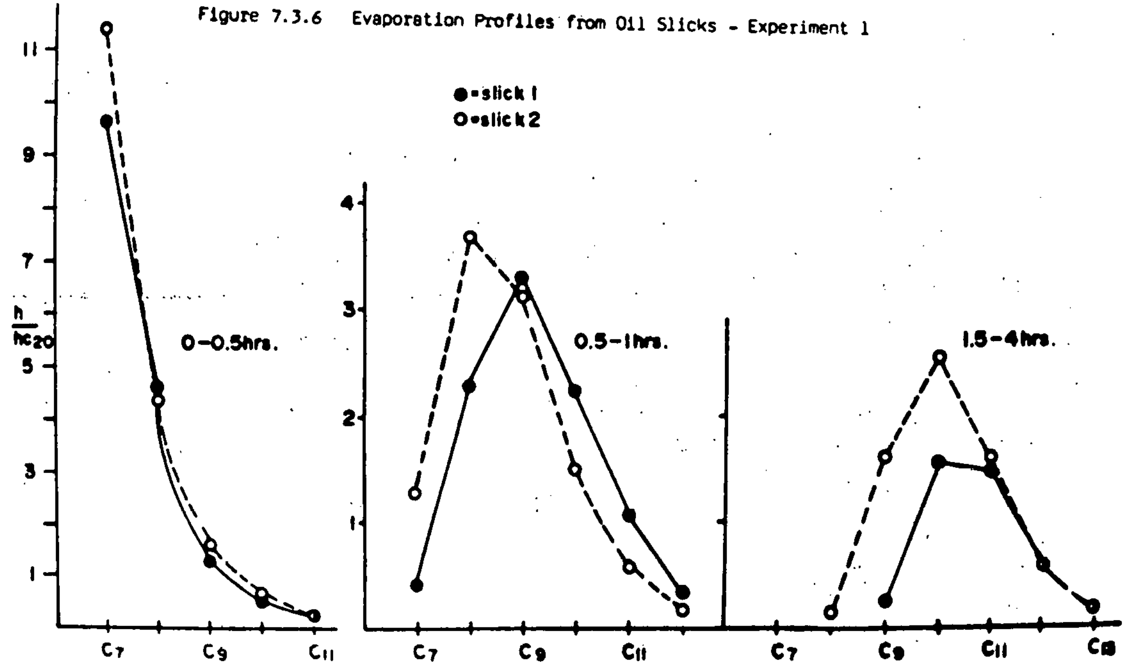
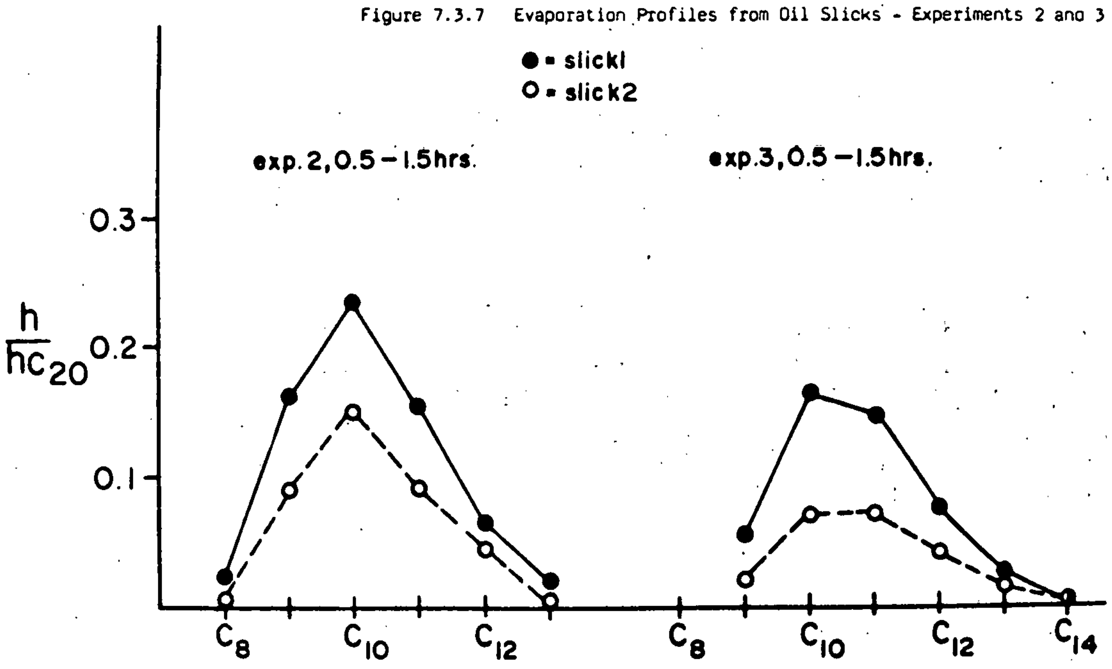


Figure 7.3.7 Evaporation Profiles from Oil Slicks - Experiments 2 and 3



this could also be the reason for the slower evaporation rate.

The results of experiments 1, 2 and 3 indicated that another system should be tried in which more sea water and more oil would be used. This would ensure that the air samples would be concentrated enough without having to interfere in the natural evaporation process, e.g., partially closing the system. System C seemed to fulfill those requirements. Figure 7.3.8 shows the results obtained when apparatus C was used (experiment 4). There is a slight difference between the two envelopes in the relative amounts of n-C_{10} and n-C_{11} (less than 10). Experiment 5 was the same as experiment 4 except for the flow rate that was higher and the distance between the oil slicks and the funnels, which was smaller in experiment 5. Results are illustrated in Figure 7.3.9; samples were too concentrated and the evaporation rate was slower than in experiment 4, possibly because the funnels were too close to the oil surface. Differences between the two envelopes were in the same order as in experiment 4.

(ii) Oil vs. oil + dispersant evaporation experiments

a) Experiments with no mixing of the surface:

Laboratory experiments 6-9 were performed under identical conditions. Samples were taken at 0-1.5 and 1.5-4 hrs. after adding the oil and oil + dispersant using system 1. The n-alkane GC peaks were identified by retention time. Toluene, p-xylene, m-xylene, and o-xylene GC peaks were also identified by retention time and, furthermore, their GC effluents were collected and IR spectra measured. The IR spectra showed that their peaks contained an additional component, which was probably a branched alkane. The benzene peak was identified by retention time and by the appearance of the benzene band at 670 cm^{-1} in the IR spectrum of the mixture. For air samples collected at 0-1.5 hrs., the following ratios of the GC peak heights were calculated: benzene/octane, toluene/nonane and p-xylene + m-xylene/nonane. Table 7.3.6 lists the values obtained.

From the values shown in Table 7.3.6, it can be observed that the corresponding ratios are bigger in the oil + dispersant sample than in the oil sample. This could mean that there was less octane and nonane evaporating from the treated slick than from the untreated slick, or that more of the benzenes were evaporating from the untreated slick. This could be caused by the dispersant mixing more aliphatic than aromatic hydrocarbons into the water column. Decane was not taken into consideration in the calculations as its corresponding GC peak was small and it also contained o-xylene.

Figure 7.3.10 shows the gas chromatograms of the air samples above the treated and untreated oil spills taken at 0-1.5 hrs.

It was interesting to see whether this phenomenon also occurred when mixing was applied; thus, experiments 15 and 16 were performed with constant mixing. When calculating the above mentioned ratios for samples taken at 0-0.5 hrs., the trend found in experiments 6-9 was not observed. When mixing was applied, the dispersant affected the light and the heavy hydrocarbons differently, whereas without mixing the dispersant

Figure 7.3.8 Evaporation Profiles from Oil Slicks - Experiment 4

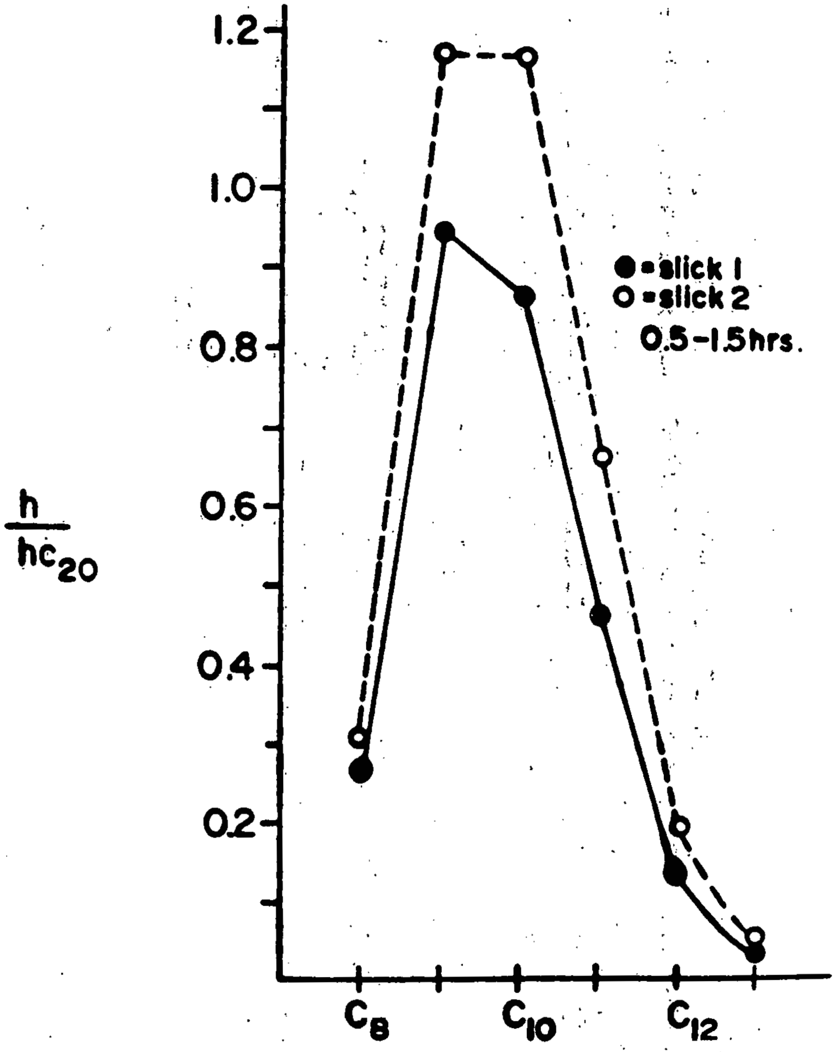


Figure 7.3.9 Evaporation Profiles from Oil Slicks - Experiment 5

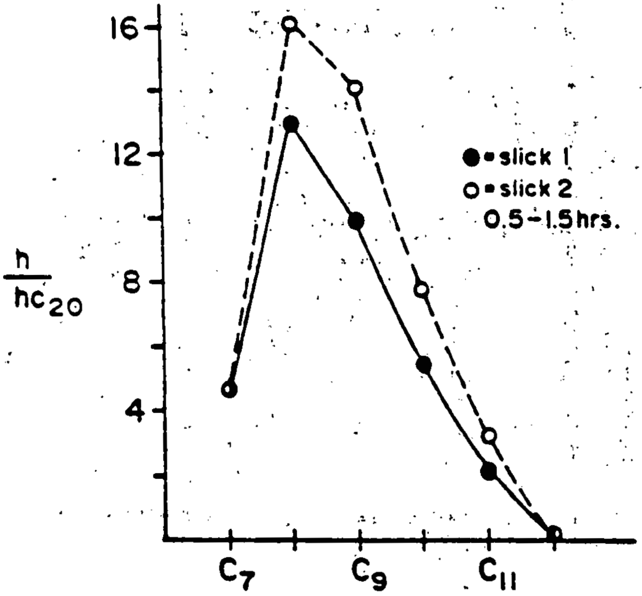


Figure 7.3.10 GC of Air Samples at 0-1.5 Hours

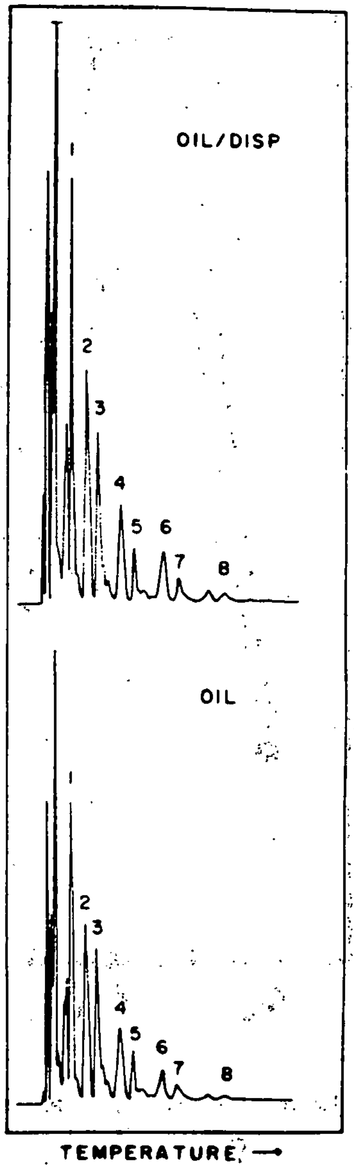


TABLE 7.3.6
Ratios of GC Peak Heights for Experiments 6-9

	Exp 6		Exp 7		Exp 8		Exp 9	
	Oil	Oil/Disp	Oil	Oil/Disp	Oil	Oil/Disp	Oil	Oil/Disp
ben/oct	1.16	1.35	1.17	1.37	1.07	1.54	1.11	1.25
tol/non	1.36	1.70	1.54	2.00	1.37	2.50	1.29	1.35
m-xy/non	0.63	0.93	0.65	0.82	0.64	1.12	0.67	0.79

ben = benzene

tol = toluene

non = nonane

oct = octane

o,m-xy = p-xylene + m-xylene

affected aromatics and aliphatics differently. This is illustrated in Table 7.3.7 which shows the ratios of corresponding peak heights in the two gas chromatograms obtained from air samples in experiment 15. The order of the compounds in Table 7.3.7 is the order in which their peaks appear on the gas chromatogram. If relative amounts of those components were the same in both samples, those ratios should have been constant; however, they increase from the lighter components toward the heavier ones, indicating that relatively less of the light ones, such as heptane, benzene and octane, evaporated from the treated slick.

The chromatogram of the samples taken at 1.5-4 for experiment 6-9, Figure 7.3.11, show that the evaporation was faster for the oil slick. The n-C_7 peak was very small in the oil sample and n-C_9 was the strongest peak. In the oil + dispersant sample, n-C_7 was relatively more intense and n-C_8 peak was almost as high as the n-C_9 peak. Surface samples taken in experiment 6 at 1.5 and 4 hrs. after the spills indicated the same results, i.e., the oil slick evaporated faster. After 4 hrs., n-C_8 was gone from the oil slick, but it still appeared in the oil + dispersant slick. Slight mixing might have been performed when the surface samples were collected and when charcoal tubes were changed.

In order to obtain more conclusive data about the effect of the dispersant on aromatic and aliphatic hydrocarbons, a known mixture of light aromatics and aliphatic hydrocarbons was investigated. When no mixing energy was applied there was no significant difference between the relative heights of the n-alkanes and benzene with and without dispersant. When mixing was applied, there were differences; the amount collected above the mixture was larger than the amount collected above the mixture/dispersant. The relative amounts of benzene, octane, n-C_{12} and n-C_{14} in the mixture/dispersant were higher than in the mixture only. Relative amounts of Toluene, p-xylene + m-xylene and decane + o-xylene were the same in both samples. Table 7.3.8 shows the ratios of the peak heights in both samples. These results suggest that the dispersant has different effects on light hydrocarbons than on heavier ones without regarding aromatic character but, as this is a simple mixture and not oil, it may be inaccurate to apply results from one system to the other.

In experiment 10 and 11, air samples were taken over 30 hrs. so that evaporation rates of heavier hydrocarbons could be obtained. Experiments 10 and 11 were the same except for the flow rate of the pump, which was higher in experiment 11. Evaporation rates of each of the n-alkane can be obtained by plotting the total amount collected during time x as a function of time. The total amount of a certain n-alkane collected up to a certain time is proportional to the sum of HC_x/HC_{20} in the air samples taken up to that time. For example, the total amount of n-C_8 that was collected during 4 hrs. will be proportional to: (HC_8/HC_{20}) 0-0.5 + (HC_8/HC_{20}) 0.5-1.5 + (HC_8/HC_{20}) 1.5-4. This is correct only if the same amount of standard was added to all samples. Since the collection efficiency is unknown, the proportionality constant between the total amount evaporating and the sum of the relative height cannot be calculated, but plotting that sum as a function of time will be sufficient to show evaporation rates.

Table 7.3.7 Ratio of Corresponding Peak Heights - Experiment 15

hep	R-ben	R-oct	R-tol	R-non	R-p,m-xy	R-o-xy-+dec
8	0.91	0.92	1.3	1.34	1.57	2.3

Is the ratio of the GC peak height of x in the oil/dispersant sample the GC peak height of x in the oil sample.

h = heptane

b = benzene

o = octane

n = nonane

t = toluene

m-xy = p-xylene + m=xylene

xy+dec = o-xylene + decane

Table 7.3.8 Ratio of GC heights for Both Samples

R-oen	R-oct	R-tol	R-non	R-p,m-xyl	R-o-xyl+dec	R-dode
1.02	1.21	1.71	1.69	1.72	1.76	0.47

Is the ratio of the GC peak height of x in the mixture sample to the peak height of x in the mixture/dispersant sample.

ben = benzene

oct - octane

tol - toluene

non = nonane

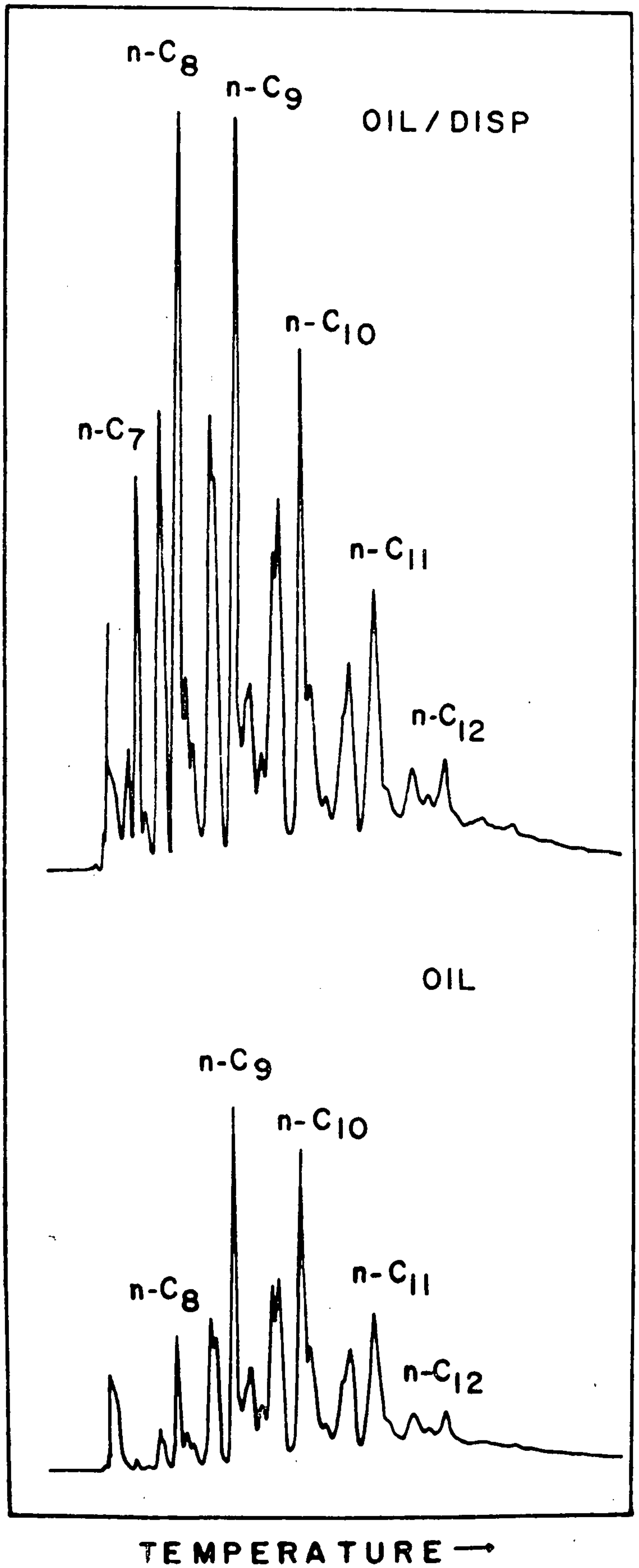
p,m-xyl = p-xylene + m-xylene

o-xyl+dec = o-xylene + decane

dode = dodecane

tetd = tetradecane

Figure 7.3.11 GC of Air Samples at 1.5-4 Hours - Experiments 6-9



Figures 7.3.12, 7.3.13, and 7.3.14 show the envelopes obtained for experiment 10. Comparison to experiment 1 indicates that the small differences in the evaporation rates of the oil slick and the oil + dispersant slick is insignificant and that they actually behaved similarly. Figure 7.3.15, 7.3.16, and 7.3.17 show the evaporation rates of n-C_7 to n-C_{14}; again the n-alkanes of both slicks evaporated at about the same rates.

The total amount of vapors collected is proportional to the relative areas of the whole chromatogram of the air sample (not including n-C_{20}) to the n-C_{10} peak area. By plotting the total relative area as a function of time, total evaporation rate of the slick can be obtained. Figure 7.3.18 shows the evaporation rate of the slicks for experiment 10. The slight difference between the oil and the oil + dispersant slicks is meaningless and the evaporation rates can be considered the same.

When looking at the envelopes (Figure 7.3.19, 20 and 21 obtained for experiment 11, and at the evaporation rates of the individual n-alkanes (Figure 7.3.22, 23 and 24) it can be concluded that the evaporation process is faster in the oil slick than in the oil + dispersant slick. When comparing the difference to the results of experiment 1, it is really difficult to say whether the differences were due to the dispersant or not, since they were very much like the differences occurring in experiment 1. Figure 7.3.25 shows that the total evaporation rates of the slicks were similar.

Since the only difference in the experimental conditions in experiments 10 and 11 was the pump flow rate, it could be assumed that the oil slick is affected to a greater extent from the pumping rate than the oil + dispersant slick. Experiment 12 was performed to verify this. Since the crude filters could cause differences, they were removed (system B used) and the pump flow rate was increased by a factor of almost 3. Samples in experiment 12 were taken only up to 4 hrs.; this was enough to determine the rate of evaporation and the differences between the treated and untreated slicks. This experiment gave very close results for the n-alkanes evaporating from both slicks as illustrated in Figures 7.3.26 and 27. Therefore, the flow rate does not affect the oil slick by causing it to evaporate faster.

Experiments 6 to 12, which were all performed without mixing, did not show a constant trend; evaporation was either the same or the untreated slick evaporated slightly faster. However, the difference was not much larger than in experiment 1 (oil vs. oil, using system A). When the surface was not mixed, the dispersant did not have a significant effect on the evaporation of the n-alkanes.

b) Experiments with mixing directly after the spill

In the case of an oil spill in the open sea, there is mixing of the surface slick into the water column by waves; thus, it is necessary to determine the effect of mixing on the dispersant. Experiments 13 and 14 were performed using system C. The oil was first added to both beakers and the dispersant was then added to one of them and both beakers were shaken for a few seconds. After shaking the beakers, the water in the

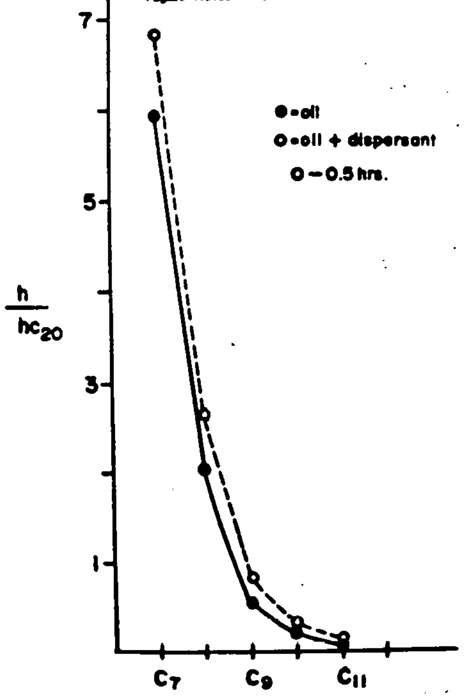


Figure 7.3.12 Evaporation Rates Experiment 10

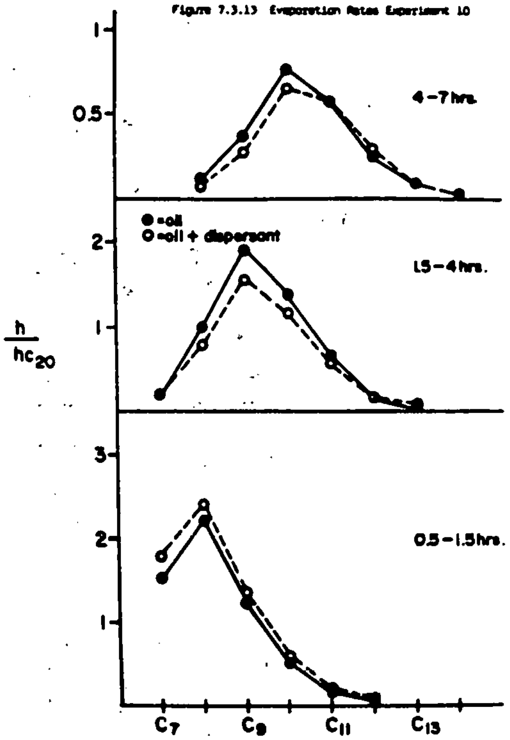


Figure 7.3.13 Evaporation Rates Experiment 10

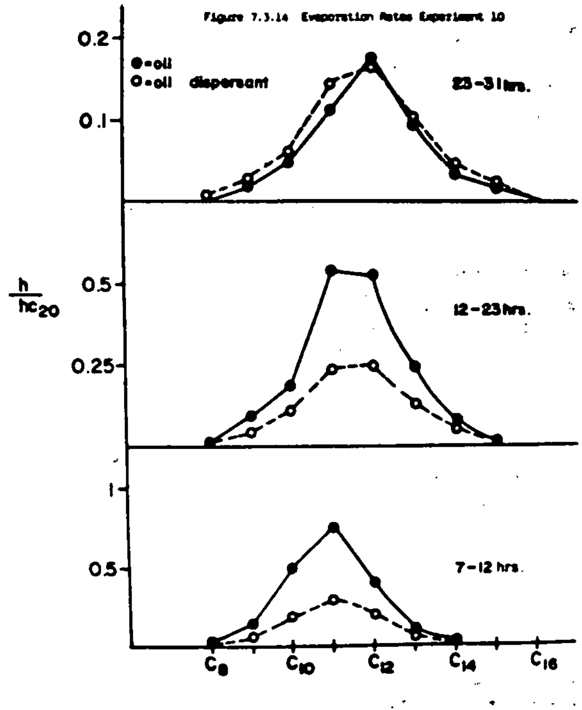


Figure 7.3.14 Evaporation Rates Experiment 10

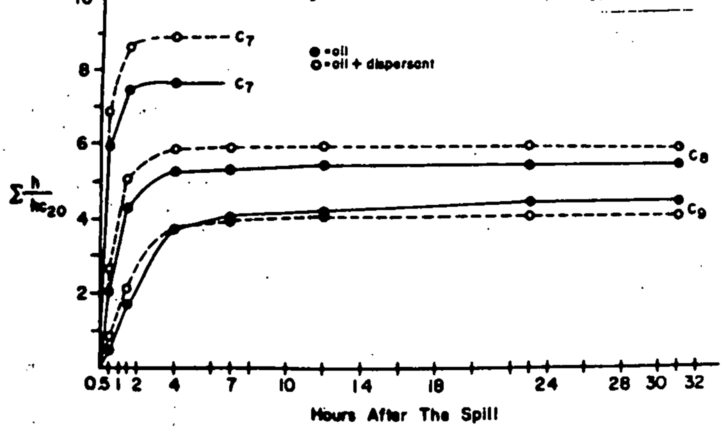


Figure 7.3.15 Evaporation Rates of nC_7 to nC_{14}

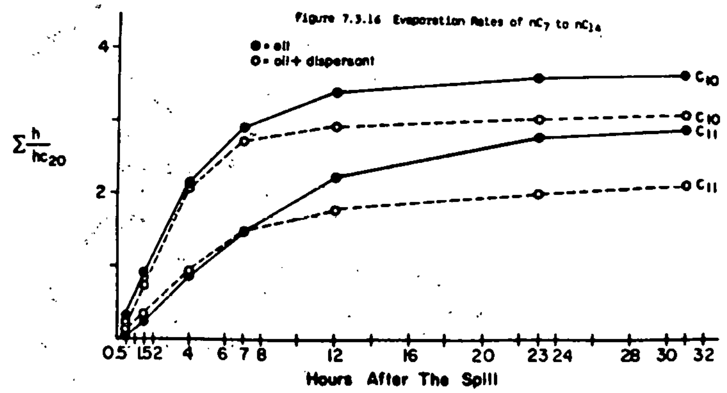


Figure 7.3.16 Evaporation Rates of nC_7 to nC_{14}

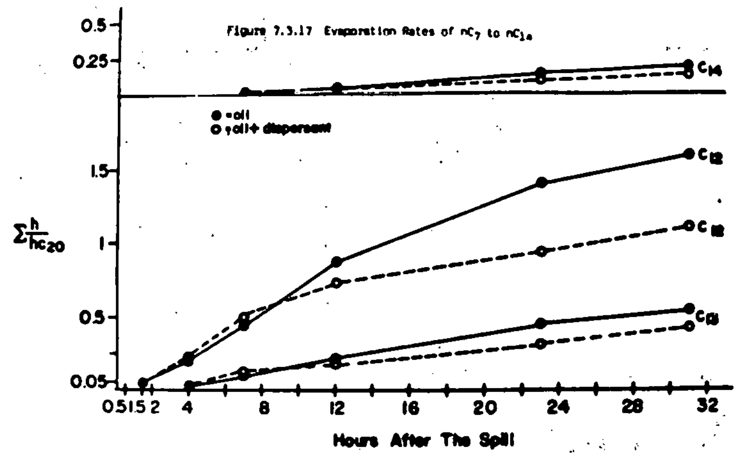


Figure 7.3.17 Evaporation Rates of nC_7 to nC_{14}

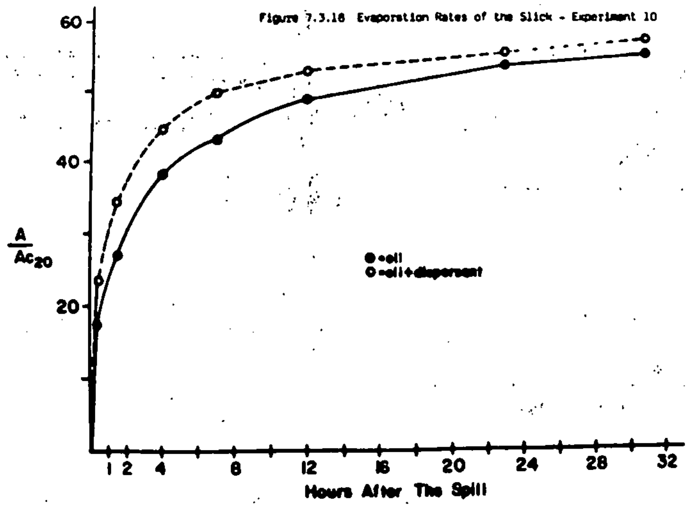


Figure 7.3.18 Evaporation Rates of the Slick - Experiment 10

Figure 7.3.19 Evaporation Rates - Experiment 11

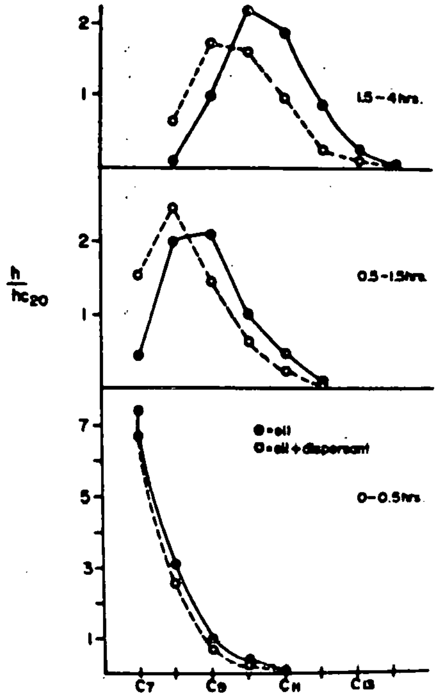


Figure 7.3.20 Evaporation Rates - Experiment 11

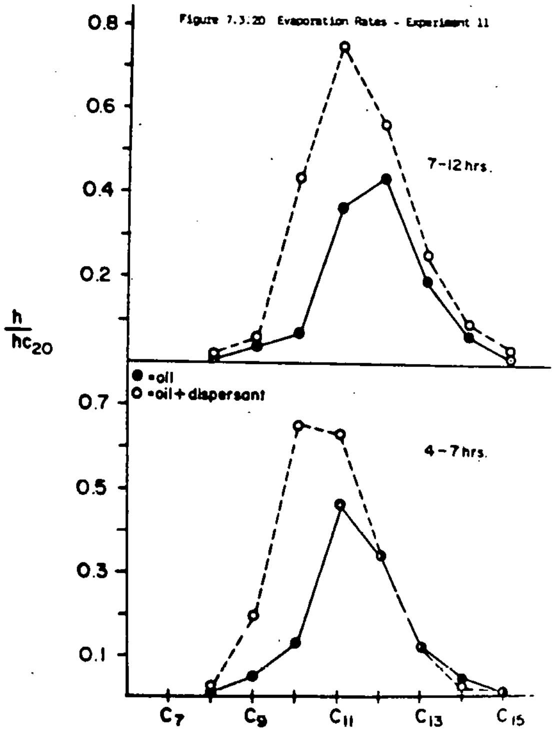


Figure 7.3.21 Evaporation Rates - Experiment 11

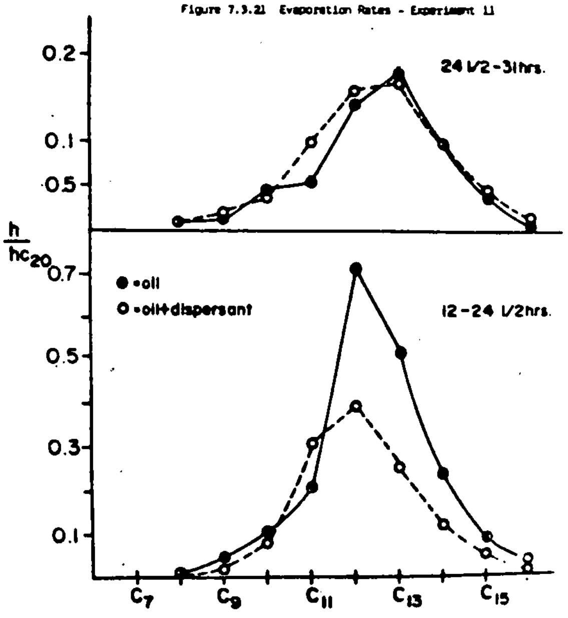
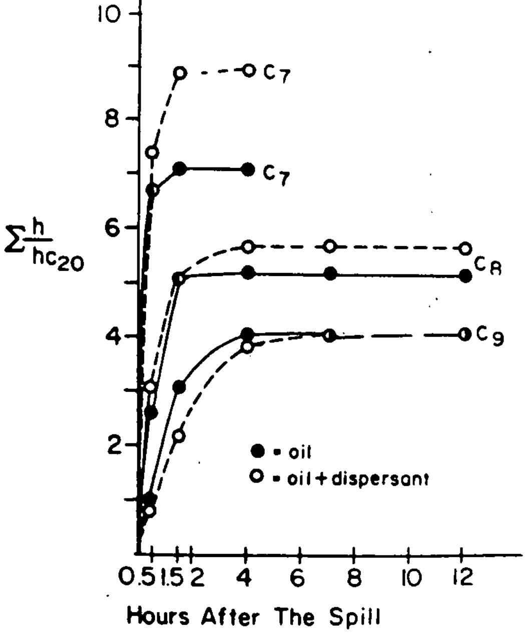


Figure 7.3.22 Evaporation Rates - Experiment 11



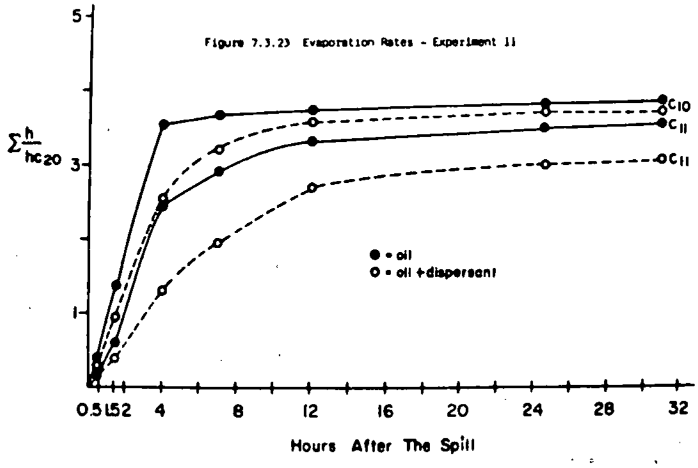


Figure 7.3.23 Evaporation Rates - Experiment 11

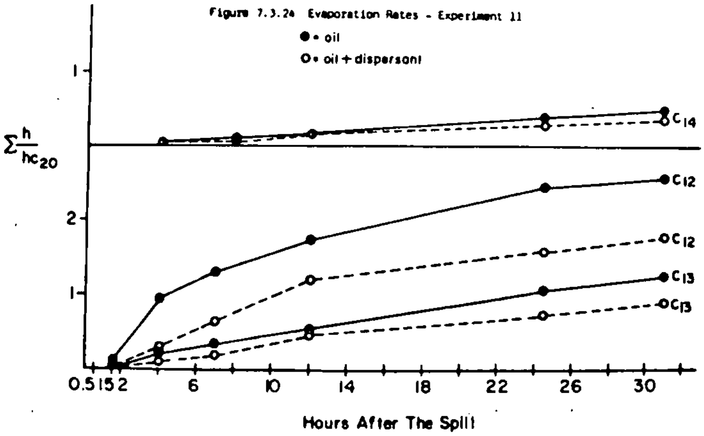


Figure 7.3.24 Evaporation Rates - Experiment 11

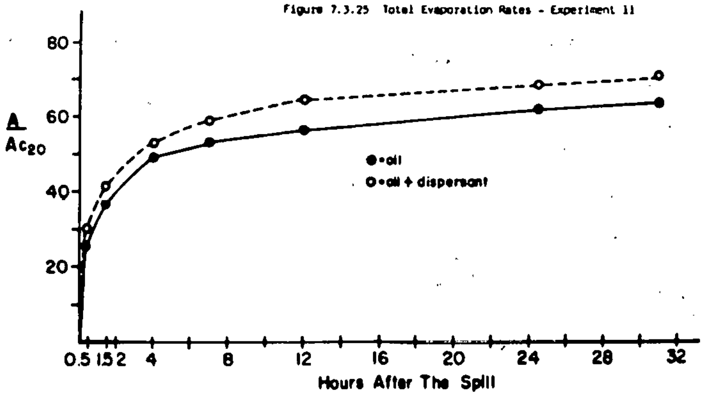


Figure 7.3.25 Total Evaporation Rates - Experiment 11

Figure 7.3.26 Evaporation Rates - Experiment 12

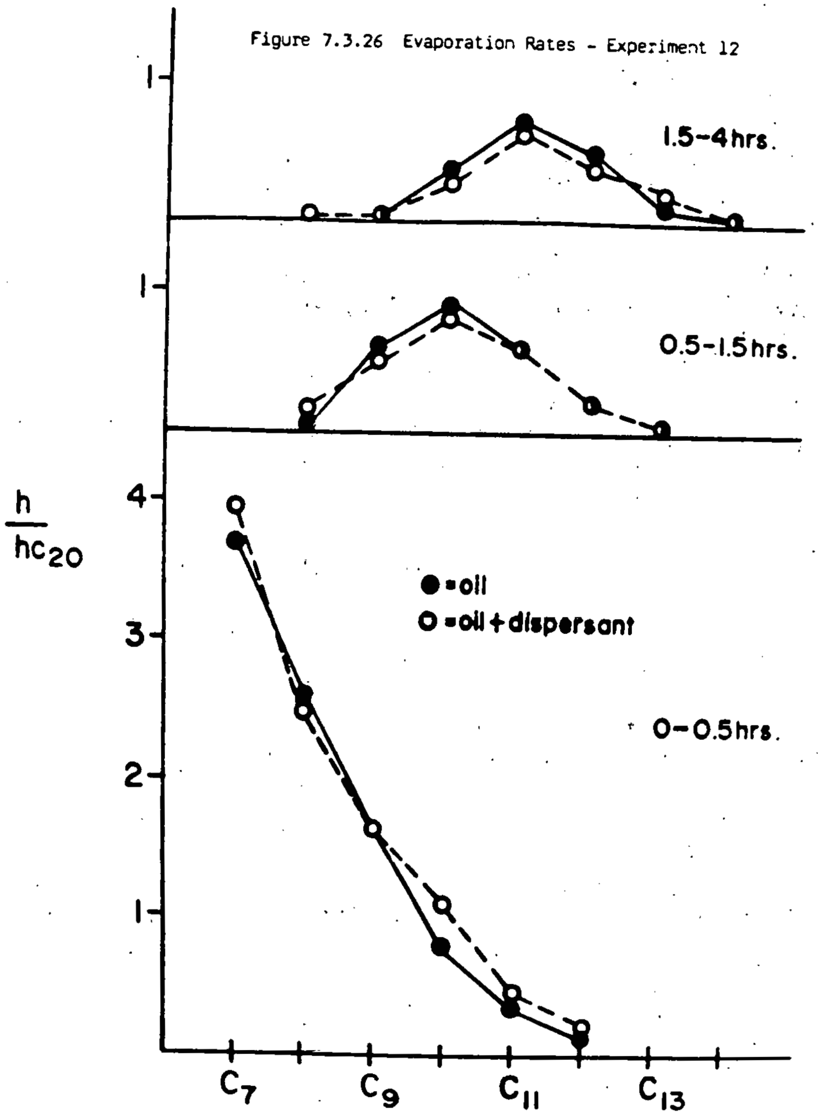
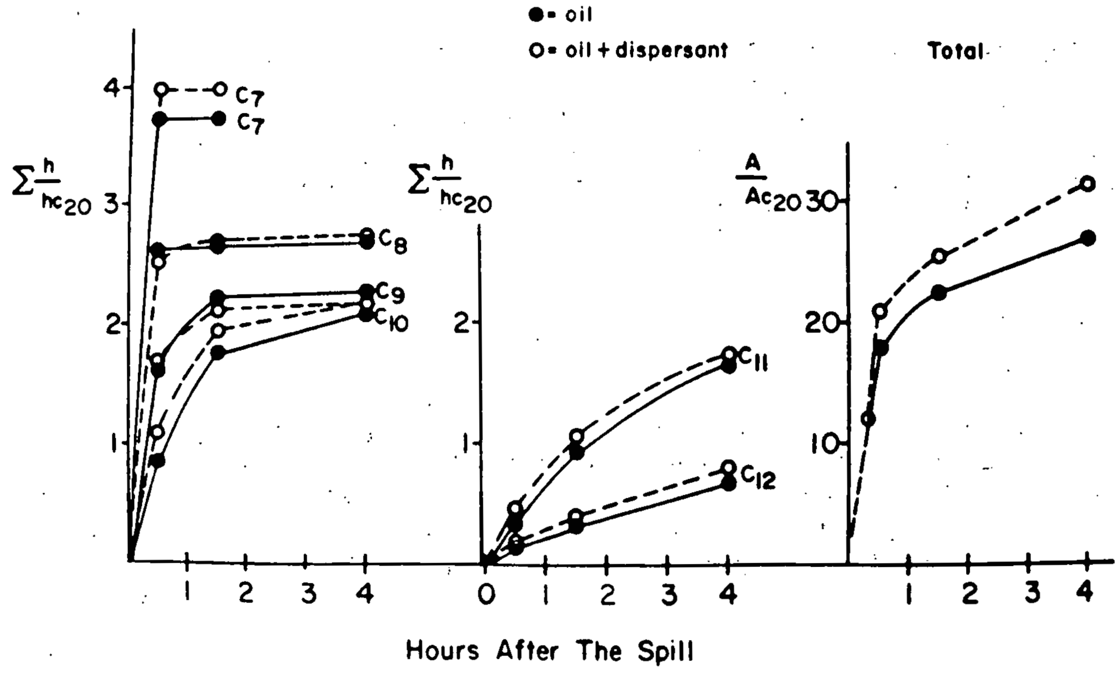


Figure 7.3.27 Evaporation Rates - Experiment 12



oil only beaker remained clear, whereas the water in the oil + dispersant beaker became dark. However, the color gradually became lighter indicating that some of the oil originally in the water was returned to the surface. Mixing made the dispersant more effective and the evaporation rate of the n-alkanes from the treated slick was slower than from the untreated slick. The difference was larger than could have been caused by experimental errors as indicated in experiment 4. Figures 7.3.28 and 7.3.29 show the difference in the relative heights of the n-alkanes as a function of the carbon number. n-C_7 showed up in the air sample taken above the treated slick during 1.5-4 hrs., whereas n-C_8 was very weak and n-C_7 disappeared from the corresponding air sample taken above the untreated slick. The heavier components such as n-C_{12}, n-C_{13}, n-C_{14} and n-C_{15} started to appear in both samples at about the same time, but it took much longer for the light ones, n-C_7 to n-C_{10} to evaporate from the treated spill as indicated by Figures 7.3.30 and 31.

c) Experiments with constant mixing during the entire experiment.

In experiments 13 and 14, mixing was applied only at the beginning of the experiment; the effects of a dispersant will probably be even greater when there is constant mixing throughout the experiment. Experiments 15 and 16 were performed with constant mixing. At the beginning of the experiment, the beakers were shaken and then the water was stirred with magnetic stirrers. This kept the water of the treated spill dark while the water of the untreated spill was clear with only a few drops of oil sinking to the bottom of the beaker and rising to the surface. In these experiments, there was a big difference between the evaporation of the two slicks; the oil + dispersant air samples did not show a normal envelope, but one that had a flat maximum and a minimum as is shown in Figures 7.3.32 and 33. Evaporation was much slower for the treated spill, n-C_7 was still coming off the treated slick after four hours, whereas, n-C_8 was gone from the untreated slick. The heavier n-alkanes such as n-C_{12} to n-C_{15} showed up at about the same time from both slicks. In the untreated slick, the order in which the components evaporated seemed different from the order expected from vapor pressures. Figures 7.3.34 and 35 show the evaporation rates of n-C_7 to n-C_{12}. The largest differences are found in the lighter components.

Surface samples of the slicks were taken at 7 hrs. after the spill. Their chromatograms are shown in Figures 7.3.36. In the oil slick, all components lighter than n-C_{11} had already evaporated but in the oil + dispersant slick sample, all components heavier than n-C_8 appeared. The data obtained from the surface are samples were in agreement with those obtained from the oil samples; evaporation was faster from the untreated slick.

(C) Conclusions:

The laboratory study using the self-mixing dispersant Corexit 9527, indicated the evaporation of the n-alkanes from the treated and untreated slicks was similar when the water was not agitated. However, when mixing was applied, the effects of the dispersant on the evaporation became significant. The evaporation of the light n-alkanes, n-C_7 to n-C_{10}, from the treated slick was slower than from the untreated slick. The longer the mixing, the greater was the effect of the dispersant on the

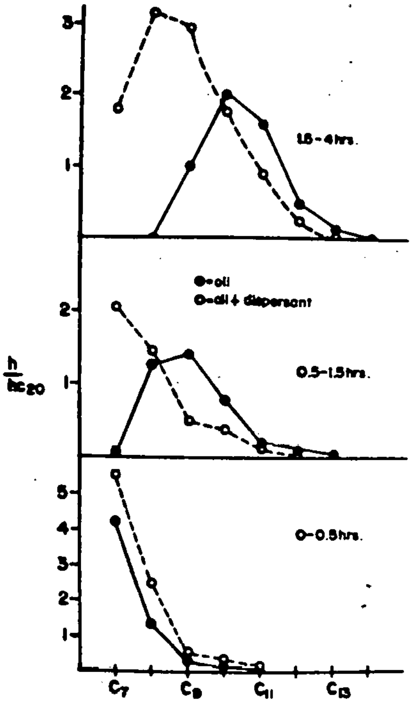


Figure 7.3.28 Relative GC Peak Heights of the n-alkanes as a function of the carbon number: C_7, C_9, C_{11}, C_{13}. 0.5 - 1.5 hrs.

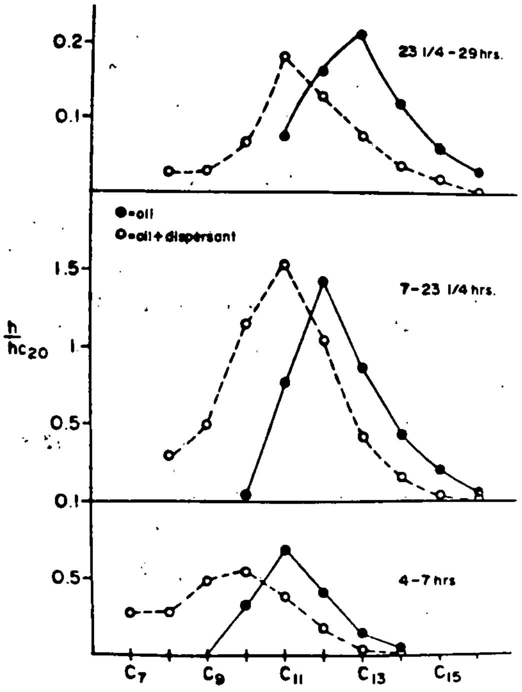


Figure 7.3.29 Relative GC Peak Heights of the n-alkanes as a function of the carbon number C_7, C_9, C_{11}, C_{13}, 7-23 1/4 hrs.

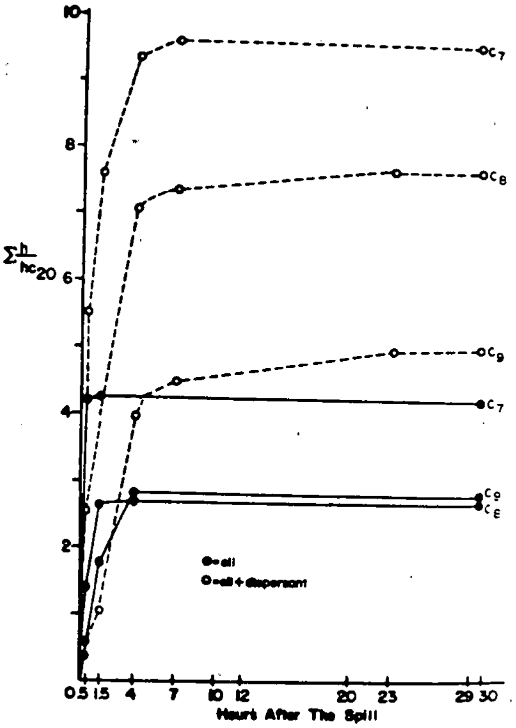


Figure 7.3.30 Evaporation Rates of $n-C_7$, $n-C_8$ and $n-C_9$ Experiments 13 and 14

Figure 7.3.31 Evaporation Rates of n-C_{10} to n-C_{13} - Experiments 13 to 14

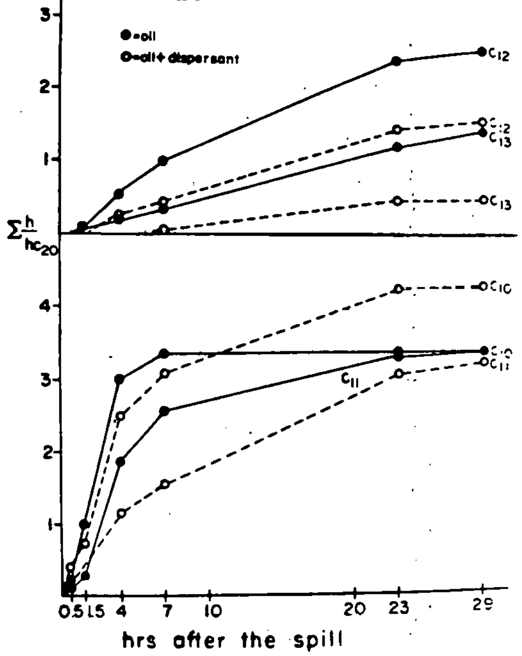


Figure 7.3.32 Relative GC Peak Heights of the n-alkanes as a function of the carbon number. Air Samples, Experiments 13 and 14.

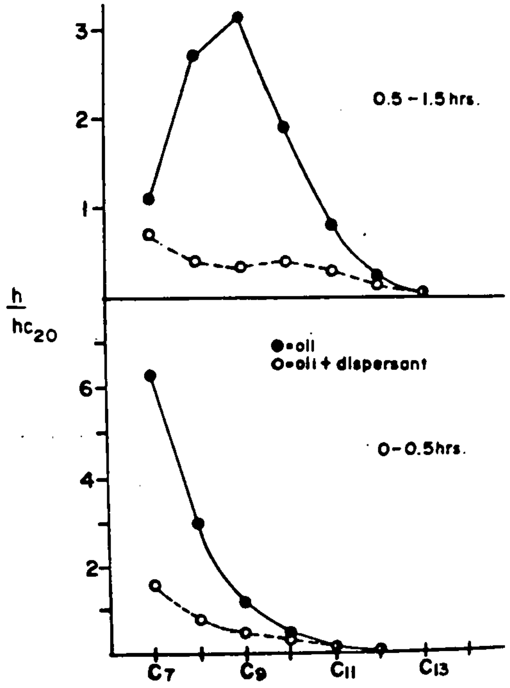


Figure 7.3.33 Relative GC peak heights of the n-alkanes as a function of the carbon number. Air Samples Exp. 16

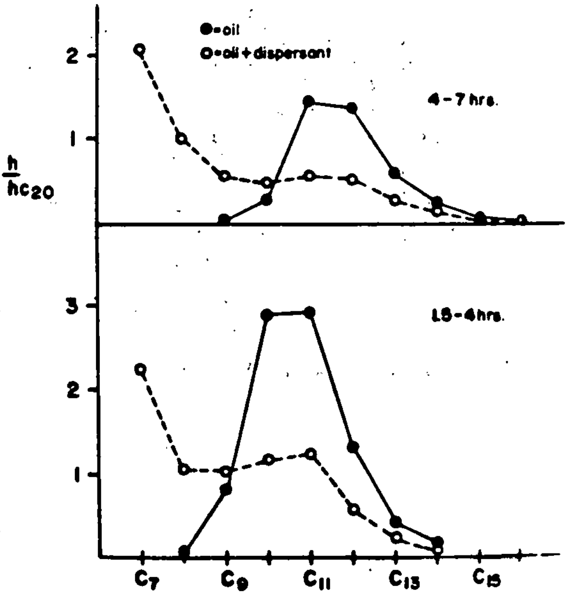


Figure 7.3.34 Evaporation Rates of n-C_7, n-C_8 and n-C_9. Experiment 16.

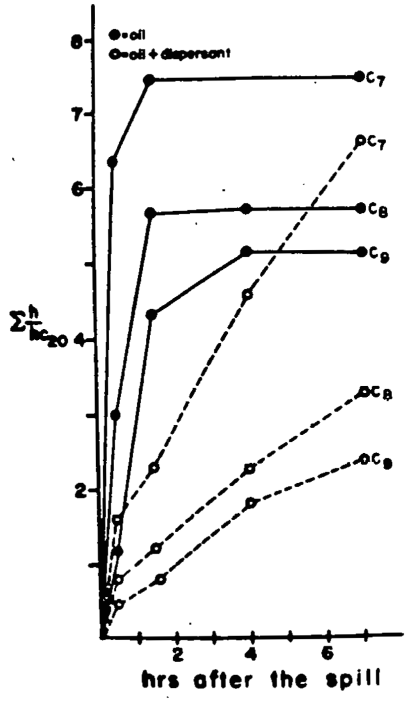


Figure 7.3.35 Evaporation Rates of n-C_{10}, n-C_{11} and n-C_{12}. Experiment 16.

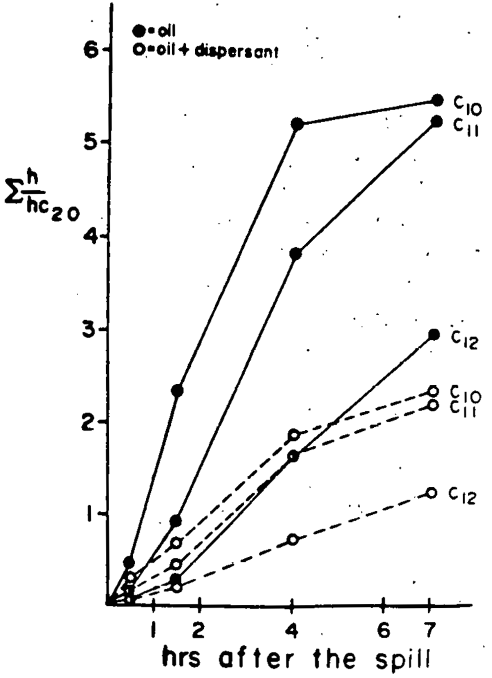
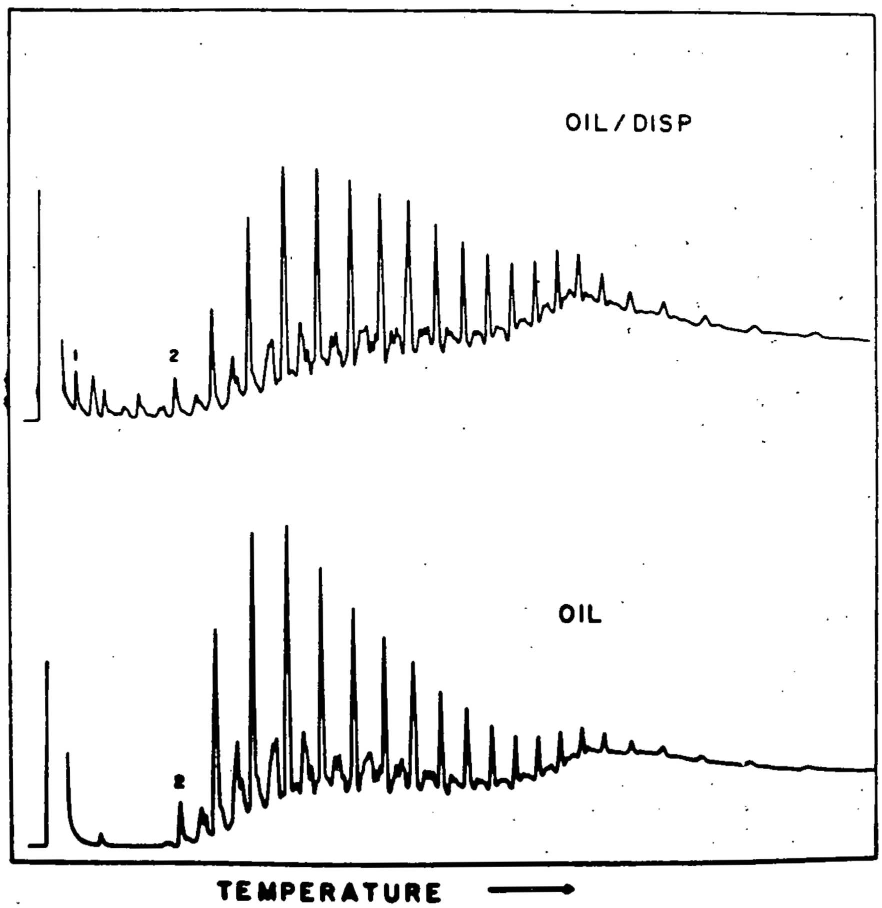


Figure 7.3.36 GC of surface samples taken 7 hours after the oil was added. Exp. 16



evaporation rate. The dispersant affected the evaporation of the lighter n-alkanes to a greater extent than the heavier ones. The slower evaporation of the treated slick could be due to the mixing of some of the oil into the water column. The oil would then be less exposed to the air and it would take longer for the light components to evaporate.

Since the surface areas of the flasks used in the laboratory experiments were limited, the dispersed oil was stopped by the wall of the flasks and some of it accumulated along the walls. Therefore, the oil was not dispersed as efficiently as it would have been if the surface area was infinite. Therefore, the walls may have caused the dispersant to have a different effect on the evaporation in the laboratory experiments compared to that in the open sea, since in the open sea, the dispersion of oil would be greater.

II Long Path Gas Cell

(A) Predicting the Effects of Medium and Low Resolution Infrared Spectrometers

In working in the field, one is often forced to use low-resolution, portable spectrometers. The performance of these instruments is obviously inferior to a high-resolution research-grade laboratory instrument. This work is involved with using a high resolution infrared spectrometer to predict the performance of low resolution instruments. Spectra of single and multi component mixtures of hydrocarbon vapors are used to measure and predict the results of low and high-resolution spectrometers. In this way, the effects of low resolution spectra in quantitative infrared analysis can be measured and predicted. Various spectral manipulation and subtraction techniques are also demonstrated in this work.

This study is done with methane, ethane and propane vapors, individually and in two and three component mixtures. This work was confined to the carbon-hydrogen stretching region, from 3250 to 2790 cm-1. High resolution spectra were taken at a spectral bandwidth of 1.6 cm-1. This is a reasonable value for a laboratory instrument. Lower resolution spectra were observed at bandwidths of 10, 25 and 50 cm-1. High resolution spectra can be convoluted, or mathematically filtered, to reproduce the effects of a lower-resolution spectrum. In this way, a low resolution spectrum can be both measured, as well as predicted from the convolution of a high-resolution spectrum of the same sample.

The equation for a Gaussian slit function is given by:

$$G = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\tfrac{1}{2}\left(\frac{x-\bar{x}}{\sigma}\right)^2\right]$$

where width at ½ height $\equiv W = 2\Delta V_{\frac{1}{2}} = 2\sigma\sqrt{2\ln 2}$

$$W = 2.354\sigma$$

This is one of the models of spectral slit functions which are currently used in mathematically describing a spectral peak. Convolution is a process in which a mathematical modification function is imposed on the function of the spectral peak. This process is used in filtering and smoothing spectral data. In this case, a high-resolution spectrum can be convoluted with a Gaussian function to produce a spectrum of lower resolution. One of the purposes of this work is to observe how a mathematically convoluted spectrum compares with a measured spectrum at the same spectral slit width.

Figure 7.3.37 shows a high resolution spectrum of methane vapor, in the 3250-2750 cm-1 region. The detail in such a high resolution spectrum makes identification and quantitation of a compound relatively simple. In a spectrum of lower resolution, this detail is lost or reduced, making identification more difficult. This loss of detail also occurs in convoluted spectra. One can compare the results of a low resolution spectrum with a high resolution spectrum convoluted to a lower resolution. This is illustrated in Figure 7.3.38. This shows convoluted and measured spectra of methane vapor from 3250 to 2750 cm-1. The resolution of these spectra was 10, 25 and 50 cm-1, respectively. The sample in all cases is the same, the spectral conditions being modified for each spectrum. Here, one can see the good agreement in the real measured spectra and the predictions made by convoluting the high resolution spectrum.

In convoluting a spectrum, different procedures can be followed. A spectrum can be convoluted to a given resolution in one step, or in a series of "smaller" convolutions. Figure 7.3.39 illustrates this, using a methane spectrum convoluted to 25 cm-1 resolution in two different ways. The first spectrum is a convolution of a high resolution spectrum to 25 cm-1 in one step, in 0.1 cm-1 increments. This refers to the frequency of application of the convolution; here, the function was applied to the data at 0.1 cm-1 intervals. The second spectrum shows a different convolution procedure. In the first step, the high resolution spectrum was convoluted to 5 cm-1 resolution in 0.1 cm-1 increments, and then this spectrum was further convoluted to 25 cm-1 resolution in 1 cm-1 increments. This two step convolution has the effect of a one-step convolution to 25 cm-1 resolution. The difference in the increments applied in the two steps has the effect of smoothing the resultant spectrum when compared to the one step convolution. The variations in the two methods of convolution is significant, suggesting that the convolution procedure used could make a considerable difference in a given circumstance.

Real vapor samples are more frequently mixtures of two or more components rather than a single pure compound. Figure 7.3.40 shows complete spectra of methane, ethane and propane, showing the differences in band structure of the three compounds.

In predicting the appearance of spectra of mixtures, there are a variety of possible approaches. Absorbance spectra of individual pure compounds can be added to produce a synthetic spectrum of a multicomponent mixture of the compounds involved. An important question is how such synthetic spectra compare with convoluted spectra of real multicomponent mixtures.

Figure 7.3.41 shows three spectra of a two component mixture of methane and ethane. Here, the major peaks of each component are approximately equal in absorbance. This shows a high-resolution spectrum, as

Figure 7.3.37 High Resolution Spectrum of Methane Vapor

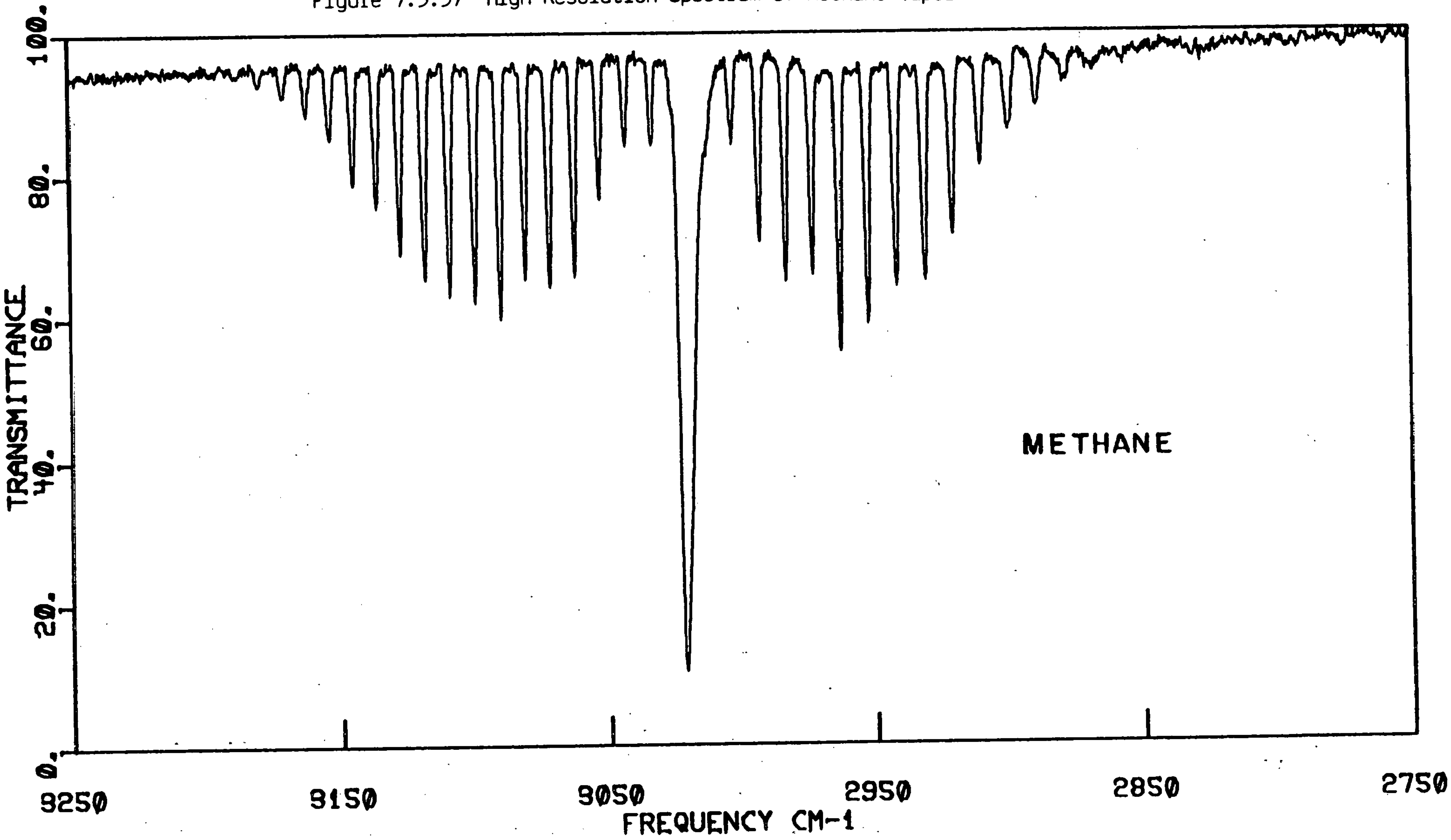


Figure 7.3.38 Convoluted and Measured Spectra of Methane Vapor

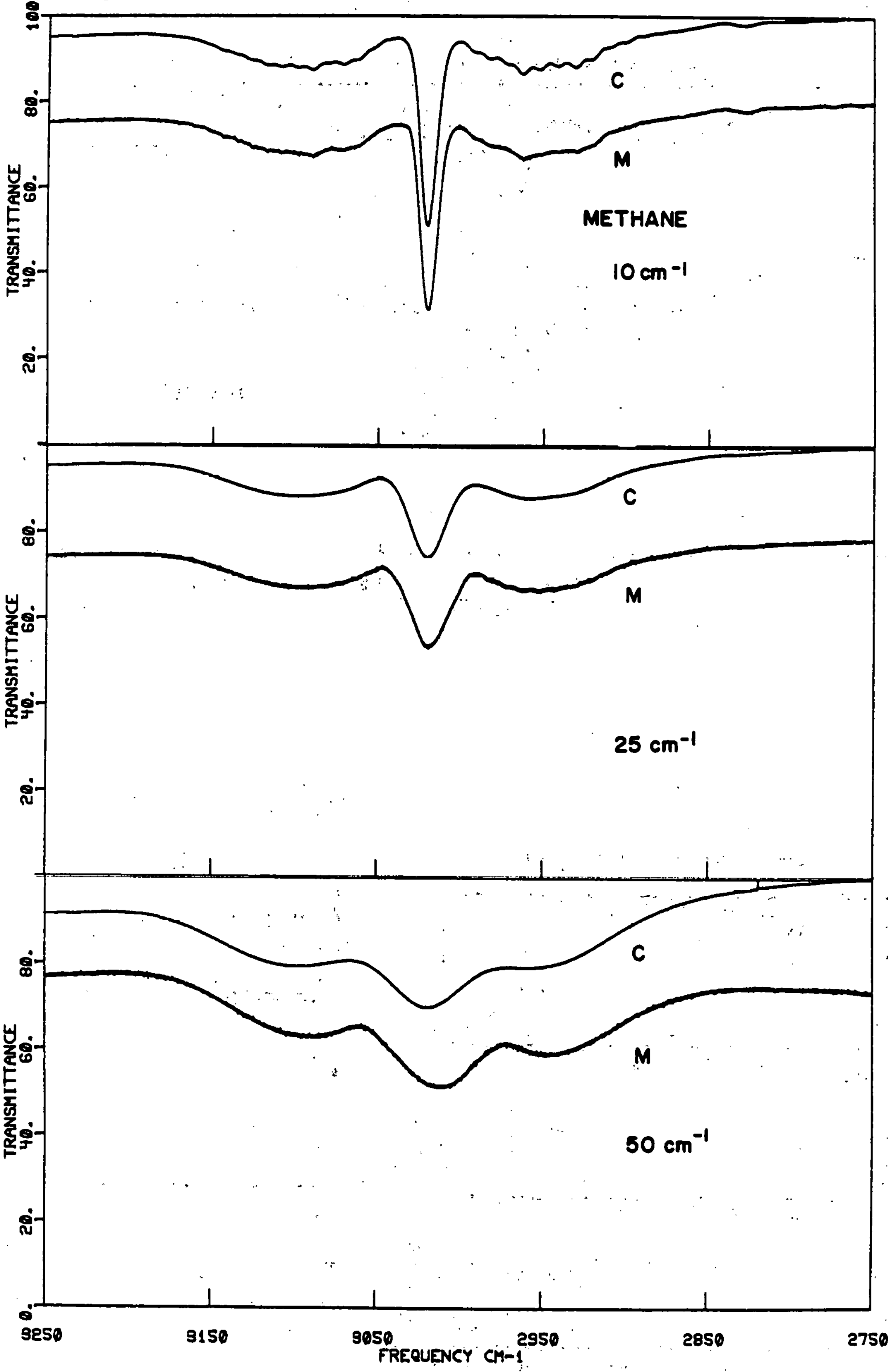


Figure 7.3.39 Methane Spectrum Convoluted to 25 cm-1 Resolution

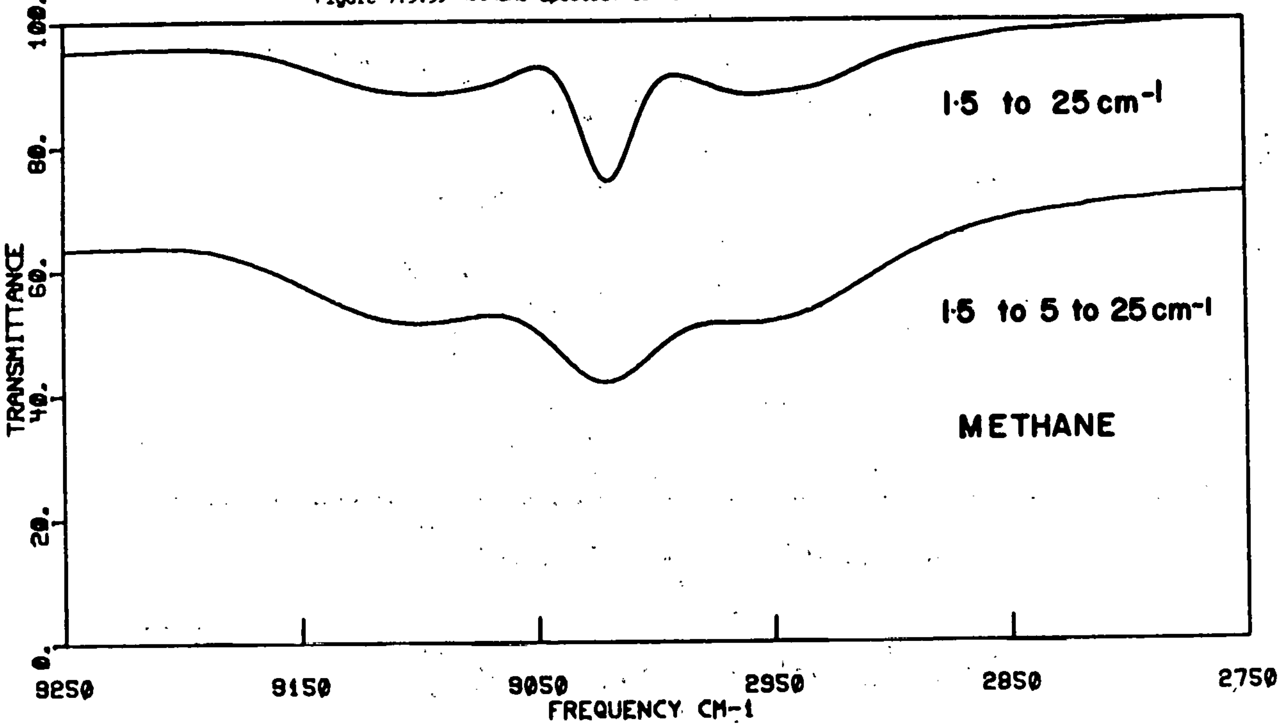


Figure 7.3.40 Spectra of Methane, Ethane and Propane

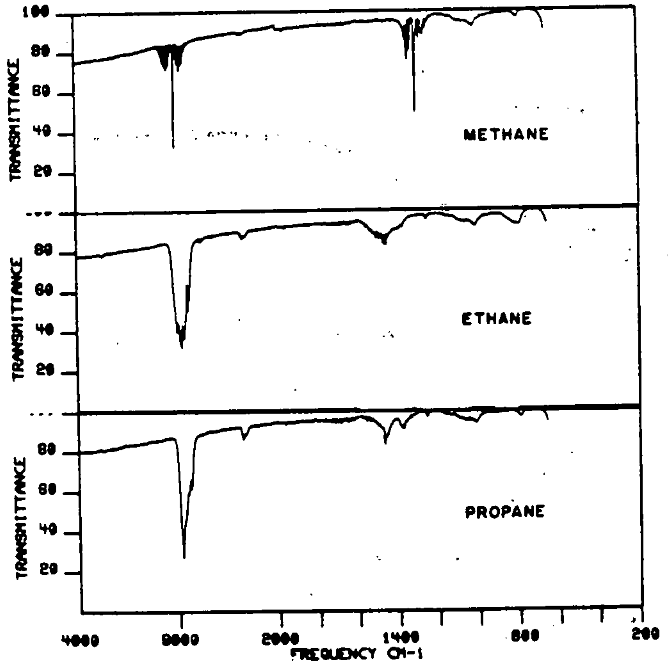
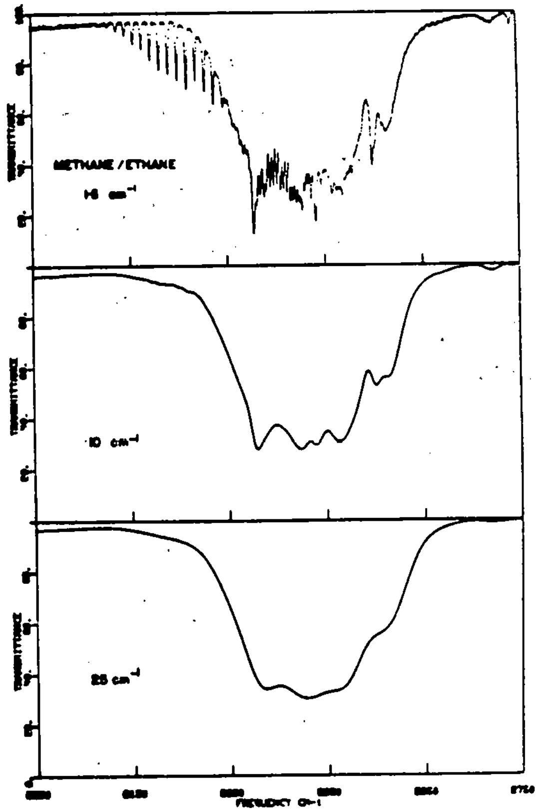


Figure 7.3.41 Two Component Mixture of Methane and Ethane



well as two convolutions, two resolutions of 10 and 25 cm-1, respectively. Once again, most of the spectral information is lost as the resolution decreases.

The following figures illustrate spectral subtraction. The spectrum of a pure compound can be subtracted from the spectrum of a mixture, leaving the spectrum of the remainder of the mixture. In this simple example, the spectrum of ethane is subtracted from the spectrum of the methane/ethane mixture. Theoretically, this should result in the spectrum of methane, the other component of the mixture. Figure 7.3.42 shows the spectra of the methane/ethane mixture, and the pure ethane being subtracted from it. Figure 7.3.43 shows the results of the subtraction, and a real measured spectrum of methane for comparison. One can see that spectral subtraction can be very effective in separating components of a mixture.

The question arises whether this procedure can be used as effectively at lower resolutions. Figures 7.3.44 and 7.3.45 repeat the above experiment, with all spectra convoluted to a resolution of 25 cm-1. One can see that lower resolutions apparently have little affect on the subtraction procedure.

In predicting the appearance of a spectrum of a mixture, spectral addition can be used. The absorbance spectra of the individual components can be added to give a synthetic spectrum of a "mixture" of the components. A comparison of added spectra with a real convoluted mixture is shown in Figure 7.3.46. The first spectrum is a high-resolution spectrum of the methane/ethane mixture convoluted to a resolution of 25 cm-1. The second spectrum illustrates how two spectra can be added and then convoluted. Here, the high-resolution spectra of methane and ethane are added, and the resultant sum is convoluted to 25 cm-1. The third spectrum shows the procedure of convolution, then addition. Here, the two high resolution spectra are individually convoluted, and then added together. These three spectra illustrate the prediction of performance of a low resolution instrument using a high-resolution instrument and computer. A low resolution spectrum of a mixture can be predicted from high resolution spectra of each of the components of the mixture. This can be done either by addition and then convolution to the desired resolution, or vice versa.

The following work with ethane and propane reproduces the results just shown with methane and ethane. Figure 7.3.47 gives a high resolution spectrum of a one to one absorbance mixture of ethane and propane, from 3250 to 2790 cm-1. This spectrum is also shown convoluted to resolutions of 10 and 25 cm-1. Figure 7.3.48 and 7.3.49 show the subtraction of propane from the mixture of propane/ethane, giving a spectrum of ethane. These are all high resolution spectra. Figures 7.3.50 and 7.3.51 duplicate this subtraction for spectra convoluted to a resolution of 25 cm-1.

The results shown above can be extended to mixtures of more than two components. Figures 7.3.52 show spectra of a mixture of methane, ethane and propane in the 3250 to 2750 cm-1 region. The two spectra are a high resolution spectra, and the convolution of this spectrum to a resolution of 25 cm-1. Subtractions can be made in a three component system to sequentially extract each component from the system. Figure 7.3.53 shows

Figure 7.3.42 Spectra of Methane/Ethane Mixture and Pure Ethane Being Substracted From It.

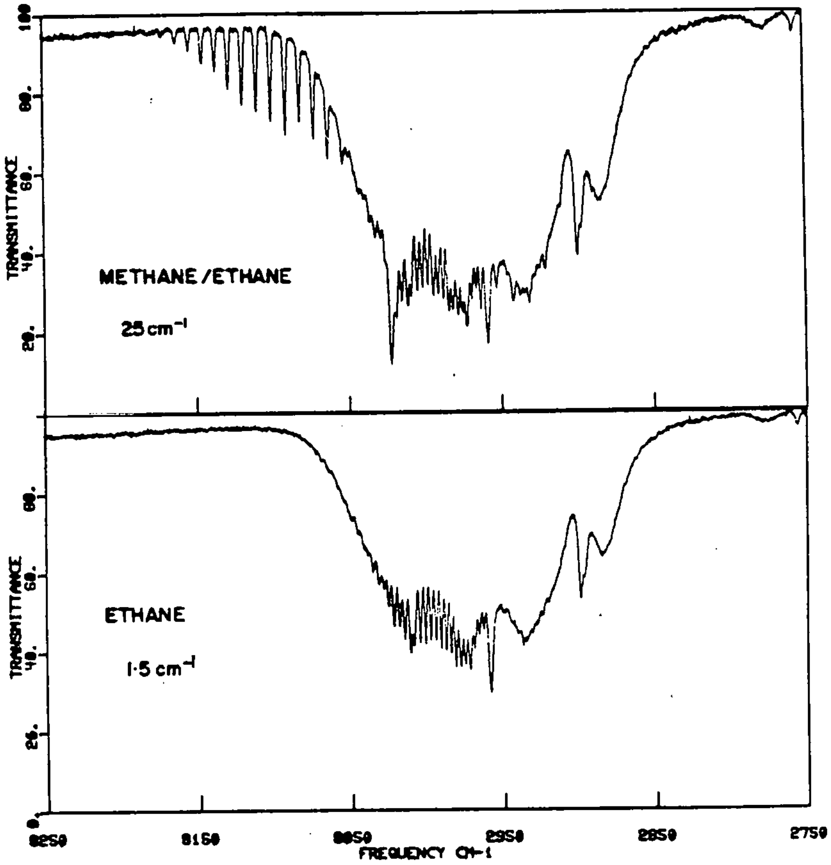


Figure 7.3.43 Results of the Subtraction and a Real Measured Spectrum of Methane

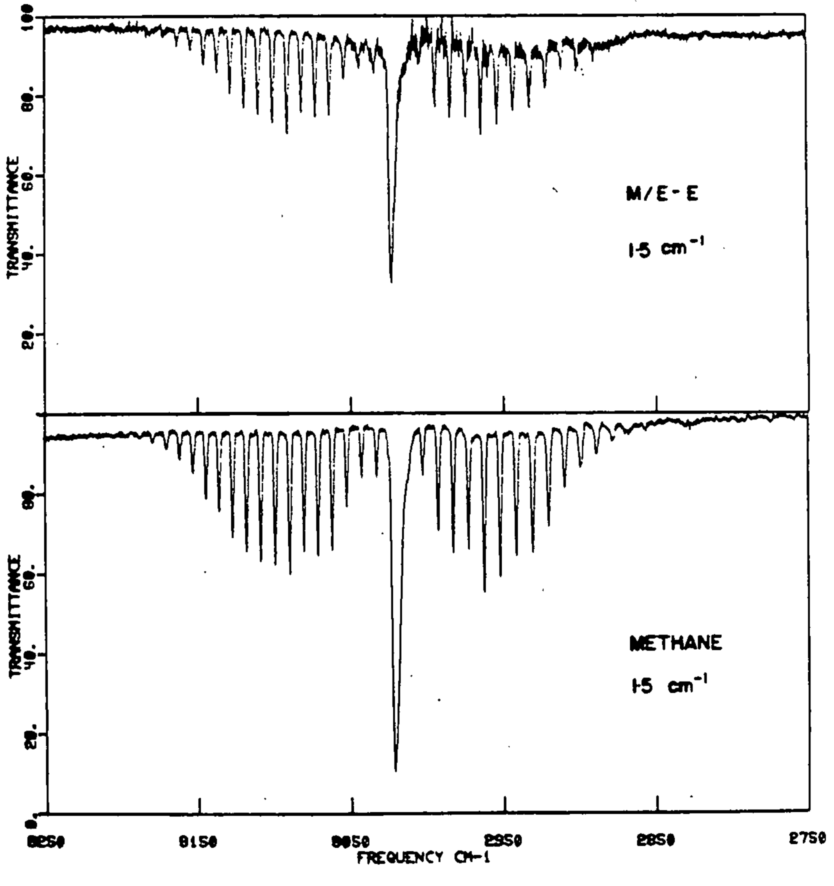


Figure 7.3.44 Spectra of a Methane/Ethane Mixture and Ethane that have been Convoluted to 25 cm-1

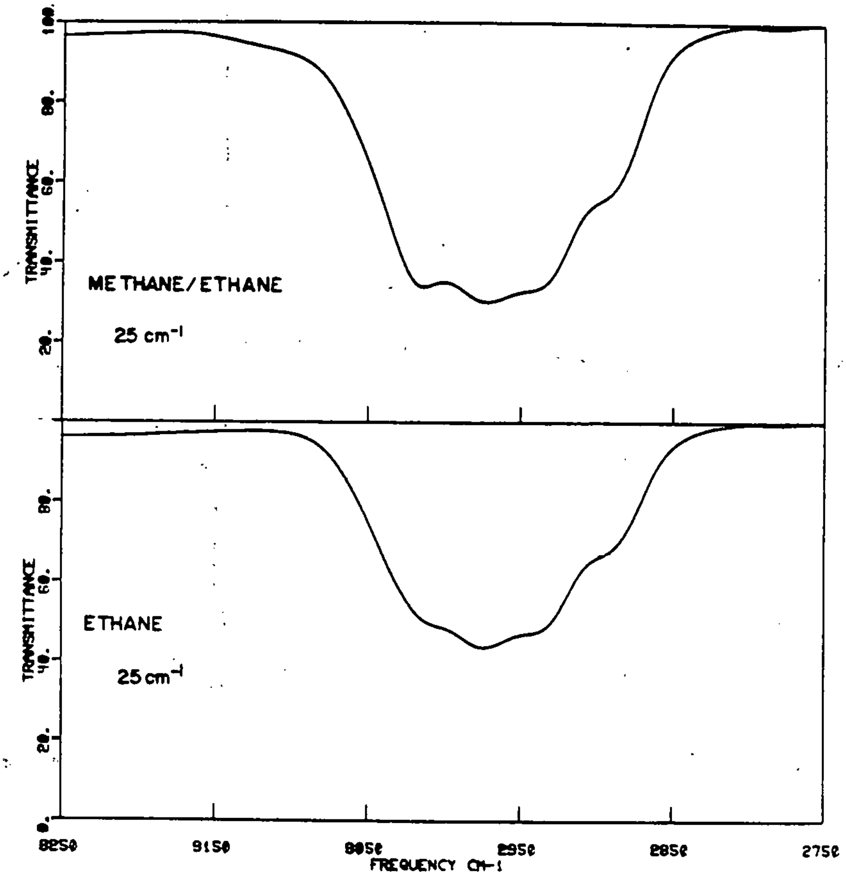


Figure 7.3.45 Convoluted Ethane Spectrum Subtracted from Convoluted Spectrum of pure methane (bottom)

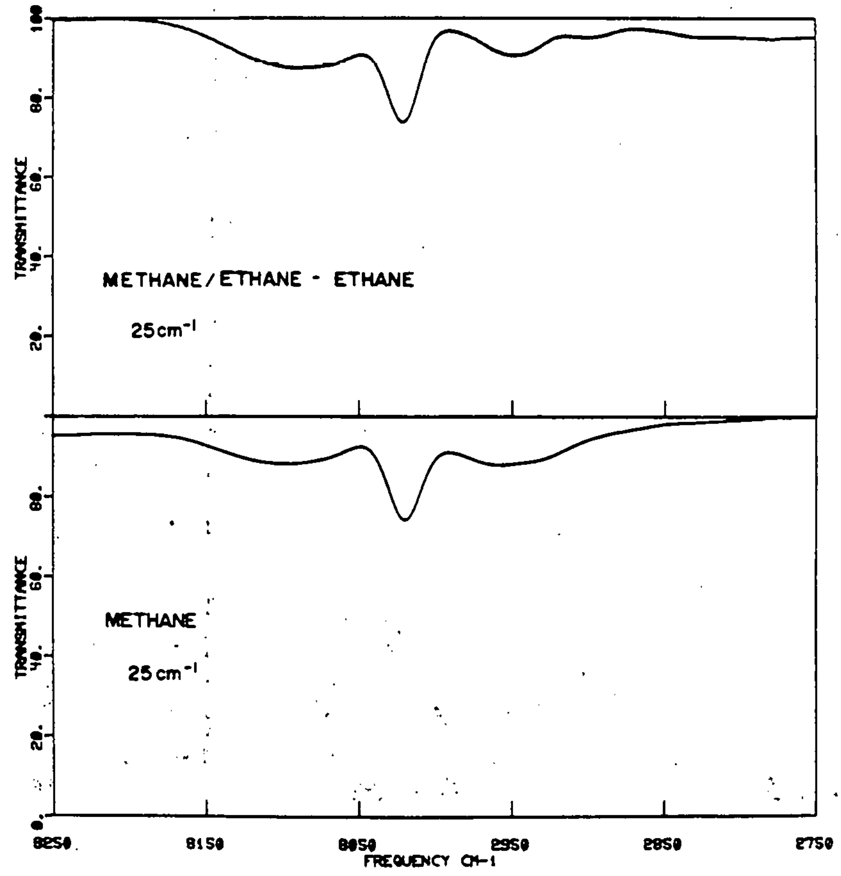


Figure 7.3.46 Results of Computer Addition of Two Spectra Before or After Convolution of Spectra

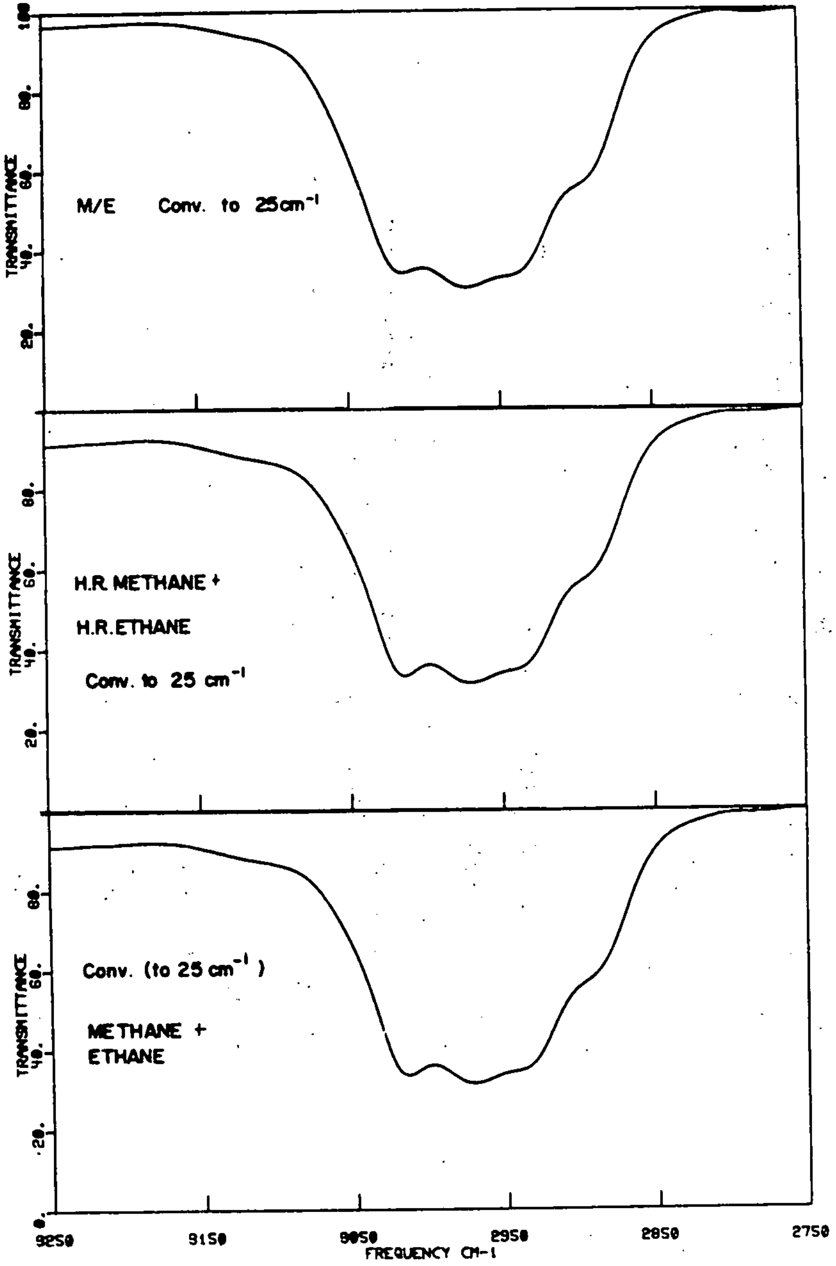


Figure 7.3.47 A High Resolution Spectrum of a One to One Absorbance Mixture of Ethane and Propane

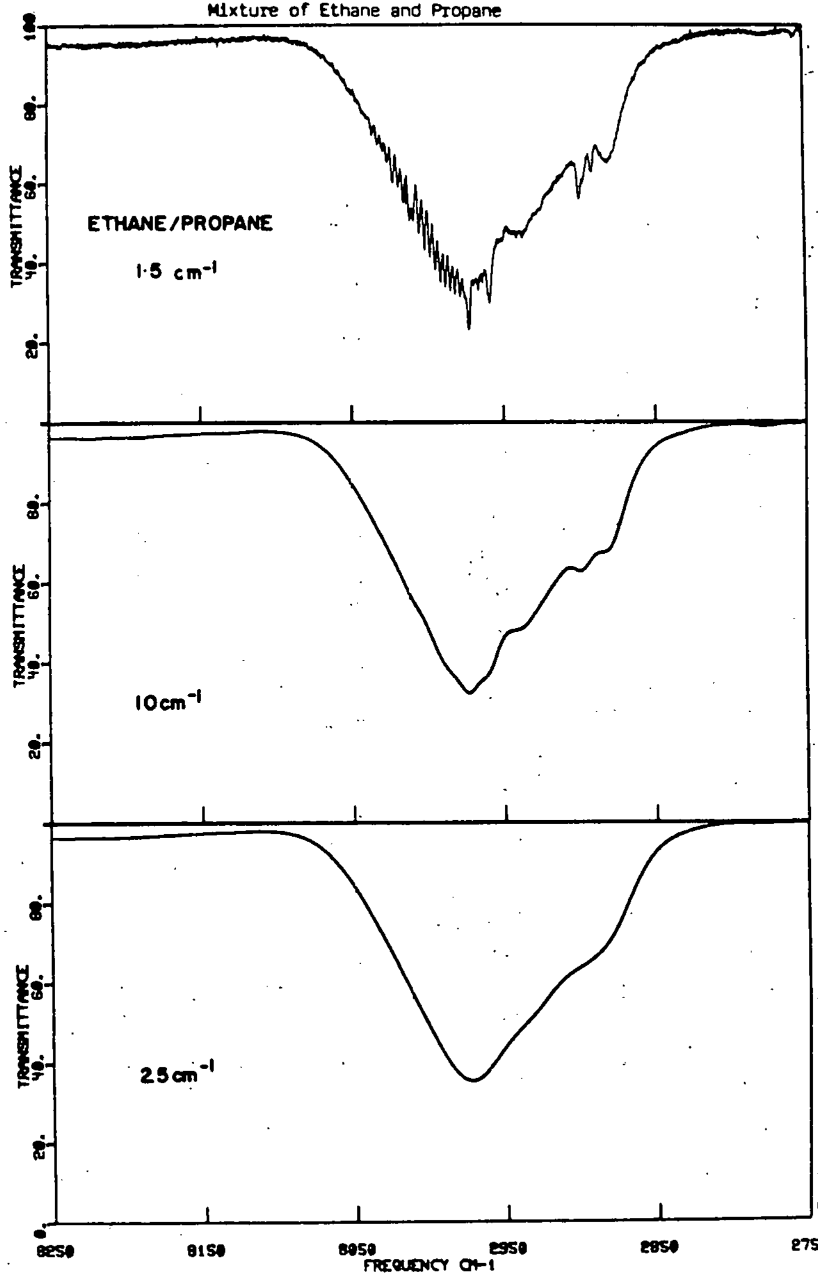


Figure 7.3.48 Subtraction of Propane from the Mixture of Propane/Ethane

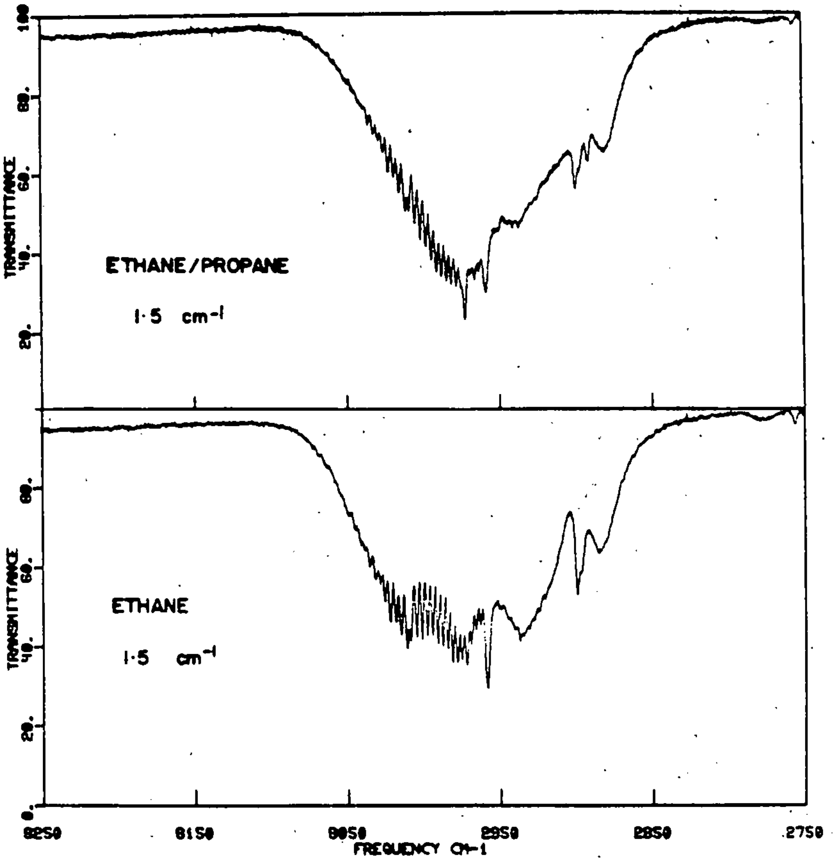


Figure 7.3.49 Subtraction of Propane from the Mixture of Propane/Ethane

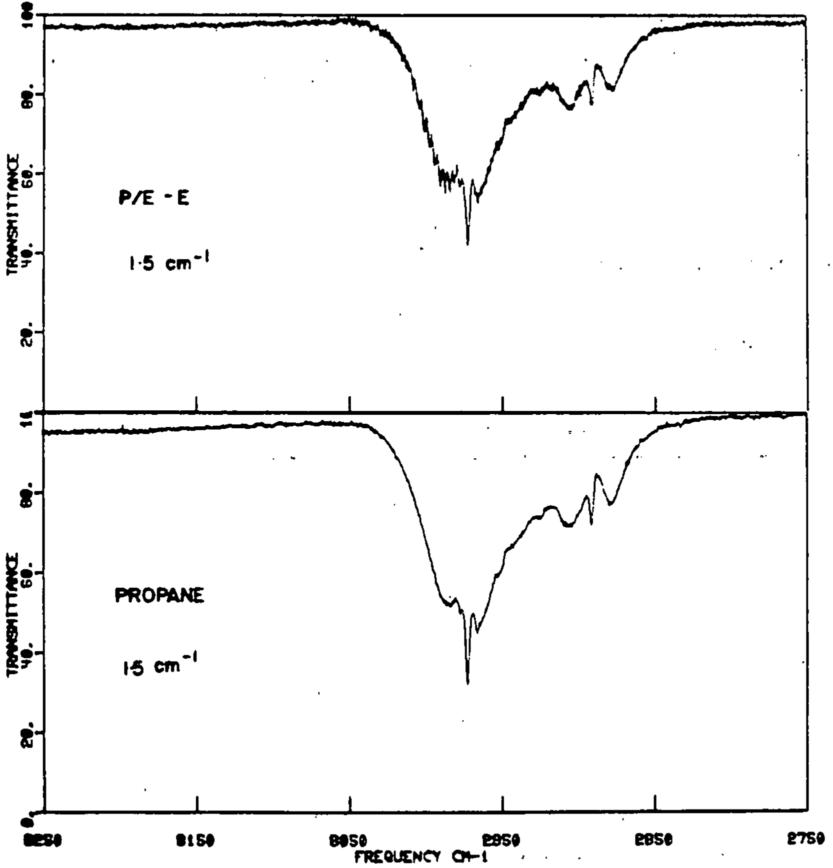


Figure 7.3.50 Convoluted Spectra of Ethane/Propane Mixture and of Pure Ethane

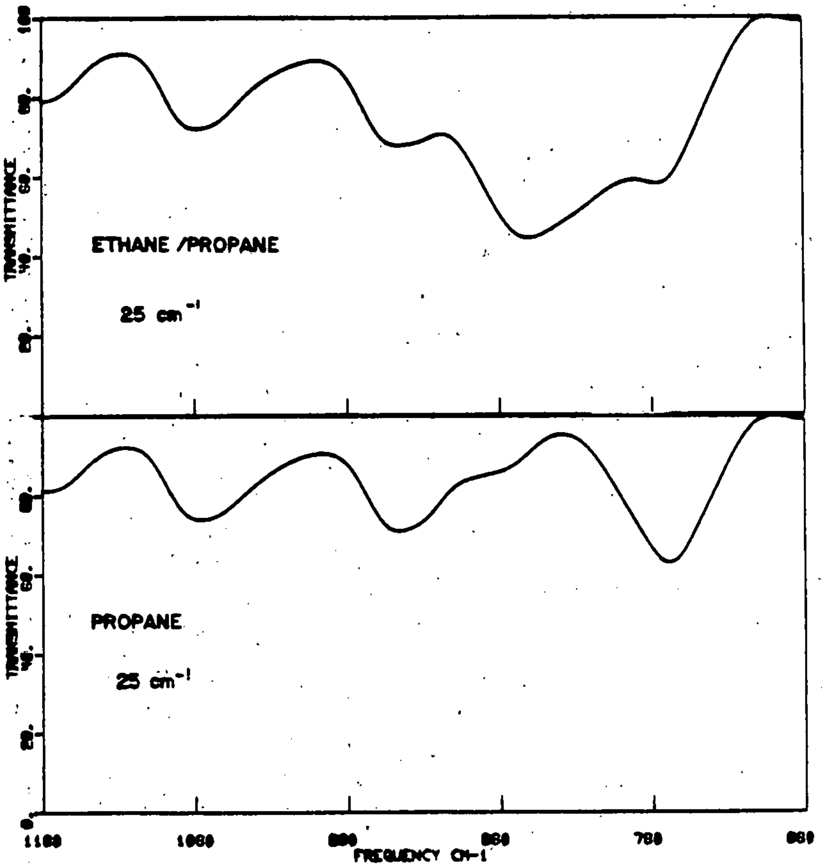


Figure 7.3.51 Subtraction of Convoluted Propane Spectrum from Convoluted Ethane/Propane Spectrum (top) and Convoluted Spectrum of Pure Ethane

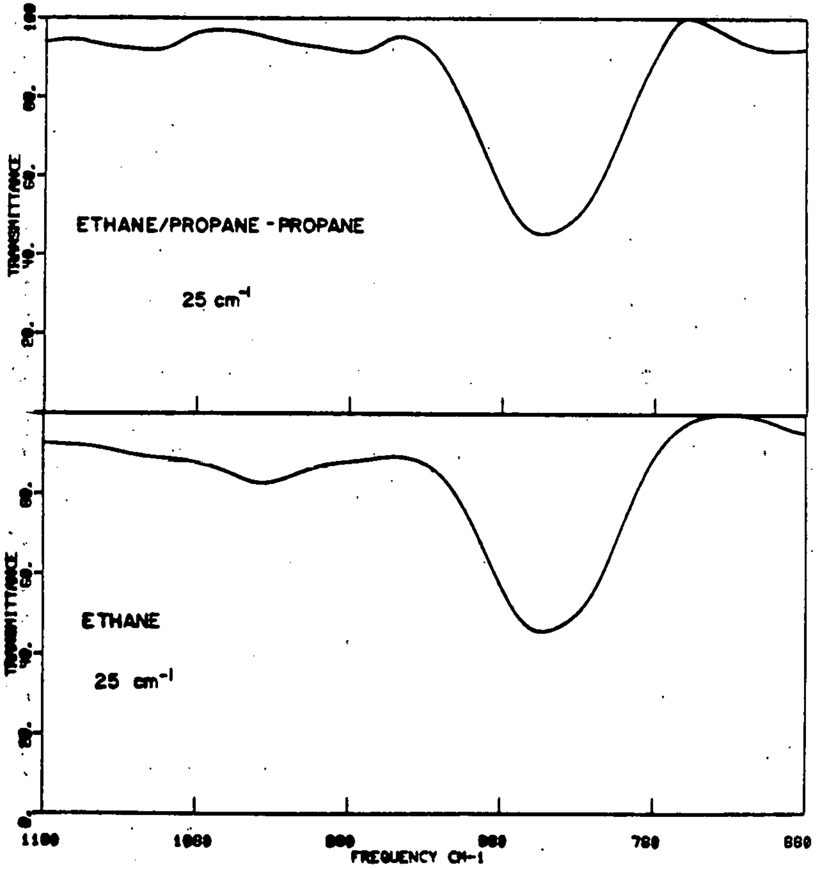


Figure 7.3.52 Spectra of a Mixture of Methane, Ethane and Propane

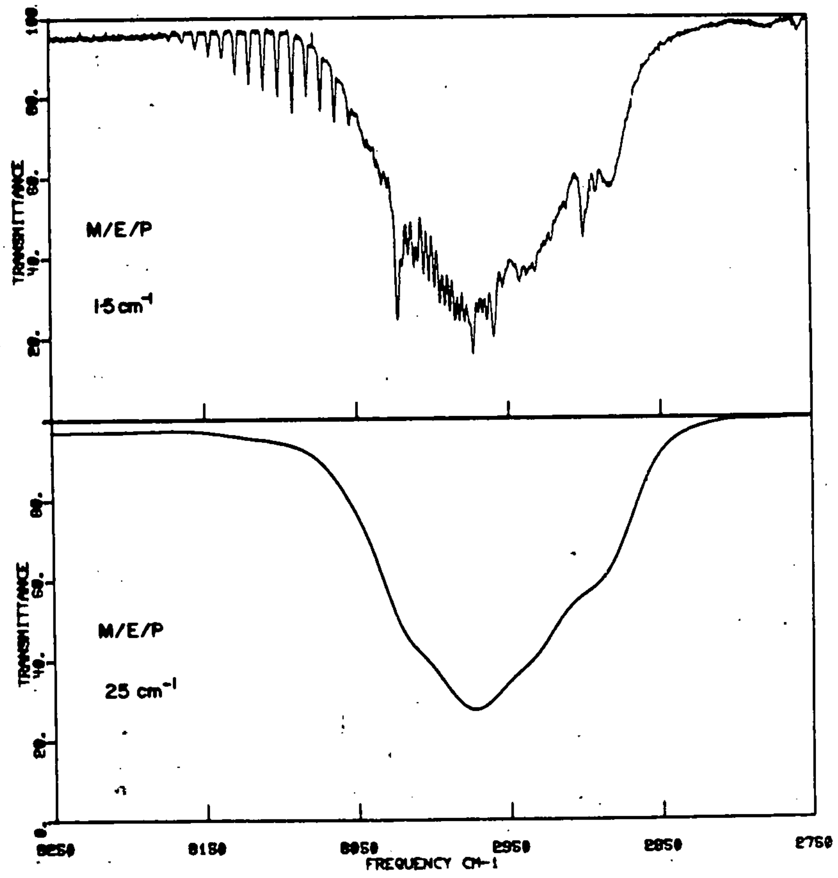
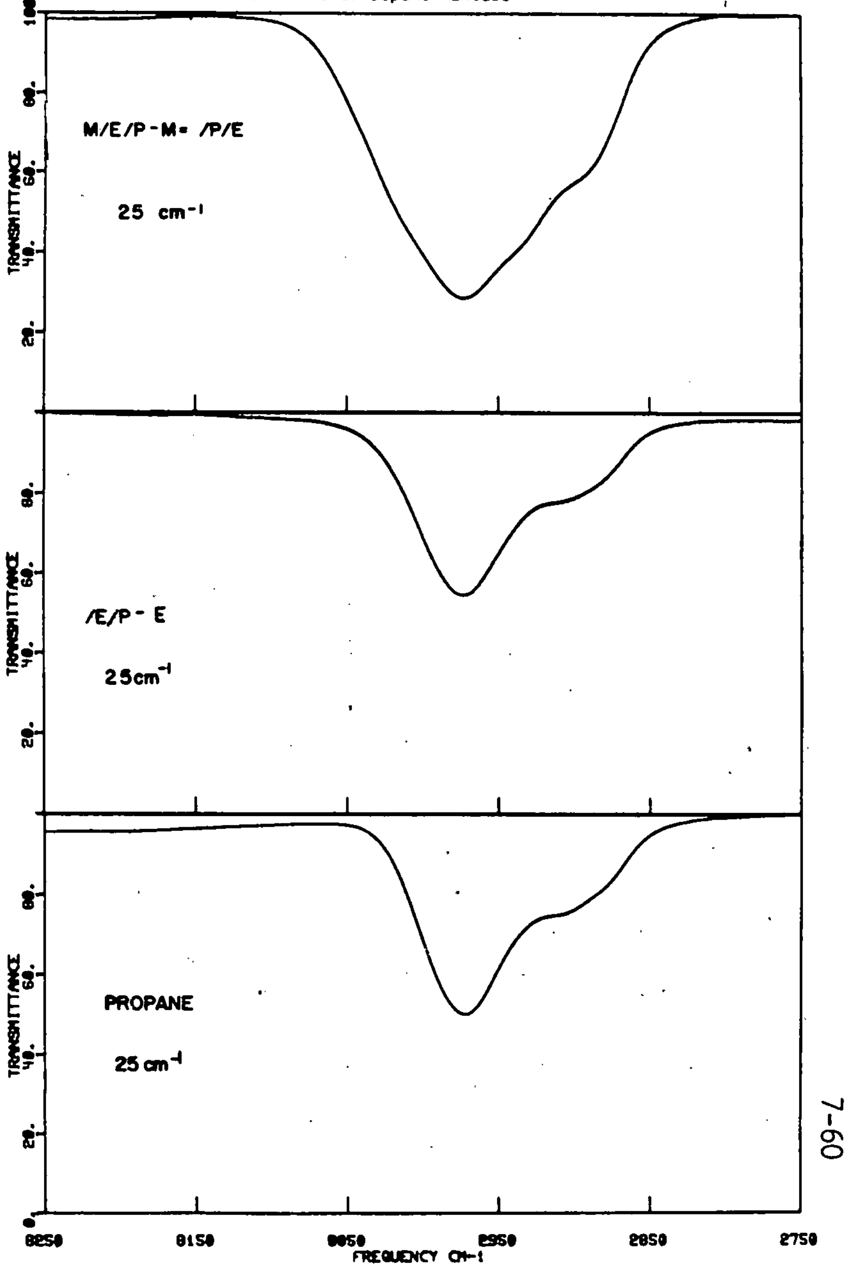


Figure 7.3.53 Sequential Subtraction of Convoluted Spectra of methane (1) and Ethane (2) from the Convoluted Spectrum of a Methane/Ethane/Propane Mixture



this type of subtraction. The first spectrum is the convoluted spectrum of pure methane, subtracted from the convoluted spectrum of the three-component mixture. The second spectrum shows the subtraction of ethane from this first subtraction.

From these two subtractions, one should expect to be left with a convoluted spectrum of propane, the third component of the system. The final spectrum shows the spectrum of propane for comparison. Obviously, convoluted spectra can also be subtracted with reasonable accuracy in spectra of more than two components.

This study illustrates some of the techniques which can be used in manipulating spectra. High resolution spectra can be convoluted to reasonably simulate the performance of low resolution instruments. Thus, the results of such instruments, as in field work, can be predicted to a fair degree. Additions or subtractions to produce a synthetic spectrum can be performed either before or after convolution, and the appearance of this lower resolution synthetic spectrum will be faithful to that produced by a low resolution instrument under the expected conditions. In addition, these techniques do not appear limited to two-component mixtures. Three component systems can be investigated, and one would reasonably expect to be able to work with larger systems as well. Thus, the performance of low-resolution field grade instruments can be predicted from spectra taken in the laboratory. Predictions made in this way may prove valuable in estimating the practicality of a projected study, or the effectiveness of an analysis before the study is begun.

B) Atmospheric Interferences in the Ambient Vapor Sampling System

In ambient air samples, two major interferences prevent the use of IR analysis for hydrocarbons: water and carbon dioxide (CO_2). Water has very strong absorptions in the IR, centered at about 3750 cm-1 and 1600 cm-1. CO_2 has two major bands, at 2350 and 675 cm-1. Taken together, these interferences can ruin quantitative results in an ambient sample. The problem is to reduce or eliminate these interferences, without significantly reducing the sensitivity of the system to hydrocarbons. This was tested by introducing toluene (C_7H_8) vapor into the system under various experimental conditions. The spectra which follow illustrate the results.

Spectrum in Figure 7.3.54 is an illustrative spectrum of toluene vapor in nitrogen gas. For this highly concentrated sample, 50 l of liquid toluene were injected and allowed to evaporate inside the flowing system, which was filled with dry nitrogen. This shows the strong absorptions of this hydrocarbon, especially around 3000 cm-1, 1600 cm-1, 1500 cm-1, 1050 cm-1 and 700 cm-1.

Spectrum 7.3.55 is a more realistic concentration, in that it was measured by pumping dry nitrogen over the surface of liquid toluene. This is approximately the concentration one would observe with a sampling device directly over a spill of toluene on water. It still shows the bands mentioned above, but greatly reduced in intensity. One can now also see weak bands from CO_2 and H_2O. These are impurities in the nitrogen diluent, or residual impurities in the cell. This and all subsequent spectra were taken at a path length of 21.75 m.

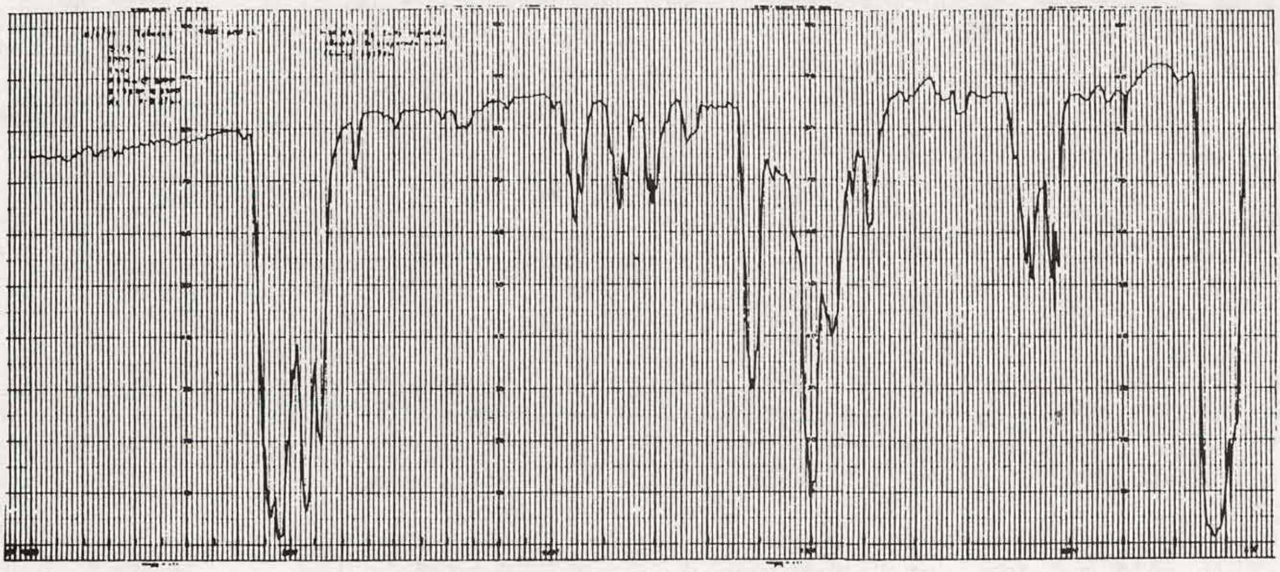


Figure 7.3.54 Illustrative Spectrum of Toluene Vapor in Nitrogen Gas

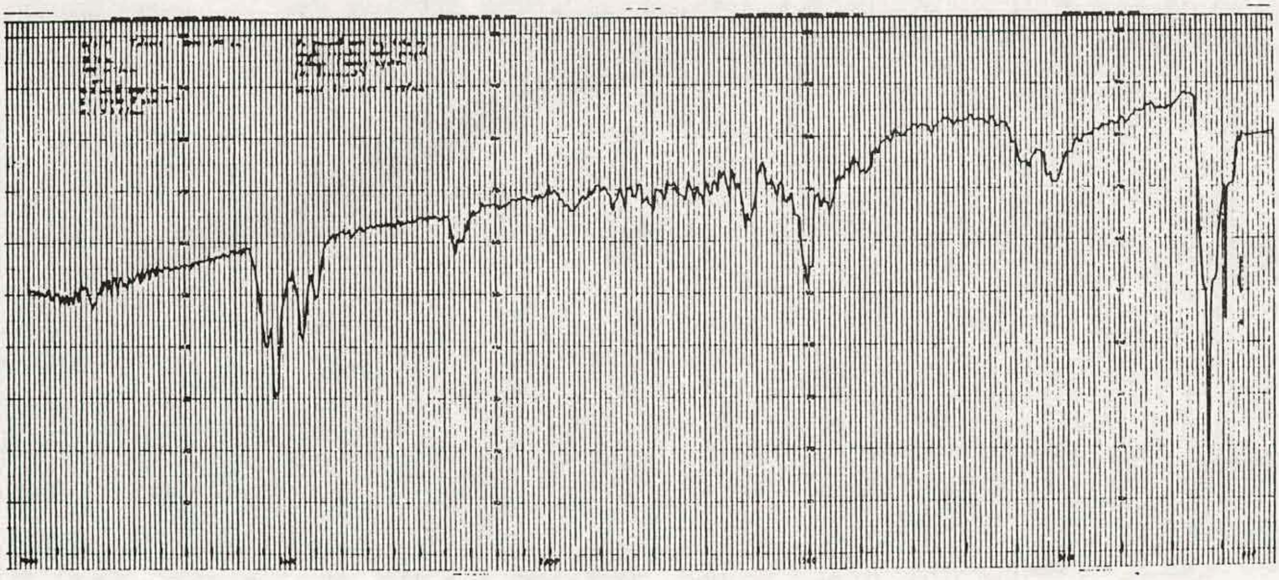


Figure 7.3.55 Spectrum of Toluene Vapor in Nitrogen Gas

Spectrum 7.3.56 is identical to 7.3.55, except for the addition of a drying tube, filled with a calcium sulfate dessicant, (DRIERITE). Most of the peaks are not significantly reduced in intensity, indicating that the Drierite is not removing appreciable amounts of hydrocarbon vapors.

In spectrum 7.3.57, air is used instead of dry nitrogen. Here, all CO2 bands are clearly seen for the first time. The Drierite will not remove this vapor, although in this case, it is not critical. The toluene can still be easily quantitated by using the bands in the 3000 cm-1 region. Water is still absent, indicating that the Drierite is effectively removing the interfering water vapor from the air. Spectrum 7.3.58 is not critical to the test, but is interesting. Here, a liquid nitrogen cold trap was added to the drying tube. Not only was all water removed, but most of the hydrocarbons were frozen out as well. The small peak at 3000 cm^{-1} is methane. Whether this is an impurity from the liquid toluene or the air is not known.

Spectrum 7.3.59 shows the spectrum of ambient air and toluene vapor, without any dessicant or filter. This shows the massive interferences present in untreated air, and the extent to which the Drierite is effective. Compare this with spectrum 7.3.57. For all of the above spectra, the flow rate was about 2 l/min past the toluene liquid. This was estimated to be the optimum flow sampling rate. Two factors are important in determining flow rates in sampling: system response time and dessicant effectiveness. As the flow rate increases through the 5.5 l liter cell, the time required to respond to a change in sample composition is decreased. The shorter the response time, the more accurately the system will reflect the concentrations of a given sample as it changes with time, as in an evaporation process. As the flow through in the dessicant is increased, the effectiveness of the Drierite is reduced, as is shown in spectrum 7.3.60. This spectrum was taken with a sampling flow rate of 5 l/min, but is otherwise identical to the conditions for spectrum 7.3.57. It shows the amount of water interference still present in the cell due to the higher flow rate.

It can be concluded that with a suitable dessicant, one can eliminate substances which interfere with quantitative ambient air analysis in the system.

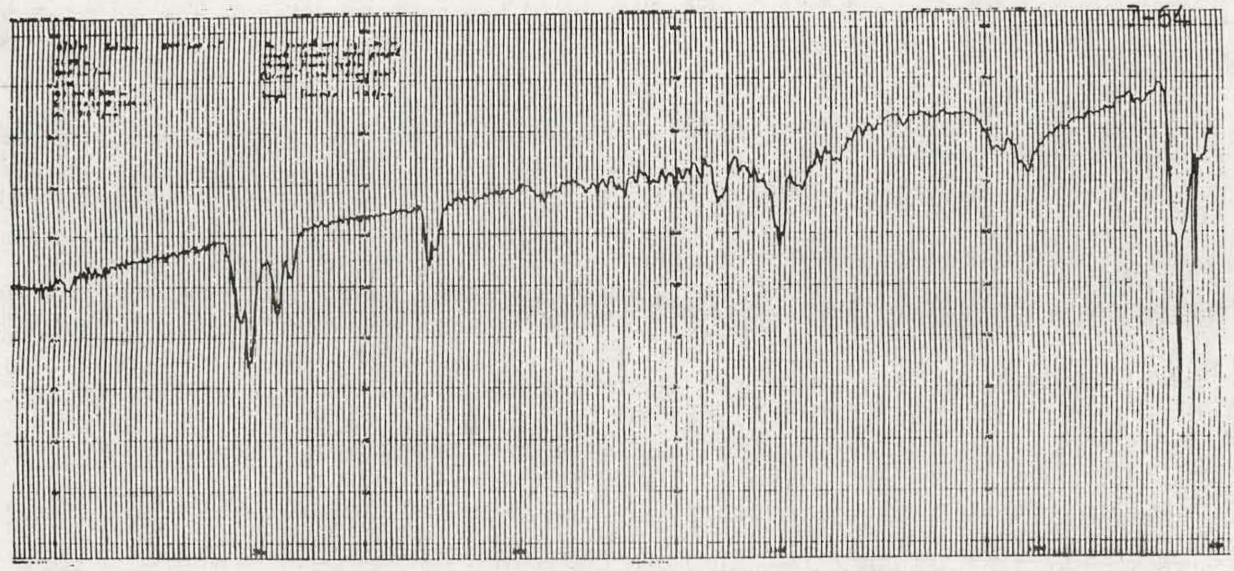


Figure 7.3.56 Spectrum of Toluene Vapor in Nitrogen Gas After Drying Tube was Added to System

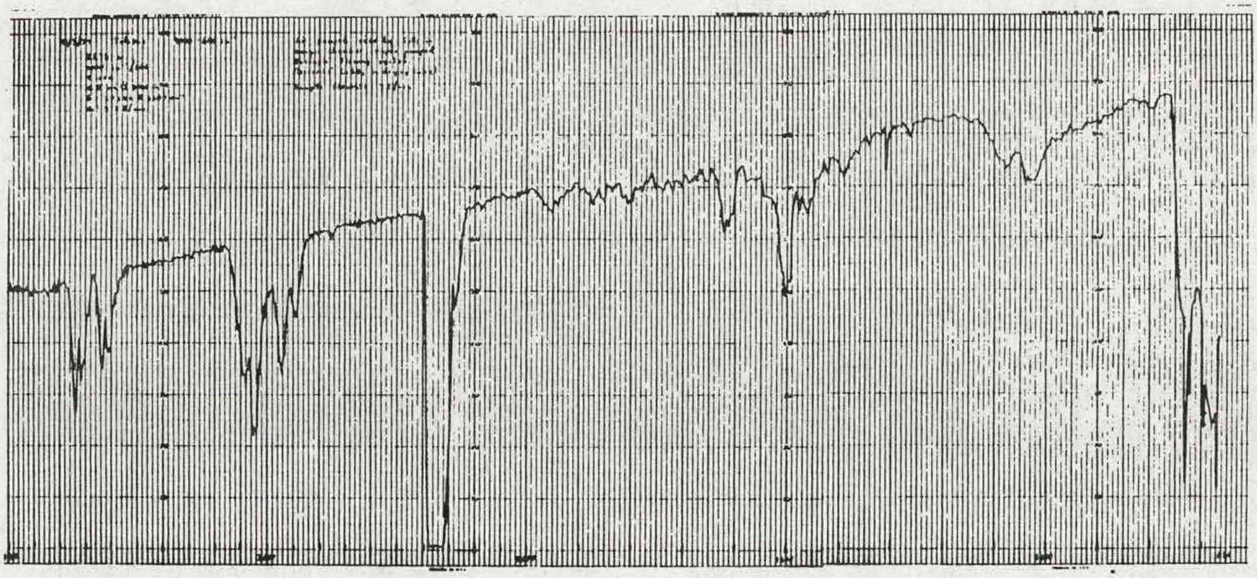


Figure 7.3.57 Spectrum of Toluene Vapor in Air

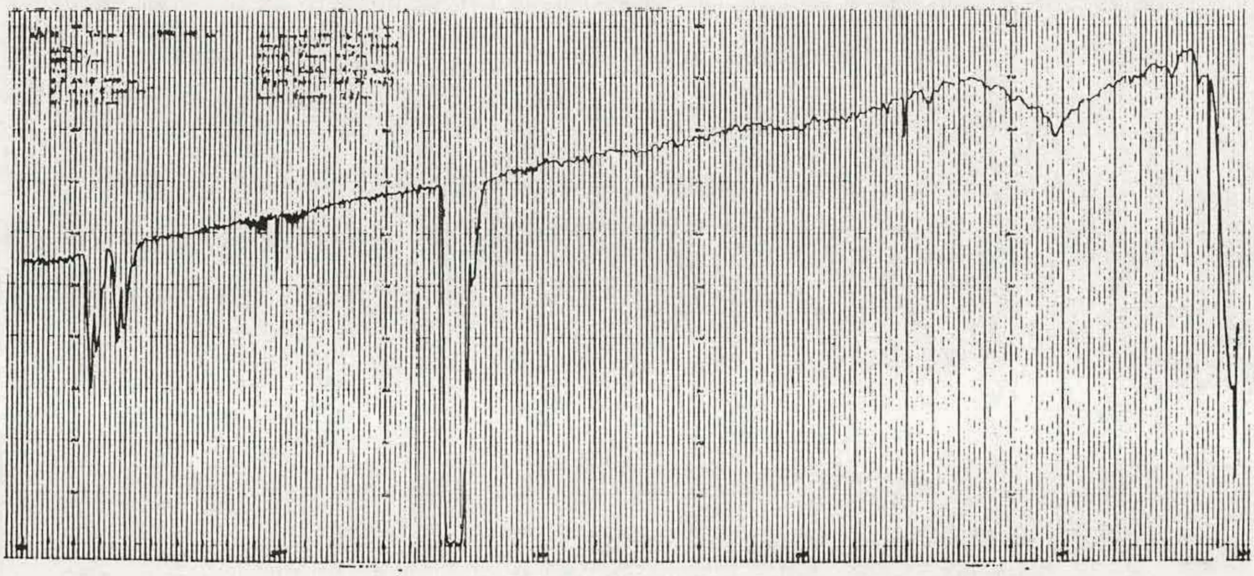


Figure 7.3.58 Spectrum of Air after Cold Trap was Added to System

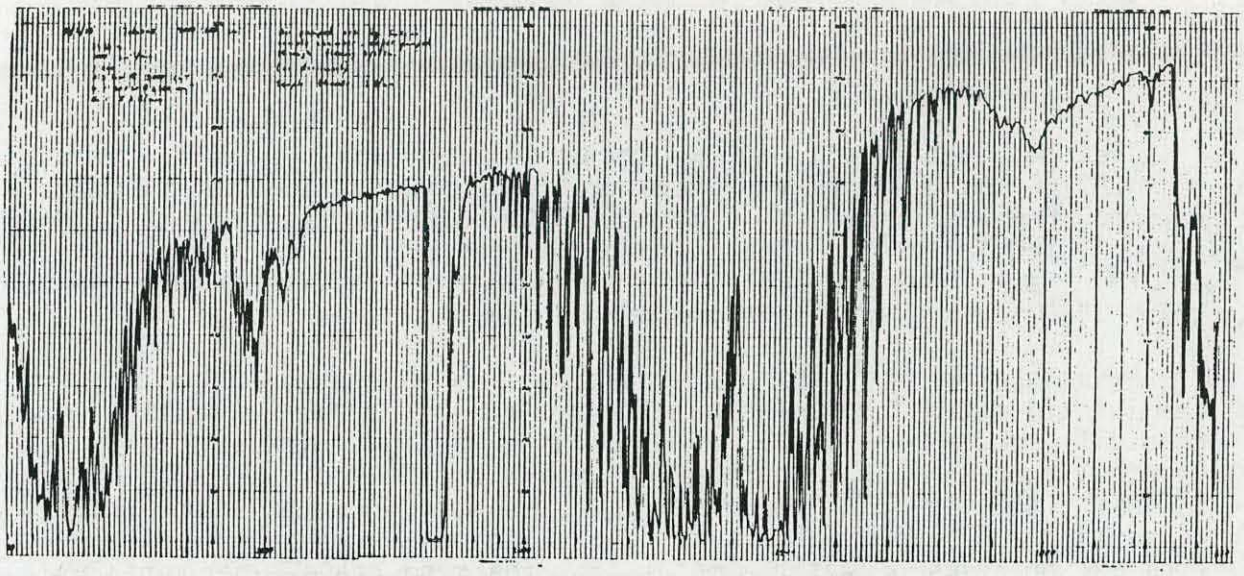


Figure 7.3.59 Spectrum of Ambient Air and Toluene Vapor, without any Dessicant or Filter

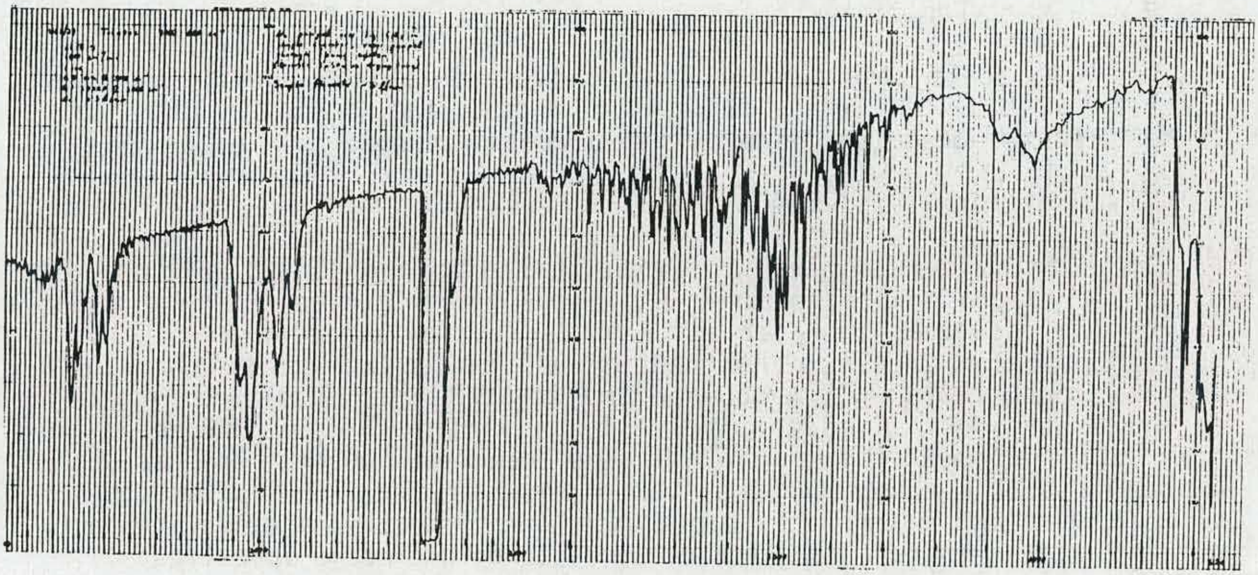


Figure 7.3.60 Spectrum of Ambient Air with Dessicant in System

References

1. M. Ahmadjian, C. Baer, P.F. Lynch & C.W. Brown, Environ. Sci. & Technol., 10, 777 (1976).

7.4 Mesoscale Experiments

7.4.1 Introduction

Treating an oil spill with a chemical dispersant reduces the amount of oil on the surface and increases the concentration in the water column. However, a number of questions need to be answered, e.g., "How much is the increase?" "Does a dispersant affect all components of oil in the same manner?" Is the effect uniform throughout the water column?" How does the effect change with time?"

Presently, we are trying to answer these questions by analyzing water samples collected from beneath both treated and untreated spills. The chemical results are important since they can be correlated with the physical processes of dispersion (1) and with the microbial utilization of the chemicals (2). Furthermore, they will eventually be used to determine the overall effect on the marine environment (3). Herein, chemical analyses of water samples from the meso scale experiments were compared for both treated and untreated spills.

7.4.2 Test Facilities

The meso scale test system, located 450 meters from Narragansett Bay consists of two 4000 liter tanks (6.2 m tall and 0.9 m in diameter). These tanks are described in more detail elsewhere (3).

7.4.3 Chemical Analysis

One liter water samples were extracted with two 15 ml. aliquots of CS_2. The aliquots were combined and the volume adjusted to 25 ml (some of the CS_2 dissolves in water and some is lost by evaporation to give a total just below 25 ml). The solution was placed in a 6 mm pathlength infrared cell (with AgCl windows), and the infrared absorbance at 2920 cm^{-1} measured with an identical cell containing CS_2 in the reference beam of the spectrometer (4,5). The measured absorbance was then converted to total hydrocarbons from a pre-determined plot of absorbance vs. con- centration (separate plots were used for oil and oil/dispersant. and were both obtained using the oil and dispersant being investigated).

The volume of the CS_2 solution was then reduced to .6 ml under nitrogen, and the complete infrared spectrum (IR) was measured under the same conditions as above. Following this, the gas chromatogram (GC) was measured.

IR spectra were measured on a Beckman 4260 spectrometer and GC on a Hewlett Packard 5710A gas chromatograph equipped with flame ionization detection and 10 m x 3 mm column packed with SP2250. The GC temperature was programmed at 8 C/min.

A. Series I

All of these experiments in the meso scale tanks were performed on API Kuwait crude oil, using Corexit 9527 as the dispersant.

Sixty ml of oil (15 ppm total concentration) were added to the water surface in each tank and 12 ml of dispersant to one of the tanks. One liter water samples were collected from each of the three ports at 1, 24, 48 and 72 hours.

In addition, in the first three experiments, 1 liter water samples were collected while the tanks were being filled, and at 30 minutes after filling. These samples were used as controls. In the fourth experiment, a control tank of the same dimension and with the same sampling ports, was used, and samples were taken at the same time as the others.

All water samples were returned immediately to the laboratory for analysis.

Several test runs without oil were made in the meso scale tanks to determine the variation of extractable organics in the tanks. Extracts of water from the tanks were compared with those of water taken directly from Narragansett Bay and, in most cases, the concentration of organics in the tanks and in the Bay were similar. The only major difference was that the tanks were generally higher immediately after filling. This was probably due to the mixing of bottom sediments in the water column.

(a) Water Analysis

Four experiments were performed with oil and oil/dispersant. In all cases, oil was added only to the north tank and oil/dispersant to the south tank. In the experiment using the control tank, it is referred to as the east tank. The weather conditions and other information on the experiments will be discussed separately.

(i) Experiment 1:

Concentrations of extractable organics from the top, middle and bottom ports (1,3,5m) as a function of time are shown in Figures 7.4.1, 7.4.2, and 7.4.3. The control values for the two tanks are given by dashed lines across the plots. Both control values are high. However, the one for the north tank was abnormally high. In this experiment, only one control sample was collected from each tank immediately after filling and, as mentioned above, the abnormally high values are probably due to the suspended sediment.

In the next two experiments, control samples were collected immediately after filling and one half hour later. The latter values are closer to the actual values of organics in sea water.

Considering the high control values, it is difficult to analyze the results of this experiment. However, general trends can be identified. Only one sample from the south tank had a concentration above the control, and that was the top sample collected after 72 hours.

The tank with the dispersant had an extremely high value for the 1 hour sample from the top, but the concentration decreased significantly after 24 hours and continued to decrease for the duration of the experiment. The highest concentration for the middle and bottom ports were found at 24 hours, and these also decreased with time.

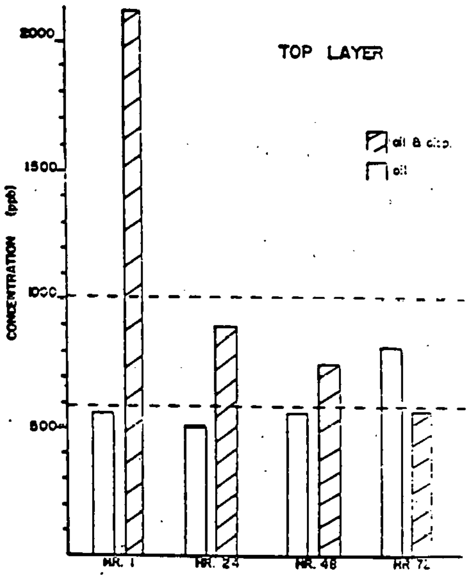


Figure 7.4.1 Concentrations of Extractable Organics from the Top Po (1m) as a Function of Time. (Exp. 1)

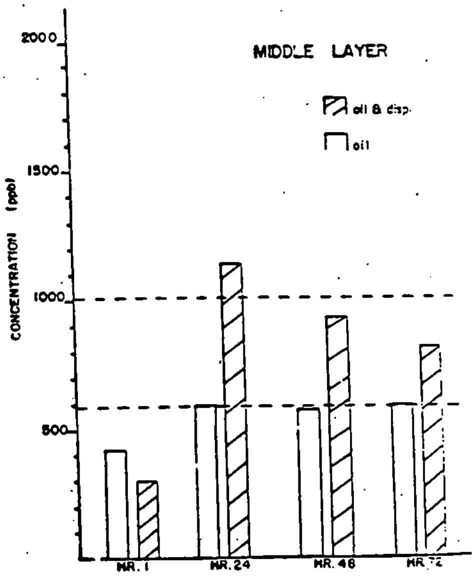


Figure 7.4.2 Concentration of Extractable Organics from the Mi (3m) as a Function of Time. (Exp. 1)

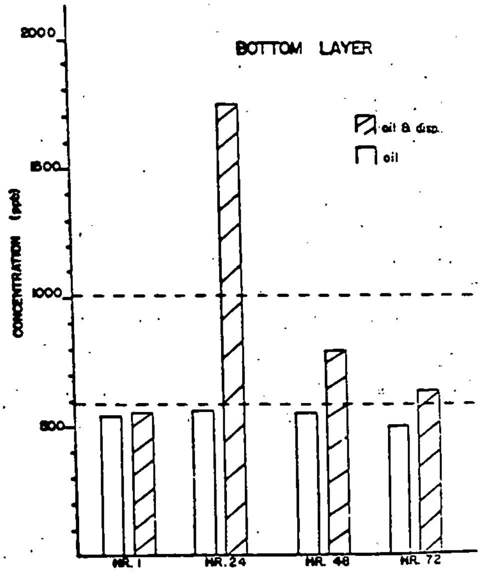


Figure 7.4.3 Concentration of Extractable Organics from the Bottom Port (5.5 m) as a Function of Time. (Exp. 1)

In general, this experiment indicated that dispersant caused a high concentration at the 1 m depth after 1 hour. Some of these chemicals moved toward the surface and others to the bottom during the next 24 hours.

(ii) Experiment 2:

Quantitative values for the total extractable organics from the second experiment in the meso scale tanks are shown in Figures (7.4.4) and (7.4.5). Control values of 210 and 243 ppb are shown as dashed lines drawn horizontally across the bar graph. The time dependence of concentration from the top, middle and bottom sampling ports (1,3, 5.5m) are given in Figure (7.4.5).

In the top port, the concentration of extractable organics (above the concentration of the control) at 1 hour was more than 27 times greater than when the dispersant was used, i.e., 4880 ppb as compared to 180 ppb. After twenty-four hours, the concentration in the tank without dispersant fell to below control level and stayed for the remainder of the experiment. In the treated tank, the concentration of extractable organics decreased by more than a factor of 3 to 1350 ppb after 24 hours, and then gradually decreased to 851 ppb after 3 days.

At the middle level, the concentration in the untreated tank gradually decreased from 324 ppb during the 72 hour experiment, whereas there was a three-fold increase in the tank with dispersant from 1 to 24 hours. This level decreased gradually after twenty-four hours.

The concentration in the bottom layer in the untreated tank reached a maximum slightly above the control level at 24 hours and then gradually decreased. In the tank with dispersant, there was a five-fold increase from 1 to 24 hours, but the maximum was not reached until 48 hours.

For comparison, the same results are plotted in Figure 7.4.5 as a function of depth for each of the sampling times. These plots clearly show that the maximum concentration moved toward the bottom in both the treated and untreated cases. However, there was a significantly greater concentration in the treated tank.

For qualitative comparison of the water sample, two sets of GC are shown in Figures 7.4.6 and 7.4.7. The 24 hour samples are compared in Figure 7.4.6. The GC of the untreated samples was expanded seven times. The distribution of n-paraffins in this sample is not similar to the treated oil and is not characteristic of petroleum. The GC of the top 1 hour treated sample is shown in Figure 7.4.7, where it is compared to all 24 hour samples from the same tank. Components boiling below n-C_{15}, which were initially dispersed, were not found at 24 hours.

(iii) Experiment 3:

The concentration for the top, middle and bottom layer as a function of time are shown in Figures 7.4.8, 7.4.9 and 7.4.10. The initial values for the top are similar to those in experiment 2. However, the decrease in the treated tank after 24 hours was much greater.

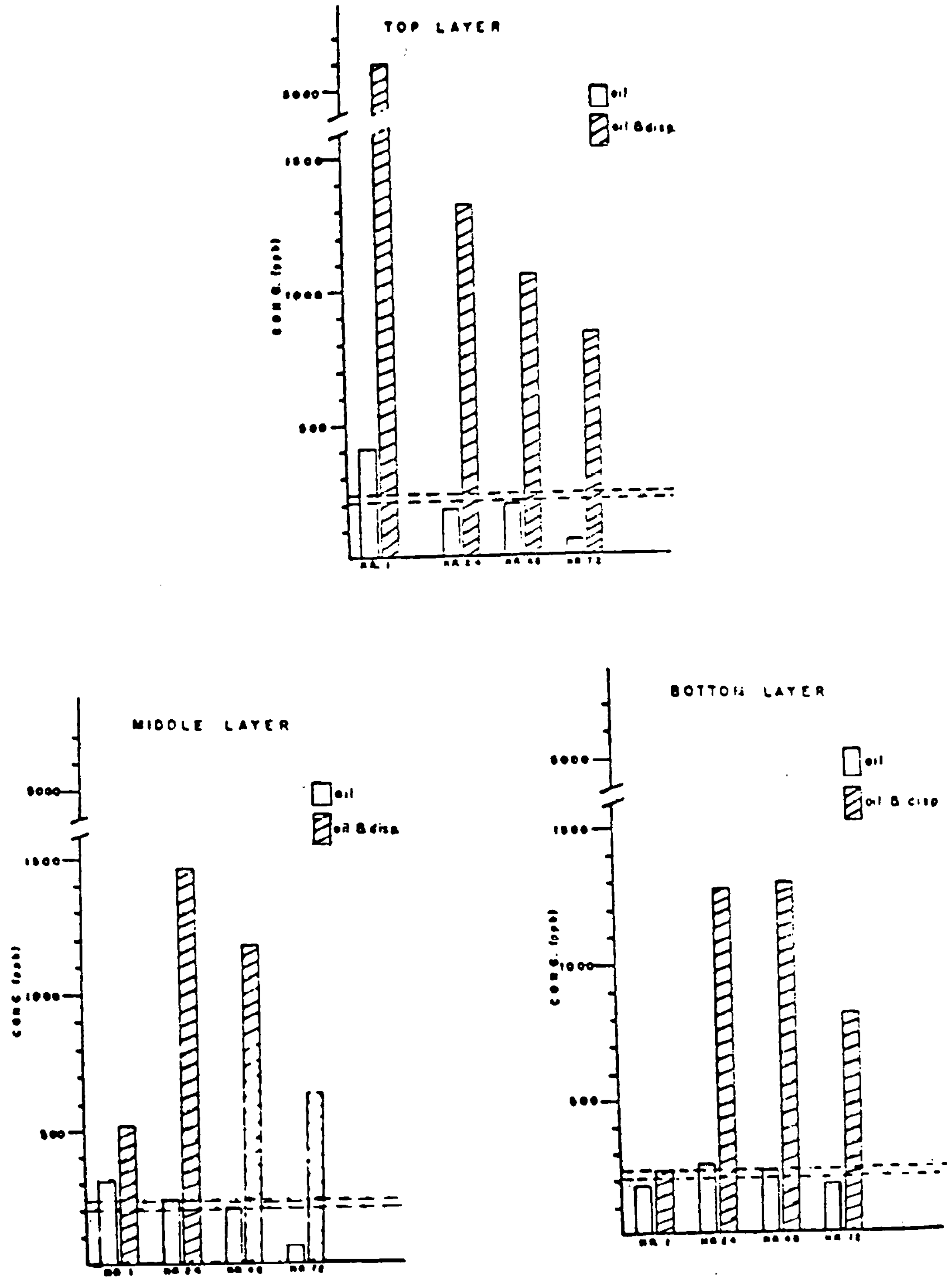


Figure 7.4.4 Concentration of Extractable Organics in the Top, Middle, and Bottom Levels. (Exp. 2)

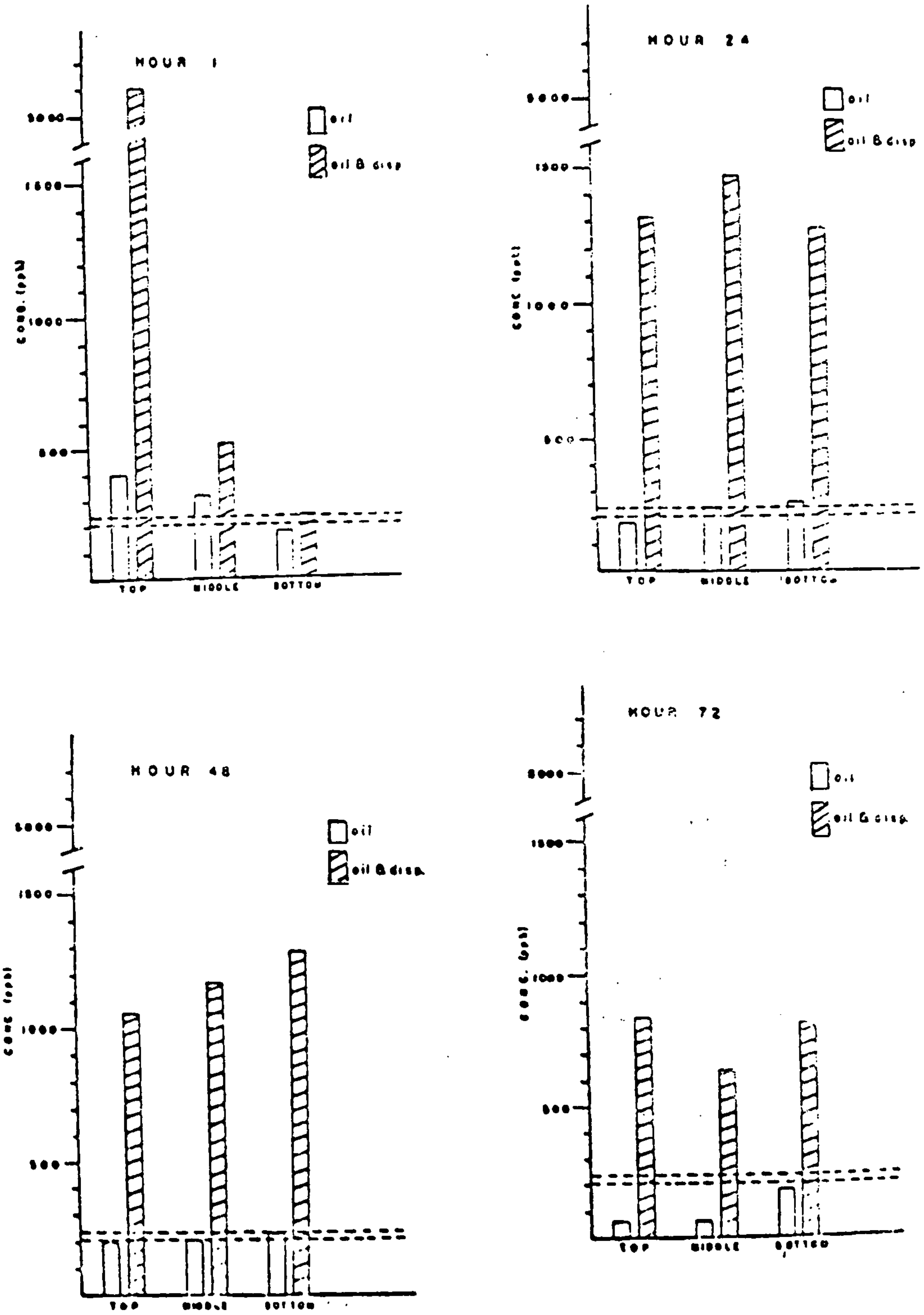


Figure 7.4.5 Concentration of Extractable Organics in the Top, Middle, and Bottom of the Treated and Untreated Tanks at Each Sampling Time

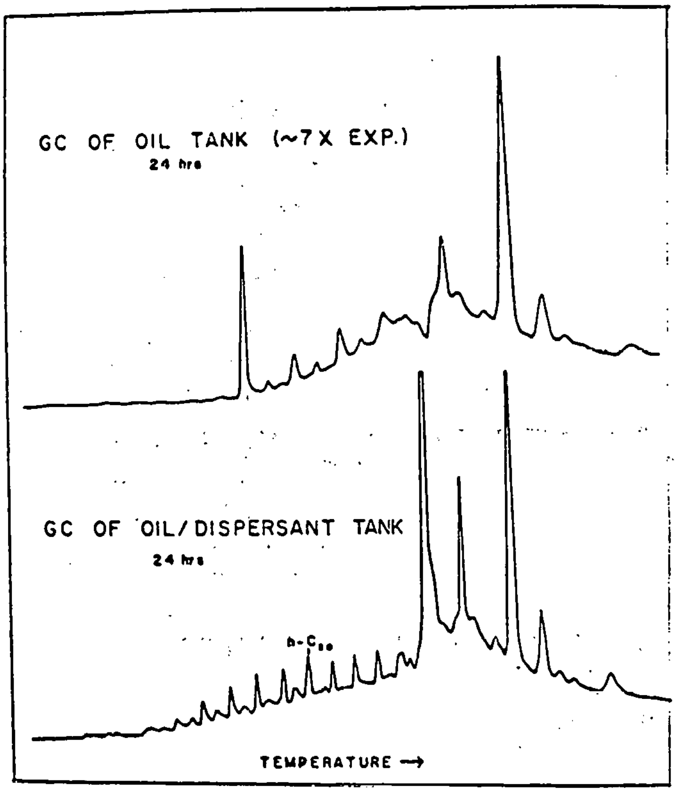


Figure 7.4.6 GC of the 24 Hour Top Samples from the Treated and Untreated Tanks

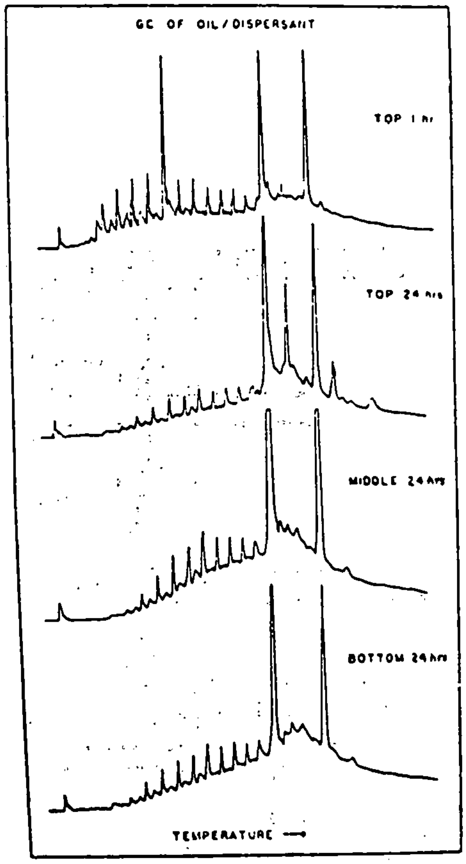


Figure 7.4.7 GC of Samples from the Treated Tank; 1 hr., top; 24 hrs., top; 24 hrs., middle; and 24 hrs., bottom (Exp. 2)

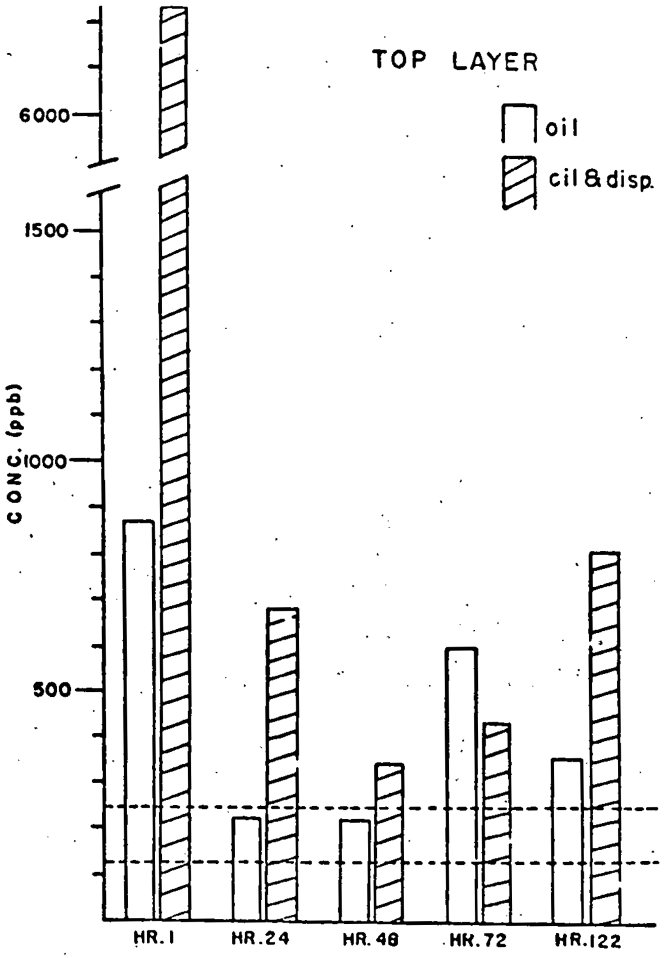


Figure 7.4.8 Concentrations of Extractable Organics from the Top (1 m) Port as a Function of Time. (Exp. 3)

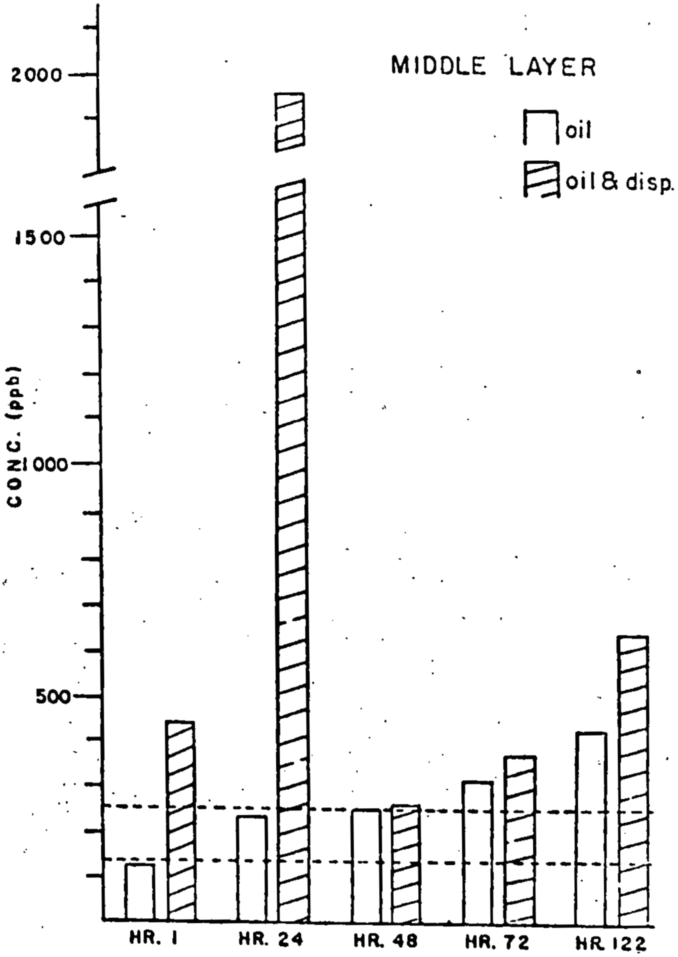


Figure 7.4.9 Concentrations of Extractable Organics from the Middle Port (3 m) as a Function of Time. (Exp. 3)

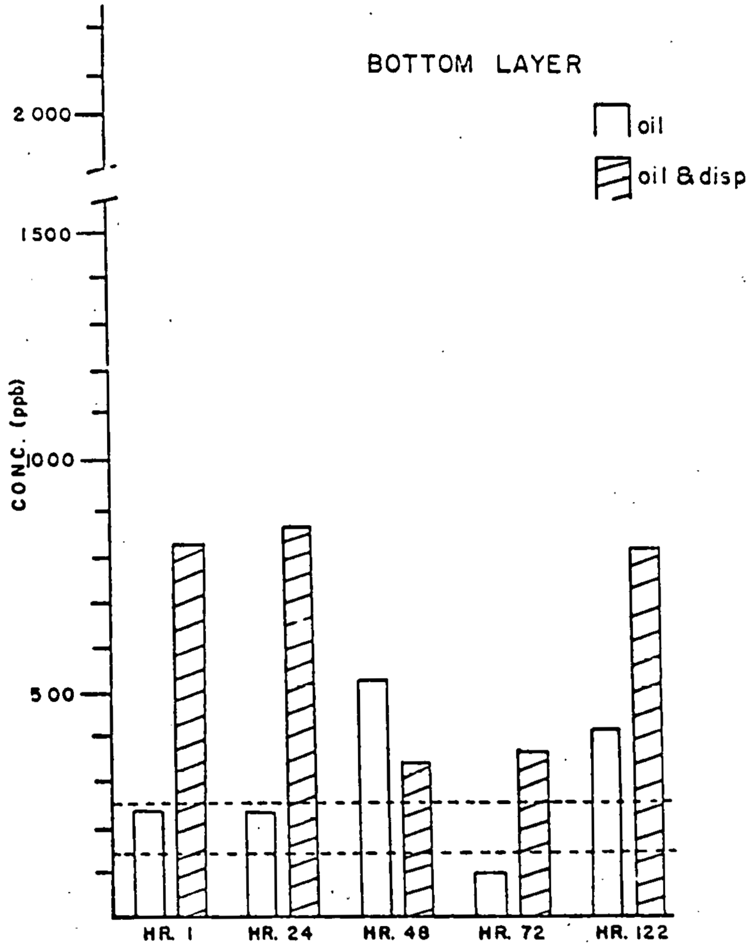


Figure 7.4.10 Concentrations of Extractable Organics from the Bottom Port (5.5 m) as a Function of Time. (Exp. 3)

The 1 and 24 hour values for the middle port are also similar to experiment 2 but, again, there is an abrupt decrease in concentration in the treated tank by the next sampling period. Samples from the bottom port of the treated tank were high at 1 hour and remained at this level for 24 hours before decreasing. However, the untreated tank had a high level at 48 hours, and then dropped to control level.

After 4 days, both tanks were agitated by stirring with a glass rod for 10 minutes, and samples were collected 24 hours later. The agitation increased the concentration at all levels.

(iv) Experiment 4:

The concentration of the top, middle and bottom layer as a function of time are shown in Figure 7.4.11, 7.4.12, and 7.4.13. In this experiment, the east control tank was used. The 1 hour concentration in the control tank was at least three times lower than previous experiments. However, the trend for the 24 to 72 hour samples was very similar to experiment 3. A very high concentration was detected in the middle port of the treated tank after 48 hours. The concentration at 1 hour was higher in other experiments, whereas the concentration at 24 hours was lower. The concentration in the bottom of the treated tank gradually increased with time. All concentrations in the untreated tank were at about the control level.

(v) Conclusions:

After only four completed experiments, it is too early to draw any definitive conclusions. The concentration values for experiment 2 seem to follow anticipated levels. For this reason, we undertook a complete analysis of all samples. The GC results shown in Figures 7.4.6 and 7.4.7 emphasize some of the major differences between the treated and untreated samples and changes of the treated samples with time and depth.

(b) Air Samples

For these experiments, 60 ml of Kuwait crude oil were added to the north and south tanks, and 12 ml of Corexit 9527 were then added to the south tank.

The surface was mixed for 10 minutes by stirring with glass rods. Air samples were collected immediately after the spill. Air samples were collected and treated similar to the air samples taken in the laboratory experiments. Figure 7.4.14 shows the system used for collecting the air samples in the meso scale experiments. The funnels through which the air was pumped were placed at about 2.5 cm above the water surface.

One experiment was conducted with the tanks covered to eliminate wind and rain effects. This was important to the water column measurements. The covers were made of wood and had four holes of 2.5 cm diameter for ventilation and one hole of about 20 cm in the center of the cover on which the funnel was placed. Prior to the addition of the oil, control samples were collected from above both tanks. Surface samples were taken and treated as in the laboratory experiments.

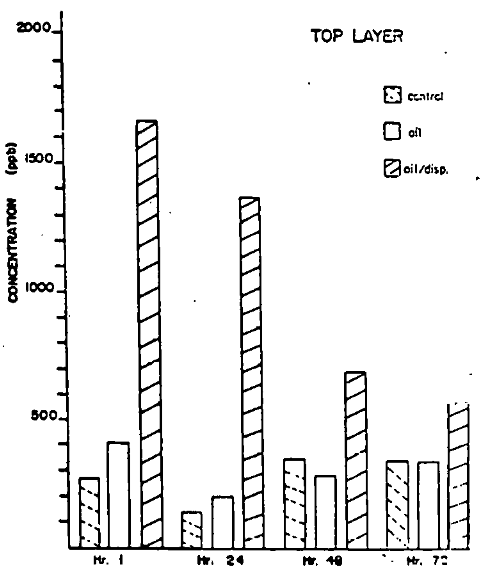


Figure 7.4.11 Concentrations of Extractable Organics from the Top Port (1 m) as a Function of Time. (Exp. 4)

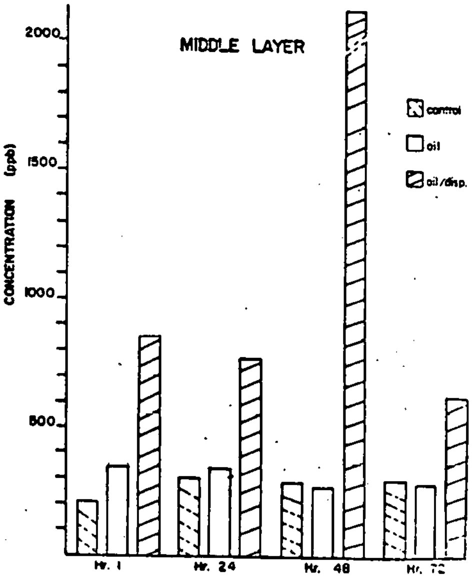


Figure 7.4.12 Concentrations of Extractable Organics from the Middle Port (3 m) as a Function of Time. (Exp. 4)

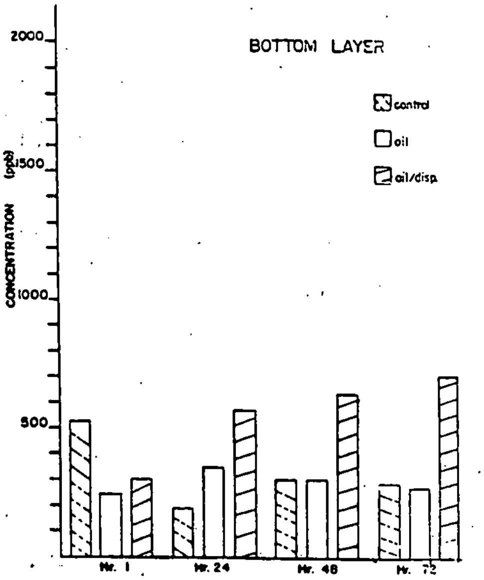


Figure 7.4.13 Concentrations of Extractable Organics from the Bottom Port (5.5 m) as a Function of Time (Exp. 4)

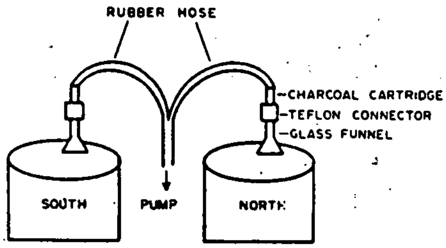


Figure 7.4.14 System Used to Collect Air Samples in the Meso Scale Experiments

The following experiments were performed:

(i) Experiment 1:

The water temperature at the beginning of the experiment was 24^{0}C. Control samples were taken during the 1.5 hours before the oil was added. Air samples were taken at 0-3 and 3-6 hours. Surface samples were taken at 72 hours after the addition of the oil.

(ii) Experiment 2:

The water temperature was 19^{0}C at the beginning of the experiment. Control samples were taken during 1 hour. Air samples were taken at 0-1.5, 1.5-4, and 4-7 hours. Surface samples were taken at 1.5, 4, 7, 48 and 72 hours after the spill.

(iii) Experiment 3

In this experiment, the tanks were covered with the wooden covers. The temperature at the beginning of the experiment was 10.5^{0}C. Control samples were taken during 50 minutes. Air samples were collected at 0.3-5, 1.5-4, 4-7 and 7-20.5 hours. Surface samples were collected at 72 hours after the spill. An internal standard, n-C_{20}, was added after the IR measurements.

(iv) Results and Discussion

Experiment 1:

The air samples collected above both tanks were quite similar. The gas chromatograms of the air samples taken at 0-3 hours are shown in Figure 7.4.15 and those taken at 3-6 hours are shown in Figure 7.4.14. Samples taken at 3-6 hours indicated the presence of n-C_{12} to n-C_{16}. All components lighter than n-C_{12} evaporated from both treated and untreated slicks within 3 hours. The surface samples taken at 72 hours after the spill indicated that all the components up to n-C_{16} disappeared from the treated and untreated slicks. the gas chromatograms of both surface samples were similar.

The IR spectra of both air samples taken at 3-6 hours indicated that the light aromatics, i.e., benzene, toluene and xylene, evaporated within 3 hours (or less) as their specific bands did not appear in the spectra (Figures 7.4.17 and 7.4.18).

Experiment 2:

All components up to n-C_{16} appeared in the air samples of the treated and untreated spills taken at 0-1.5 hours. Gas chromatograms of samples taken at 1.5-4 hours showed the presence of n-C_{11}-n-C_{17} in both air samples. All components up to n-C evaporated within 1.5 hours. The gas chromatograms of the air samples at 4-7 hours, shown in Figure 7.4.19 indicated the presence of n-C_{12}-n-C_{17} in the oil air sample and n-C-$_{13}$-n-C_{17} in the oil and dispersant air sample.

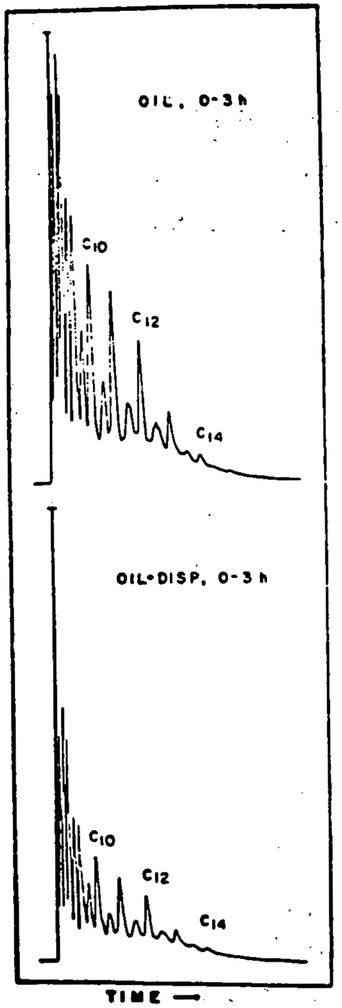


Figure 7.4.15 GC of the Air Samples Collected at 0-3 Hours (Meso Scale Exp. 1)

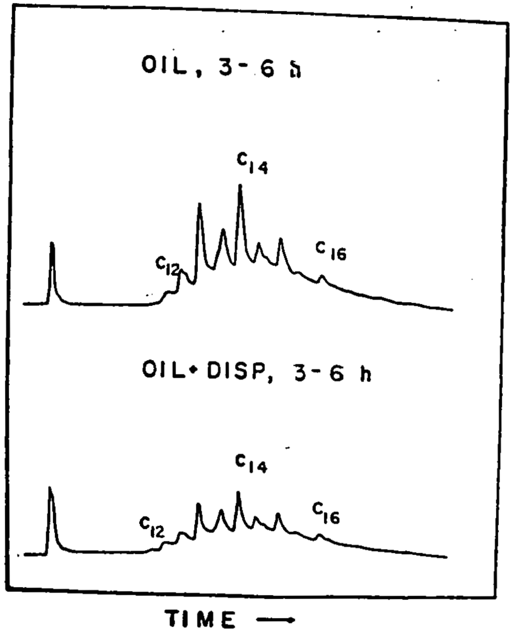


Figure 7.4.16 GC of the Air Samples Collected at 3-6 Hours (Meso Scale Exp. 1)

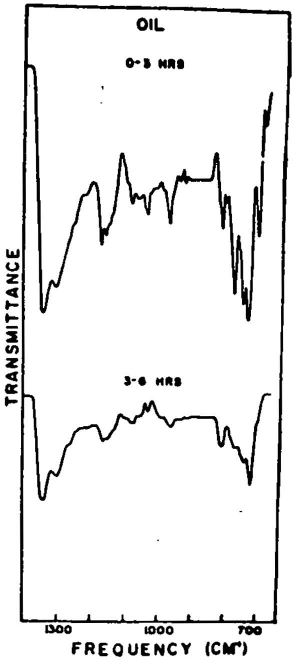


Figure 7.4.17 IR Spectra of the Oil Air Samples Collected at 0-3 and 3-6 Hrs. (Meso Scale Exp. 1)

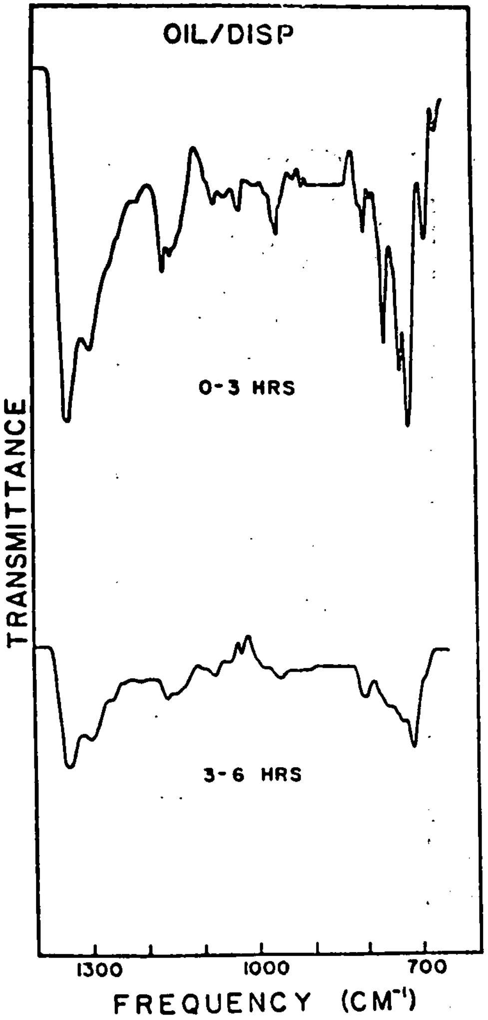


Figure 7.4.18 IR Spectra of the Oil + Dispersant Air Samples Collected at 0-3 and 3-6 Hrs. (Meso Scale Exp. 1)

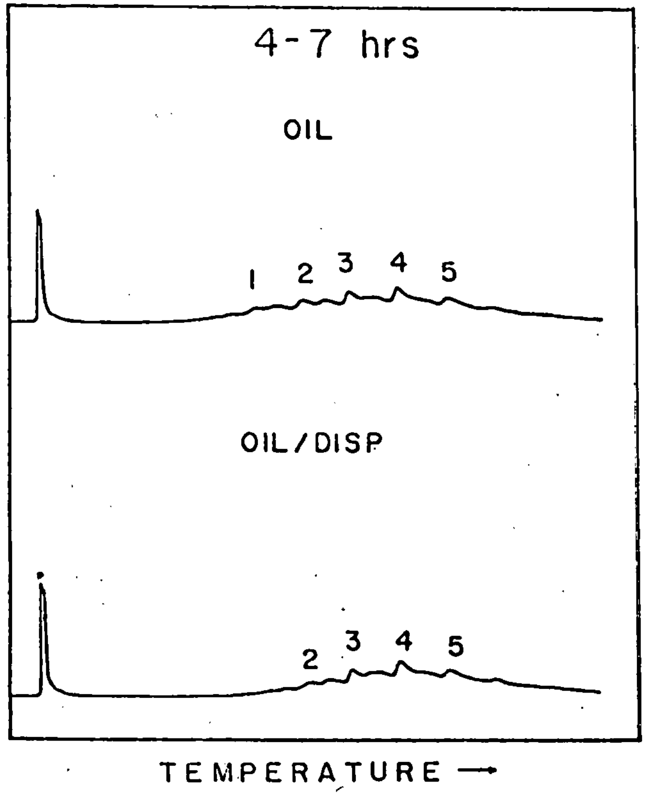


Figure 7.4.19 GC of the Air Samples Collected at 4-7 Hrs. (Meso Scale Exp. 2)

A surface sample from the oil slick taken at 1.5 hours indicated that all hydrocarbons up to n-C_{10} had disappeared. The oil and dispersant slick sample taken at the same time indicated that all components lighter than n-C_{11} had disappeared (Figure 7.4.20). The relative amount of n-C_{10} in the oil slick sample was small and this might be the reason why it did not appear in the air sample taken at 1.5-4 hours above the oil slick, which was more dilute than the surface sample.

Samples from both slicks taken at 4 and 7 hours after the spill indicated that the lightest hydrocarbon present was n-C_{12}, but the treated slick contained relatively less amounts of n-C_{12} and n-C_{13}. n-C_{13} was present in the untreated slick sample taken at 48 hours after the spill, but disappeared from the treated slick (Figure 7.4.21). Surface samples of both slicks taken at 72 hours after the spill showed that all hydrocarbons lighter than n-C_{14} had disappeared. The results obtained from the air samples are in agreement with the results obtained from the surface samples. The evaporation was slightly faster from the treated slick.

The IR spectra of the air samples taken at 1.5-4 hours showed that benzene, toluene, and xylene disappeared within 1.5 hours from both spills.

Experiment 3:

This experiment was performed with covers on the tanks as described in the experimental section. The evaporation was slower than in the open tank experiments, as expected. The control air samples indicated the presence of some organics in the air, but their amount was negligible compared to the vapors collected. Figure 7.4.22 shows the relative heights of the GC peaks of the n-alkanes at different times. The evaporation rate of the n-alkanes was slightly faster in the treated slick. However, the difference does not seem to be significant.

Figure 7.4.23 shows the IR spectra of the air samples taken at 0.3-1.5 hours. The benzene band at 670 cm-1 does not appear in either air sample, indicating that the benzene evaporated within 20 minutes (it took 20 minutes to stir the surface and to cover the tanks). Surface samples taken at 72 hours after the spill indicated that all hydrocarbons lighter than n-C_{14} disappeared from the treated and untreated slicks.

c) Conclusions:

The meso scale experiments indicated that the difference between the evaporation rates of the n-alkanes from the treated and untreated slicks were small. One experiment showed no difference and the other two showed a slightly faster evaporation from the treated slick. Oil vs. oil experiments were not performed in the meso scale, so it is difficult to conclude whether the differences were due to the dispersant or to experimental errors.

Results of the meso scale experiments were in agreement with the laboratory scale experiments when mixing was not applied. Evaporation was faster in the meso scale (open tank) experiments because of the wind. The mixing that was applied in the meso scale experiments, i.e.,

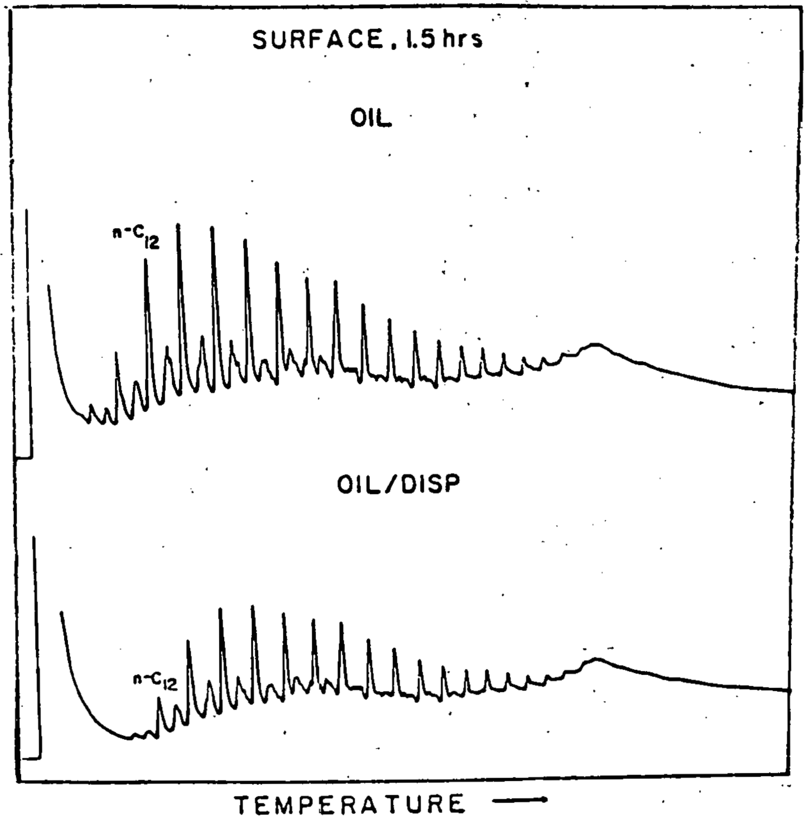


Figure 7.4.20 GC of Surface Samples Collected 1.5 Hours After the Spill (Meso Scale exp. 2)

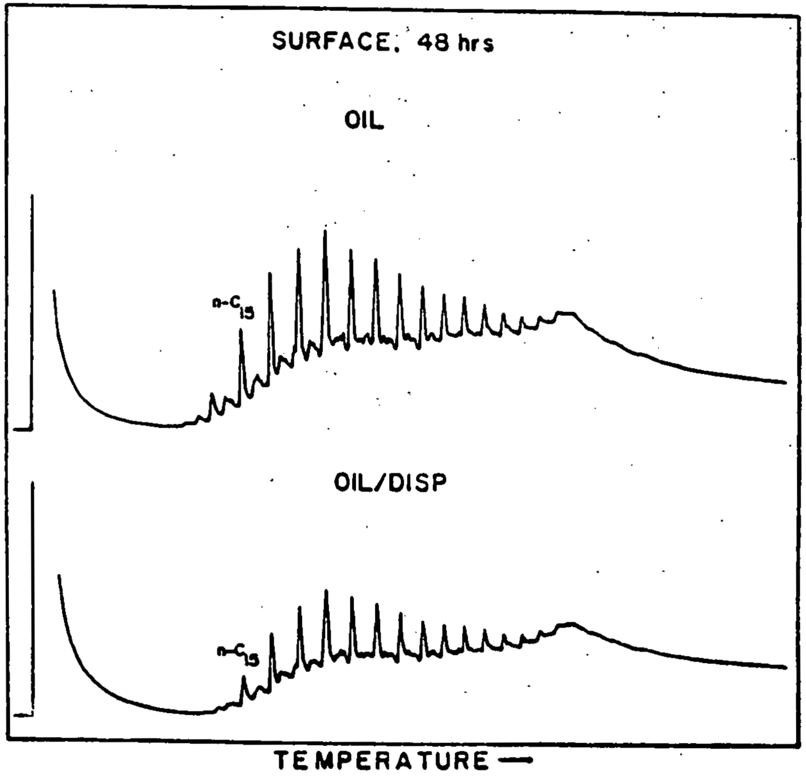


Figure 7.4.21 GC of Surface Samples Collected 48 Hours After the Spill (Meso Scale Exp. 2)

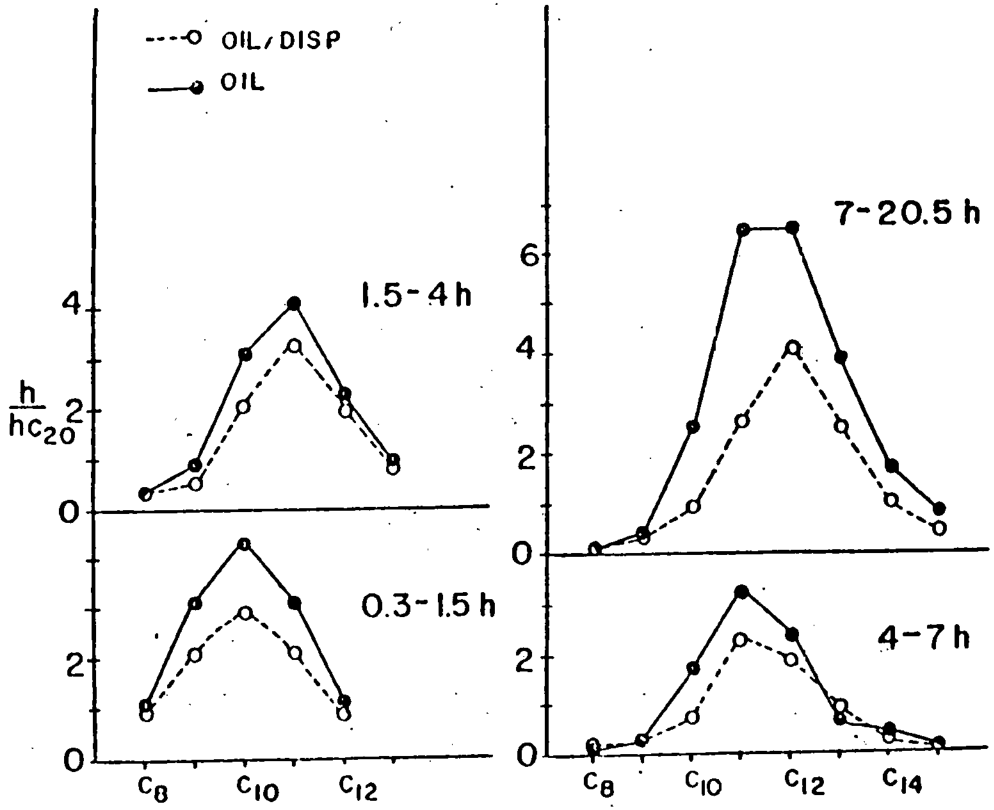


Figure 7.4.22 Relative GC Peak Heights of the n-alkanes as a Function of the Carbon Number. (meso scale Experiment 3, Air samples Taken at 0.3-1.5, 1.5-4, 4-7, and 7-20.5 hrs)

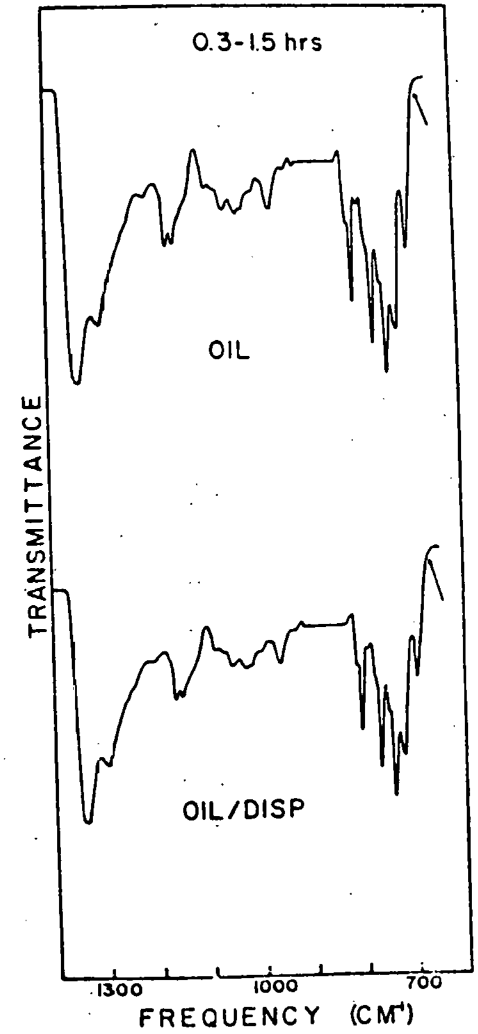


Figure 7.4.23 IR Spectra of the Air Samples Collected at 0.3-1.5 Hrs. (Meso Scale Experiment 3)

The arrows show the position of the benzene band.

stirring with glass rods, seemed to be inefficient in affecting the evaporation rates of the light n-alkanes. The wall effect that was mentioned in the laboratory experiments also exists in the tanks and could cause some differences in the effects of the dispersants on evaporation between meso scale experiments and open sea experiments.

(B) Series II

This series of experiments tested various modes of application of oil and dispersant to the seawater in the meso scale tanks. The water temperature remained a relatively constant 21^{0} C throughout the 6 experiments. Amounts of oil and/or dispersant added to the tanks as well as the mode of application are listed in Table 7.4.1. The first experiment was run for 72 hours whereas the remaining experiments were conducted for 24 hours each. At each sampling period, 1 liter water samples were collected and returned to this laboratory for quantitative infrared analysis. Table 7.4.2 a & b presents results for each experiment and the discussion of each follows:

(a) Water Analysis

(i) Experiment 1:

Control levels of approximately 100 ppb were found for all levels and sampling periods in the control (east) tank except for the middle layer at 48 hours). This value was close to the bay level (131 ppb). The highest concentrations of hydrocarbons are found in the middle layer of the south tank after 1 hour. The north tank had a relatively even distribution of hydrocarbons which is twice the control level but after 24 hours, amounts close to the control level were reached in this tank and in the south tank. For this reason, the remaining experiments were conducted for a 24 hour duration.

(ii) Experiment 2:

In this experiment, the amount of oil and dispersant added to the tank was increased while the ratio of oil:dispersant was kept to 5:1. Application was also the same as in experiment 1. Table 7.4.2b shows that the hydrocarbon levels and distribution in the north tank after 1 hour are almost identical to those in the first experiment, i.e., increasing the oil in the north tank did not increase the amount entering the water column. In the south tank, overall amounts of hydrocarbons and their relative distribution is the opposite to the first experiment. The top and middle layer increased after the first hour, while their relative distribution is the opposite in the first experiment in these two layers. The hydrocarbons do not seem to reach the bottom layer during this time.

After 24 hours, hydrocarbon levels in the north tank have increased slightly over those in the 1 hour sampling. In the south tank overall levels are still high and the distribution among layers again corresponds with the first experiment.

Table 7.4.1

Exp. #	Tank	Kuwait (ml)	Disper. (ml)	Mode of Application of Dispersant	Comments
1	8/1/78				
	North	60			sprayed*
	South	60	12	premixed w/ 120 ml sea water/sprayed on	sprayed
2	8/16/78				
	North	300			sprayed
	South	300	60	premix. w/600 ml. seawater/sprayed on	sprayed
3	8/22/78				
	North	60			sprayed
	south	60	12	premix. w/120 ml freshwater/sprayed on	sprayed
4	8/28/78				
	North	300			sprayed
	South	300	60	poured no premix.	sprayed
5	8/31/78				
	North	60			sprayed
	South	60	12.	premix. w/oil poured	sprayed
6.	9/6/78				
	North	60			sprayed
	South	60	12	premix. w/oil & 120 ml. fresh water poured	sprayed

*Indicates a spray of salt water over surface of "spill."

Table 7.4.2a Infrared Quantitative Analysis (ppb)

Hr. #	Sample Location	Tank N	S	E
1	top	223	951	-
	mid	110	1336	108
	bot	232	672	105
24	top	214	527	108
	mid	221	384	105
	bot	0	403	543
48	top	105	133	0
	mid	109	132	691
	bot	121	285	113
72	top	-	403	213
	mid	107	256	104
	bot	102	267	167
CONTROL		0	135	110
BAY	131			

Table 7.4.2b Infrared Quantitative Analysis (ppb)

Hr. #	Sample Location	Tank N	S	E
Exp. 2				
1	Top	216	98,918	105
	Mid	120	46,227	105
	Bot	326	301	107
	Ct*	184	265	
24	Top	326	11,279	326
	Mid	212	9,753	106
	Bot	319	672	219
Exp. 3				
1	Top	223	1,614	102
	Mid	283	1,578	101
	Bot	231	129	112
	Ct	219	417	
24	Top	110	395	298
	Mid	105	993	407
	bot	212	399	322
Exp. 4				
1	Top	330	36,525	333
	Mid	219	17,462	109
	Bot	474	694	245
	Ct	323	441	112
24	Top	330	6,122	260
	Mid	218	6,089	106
	Bot	168	2,978	110
Exp. 5				
1	Top	268	23,228	241
	Mid	345	22,549	223
	Bot	327	2,376	219
	Ct	354	1,590	185
24	Top	854	7,988	323
	Mid	769	7,680	330
	Bot	670	15,650	272
Exp. 6				
1	Top	326	6,852	214
	Mid	237	1,271	353
	bot	330	3,999	234
	Ct	218	1,578	280
24	Top	452	5,420	210
	Mid	447	4,709	306
	bot	457	2,363	223

*Ct - control

(iii) Experiment 3:

In this series, the mode of application of dispersant was changed by premixing it with fresh water instead of sea water as in the last two experiments. The amount of oil and/or dispersant was reduced to the levels of the first experiment.

Taking into consideration the level of the controls for the north and south tank, levels of hydrocarbons parallel those of the first experiment after the first hour with highest concentrations in the south tank remaining in the top and middle layers. After twenty-four hours, levels in the north tank decreased slightly whereas levels in the south tank decreased significantly, approaching control values in top and bottom layers. The concentration in middle layer is about double that of the control.

The fresh water application seems to mix the oil/dispersant further into the depth of the tank but after 24 hours, the patterns of mixing resembles that of the sea water premix experiments.

(iv) Experiment 4:

The dispersant/oil amount was increased to experiment 2 levels. The dispersant was not premixed in this case, but was poured directly onto the oil in the tank. This was followed by a spray with water over the surface. As can be seen from Table 7.4.2b, the hydrocarbon levels in the north tank are consistent with those of previous experiments. In the south tank overall hydrocarbon levels after one hour correspond to those in experiment 2; however, the top layer in this case, contains the highest level. This would indicate that premixing the dispersant with water does aid in the incorporation of the oil/dispersant complex to a greater depth in the water column.

After 24 hours, the south tank has the highest concentration in the top two layers while the bottom layer is relatively low, but contains more organics than is evidenced in previous experiments.

(v) Experiment 5:

Oil and dispersant were premixed and poured on the water in the south tank. Both north and south were then sprayed with additional water. The control in the south tank indicates residual oil/dispersant which may have not been thoroughly removed from the tank prior to this experiment. Taking this into consideration, the comparatively high level of hydrocarbon in the bottom layer can be explained. After one hour, the levels of hydrocarbon in the top and middle layers of the south tank are among the highest detected in any of the six experiments, although only 60 mls. oil/12 mls. dispersant were added originally. After 24 hours, the highest level in the south tank was detected in the bottom layer.

(vi) Experiment 6:

The dispersant (12ml) was premixed with oil and fresh water prior to pouring onto the water surface of the south tank. The highest concentration of organics was found in the top layer of the south tank after one hour. After 24 hours, the top and middle layer have about the same amounts of hydrocarbons; however, the levels in this experiment are an order of a magnitude less than those in the previous experiment.

GC/MS analysis was performed on samples from experiment 2. In the north tank, components were below detectable limits (Table 7.4.3). The 1 hour samples in the south tank contained detectable amount of all aromatic components listed except for benzene. Normal hydrocarbons ranged between C_{10} to C_{18} for the top layer and C_{11} to C_{18} for the middle layer. The predominant peak in the top layer was C_{12}, whereas the higher boiling C_{14} dominated in the middle layer. After 24 hours, xylene was lost in both layers. The middle layer also lost napthalene. The normal alkane range remained the same for the top layer, but the predominant peak was the higher boiling C_{14}. In the middle layer the predominant peak remained C_{14} but the low alkane shifted from C_{11} to C_{12}. GC/MS of deasphalted Kuwait oil contains all aromatics listed in Table 7.4.3 and has a n-Cn range of C_9-C_{18} with the predominant peak occuring at C_{10}.

(vii) Conclusions:

Effectiveness of the dispersant in carrying the oil into the water column is proportional to the amount of contact of the dispersant with both the polar water fraction and the non-polar oil fraction of the oil/water system. The most intimate contact between these fractions was achieved when the dispersant was premixed with the oil. In all experiments, agitation of the water surface in the tanks also aided in mixing the oil/dispersant complex into the water column. The north tank showed little, if any, increase over control values during the course of the six experiments. In the south tank, the highest concentration of hydrocarbons was found generally in the top and middle layers after 1 hour, with a relative reduction in concentration after 24 hours (in some cases reduction to control levels). The level of hydrocarbons in the south tank was determined more by the mode of dispersant application than by amount of oil/dispersant added.

GC/MS spectra and infrared values seem to indicate that after 24 hours there is an overall loss of organics from the water column and since this loss, as indicated by GC/MS, is in the more volatile components, it seems fair to conclude that these lighter components may be lost to the atmosphere.

(C) Series III

Because of the high level of residual organics detected in the south tank, both tanks were thoroughly cleaned and a second series of 5 twenty-four hour experiments were conducted. The mode of application of oil and/or dispersant as well as amounts of both are listed in Table 7.4.4. Quantitative infrared results are listed in Table 7.4.5 and are

TABLE 7.4.3

SAMPLE	BENZENE	XYLENES	NAPHTHALENE	METHYL-NAPH.	DIMETHYL-NAPTH.	n-C_n RANGE	(PREDOMINANT PEAK)
S-TOP-1hr.(99ppm)		X	X	X	X	C_{10} thru C_{18}	C_{12}
S-TOP-24hr.(11ppm)			X	X	X	C_{10} thru C_{18}	C_{14}
S-MID-1hr.(46ppm)		X	X	X	X	C_{11} thru C_{18}	C_{14}
S-MID-24hr.(10ppm)				X	X	C_{12} thru C_{18}	C_{14}
S-CTRL(0.2ppm)	BELOW DETECTABLE LIMITS						
N-TOP-1hr.(0.2ppm)	"						
N-TOP-24hr.(0.3ppm)	"						
N-MID-1hr.(0.1ppm)	"						
N-MID-24hr.(0.2ppm)	"						
N-CTRL(0.2ppm)	"						
KUWAIT CRUDE (DEASPHALTED)	X	X	X	X	X	C_9 thru C_{18}	C_{10}

SUMMARY OF RESULTS FOR GC/MS/CS ANALYSIS FOR TANK EXPERIMENT 8/16/78

Table 7.4.4

Exp. #	Tank	Kuwait (ml)	Disper. (ml)	Mode of Application of Dispersant	Comments
1	10/13/78				
	North	60			sprayed salt
	South	60	12	premix. w/oil poured	sprayed salt
2	10/17/78				
	North	60			sprayed salt
	South	60	12	premix. w/oil & 120 ml fresh walter; poured	sprayed salt
3	10/24/78	60			fresh water sprayed
	North	60	3	premix. w/120 ml fresh water; sprayed on	
4	10/30/78				
	North	160			fresh water sprayed
	south	160	32	premix. w/320 ml fresh water; sprayed on	
5	11/2/78	160			fresh water sprayed
	North	160	8	premix. w/120 ml fresh water; sprayed on	

Table 7.4.5 Infrared Quantitative Analysis (ppb)

Hr #	Sample Location	Tank N	S
Exp. 1			
Ct	Top	102	300
	Mid		295
	Bot		214
1	Top	339	22,201
	Mid	229	20,168
	Bot	292	101
24	Top	729	15,684
	Mid	88	14,888
	Bot	81	712
Exp. 2			
Ct	Top	100	79
	Mid		81
	Bot		82
1	Top	250	30
	Mid	148	1,325
	Bot	250	511
24	Top	245	45,734
	Mid	358	26,837
	Bot	306	719
Exp. 3			
Ct	Top	388	144
	Mid		145
	Bot		84
1	Top	258	935
	Mid	345	893
	Bot	206	513
24	Top	268	519
	Mid	288	553
	Bot	371	513
Exp. 4			
Ct	Top	324	383
	Mid		234
	Bot		379
1	Top	293	2,848
	Mid	261	2,286
	Bot	176	1,533
24	Top	322	935
	Mid	316	1,506
	Bot	391	1,246
Exp. 5			
Ct.	Top	327	210
	Mid		305
	Bot		371
1	Top	412	1,118
	Mid	237	559
	Bot	237	675
24	Top	375	709
	Mid	687	771
	bot	326	876

discussed below:

(a) Water Analysis

(i) Experiment 1:

A 5:1 oil to dispersant ratio was used, the oil being mixed with the dispersant prior to pouring the mixture in the south tank. Both north and south tanks were then sprayed with salt water. The results show that the very high concentrations of organics are found in the top and middle layer after 1 hour with a slight reduction after 24 hours. The bottom layer has relatively little organics even after 24 hours. The north tank shows very little change in hydrocarbon level throughout the experiment.

(ii) Experiment 2:

The ratio and amount of oil was maintained as in Experiment 1. However, the dispersant was premixed with fresh water and oil prior to pouring on the south tank. Both north and south tanks were subsequently sprayed with salt water. In the south tank after 1 hour a substantial increase in organics occurs in the middle layer while an almost non-detectable amount is seen in the top layer. The bottom layer increases slightly over that in the first experiment. An unusual occurrence is seen after 24 hours, when the top and middle layer increase substantially to levels which occurred in previous experiments only after the first hour.

(iii) Experiment 3:

The ratio of oil:dispersant was decreased to 20:1 and the dispersant was premixed with fresh water prior to spraying on the oil slick in the south tank. In this case, the levels of hydrocarbons in the south tank greatly decreased while migration of organics was deeper into the water column than previously seen.

(iv) Experiment 4:

The amount of oil/dispersant was premixed with fresh water and this mixture was sprayed on the slick. This method of premixing and spraying seemed to promote deeper penetration of organics into the south tank, with the highest levels at the top, but comparatively high levels through to the bottom. This is the first experiment showing such penetration. After twenty-four hours, the middle and bottom layers contain the highest organic concentration.

(v) Experiment 5:

In this experiment the dispersant was decreased to yield a 20:1 oil/dispersant ratio. The dispersant was premixed with fresh water and this mixture was sprayed onto the slick. Overall concentrations in the water column are lower, but the depth of penetration parallels the previous experiment.

(vi) Conclusions:

The mode of application which causes the highest concentrations of organics in the overall water column is the one which premixes oil/dispersant or oil/water/dispersant prior to adding to the water in the south tank. Depth of penetration of organics into the tank is greatest for the dispersant which is sprayed on the tanks. The controlling factor in concentration of organics seems to be premixing of oil/dispersant rather than mode of application or amounts of oil/dispersant added.

(D) Series IV Meso-Scale Flow-thru Experiment

Two experiments (referred to as Trial 1 and Trial 2) were performed using the meso-scale tank equipped with a flow-thru system. Three tanks were used as follows:

1) control
2) 300 ml of Kuwait Oil
3) 300 ml of Kuwait Oil and 30 ml of Corexit 9527

One liter water samples were collected from the top, middle and bottom ports.

(i) Trial 1:

Quantitative results for the first trial experiment (aborted) at the meso scale tanks are given in Table 7.4.6 and GC's of selected samples are shown in Figures 7.4.24. and 7.4.28. The quantitative results indicate (and this is supported by the GC results) that oil entered the water column when the dispersant was used; however, after 24 hours the concentrations dropped to about three times that of the control. Very little chemical information was gained from an experiment of this short duration.

(ii) Trial 2:

(1) Quantitative Analysis

The amounts of extractable organics as determined by infrared spectroscopy are given in Table. 7.4.7. The values for the control tanks are all below 340 ppb except for the middle and bottom sampling ports at 350 hours. The values for the oil tank are in this same range until 48 hours when a larger amount was observed. The maximum value of 29,020 ppb was reached at 192 hours. The values for samples from the oil/dispersant tank are initially high for the top and middle of the tank; however, with time, the higher concentration migrates to the bottom. At 350 hours the only significantly high concentration is for samples from the bottom port of the tank.

(2) Qualitative Analysis

Control Tank:

Gas chromatograms (GC) of all samples having significant concentrations were measured. GC's of samples from the control tank are shown in Figures 7.4.29 - 7.4.40. Most of these chromatograms contain a series of peaks as shown in Figure 7.4.31, although they may contain additional

Table 7.4.6 Concentration (ppb) of extractable Organics in Water Samples from Flow-thru Tank Experiments at Narragansett bay Campus (Trial 1)

	Hours	0	1	24
(1) Control,	Top		270	185
	Mid	382	239	148
	Bot		280	193
(2) Oil,	Top		204	227
	Mid	414	230	216
	Bot		206	195
(3) Oil/Disp,	Top		2075	668
	Mid	458	3953	623
	Bot		247	240

Table 7.4.7 Concentrations (ppb) of extractable Organics in Water Samples from Flow-thru Tank Experiments at Narragansett Bay Campus (Trial 2)

	Hours	0	1	24	48	72	192	350
(1) Control,	Top		153	178	237	190	286	110
	Mid	340	102	200	185	261	105	1,386
	Bot		183	186	160	211	249	3,007
(2) Oil,	Top			232	1021	480	29,020	76.4
	Mid	308	162	273	325	309	1,851	192
	Bot		150	157	267	229	540	966
(3) Oil/Disp,	Top		54,276	9,776	5,486	3,706	2,638	264
	Mid	445	44,179	13,195	3,286	5,066	891	402
	Bot		294	265	1,516	4,006	11,939	1,033

Figure 7.4.24 GC of Surface Oil after 24 hrs. (Trial 1)

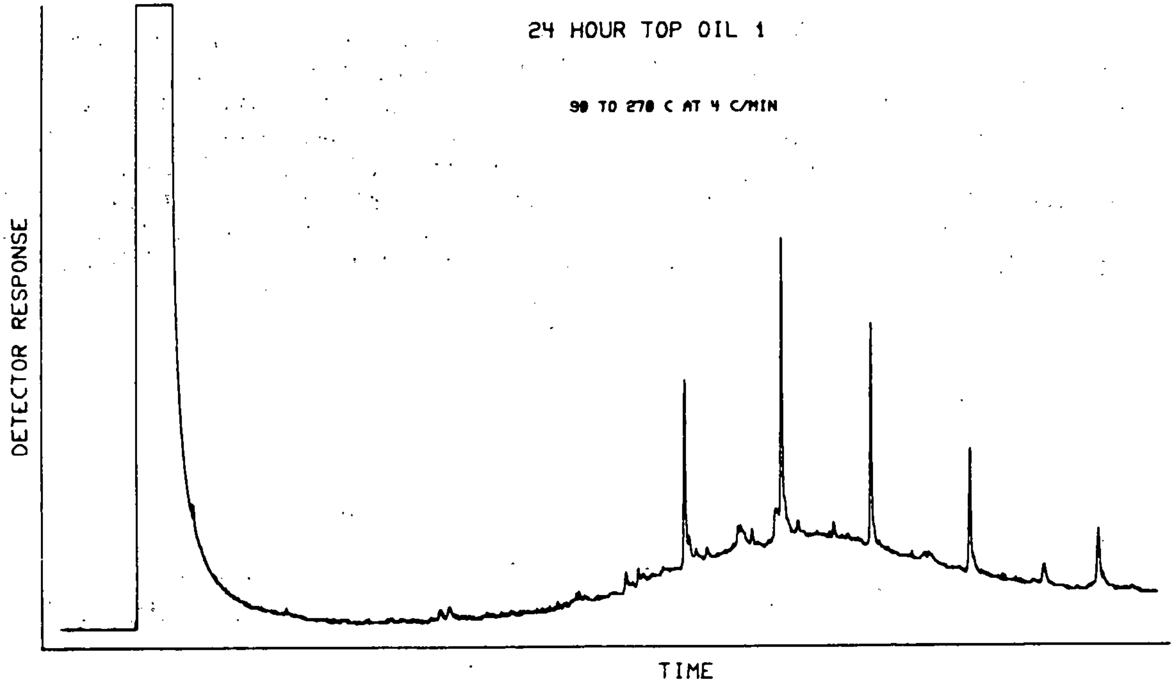


Figure 7.4.25 GC of Surface Oil/Dispersant after 1 hr. (Trial 1)

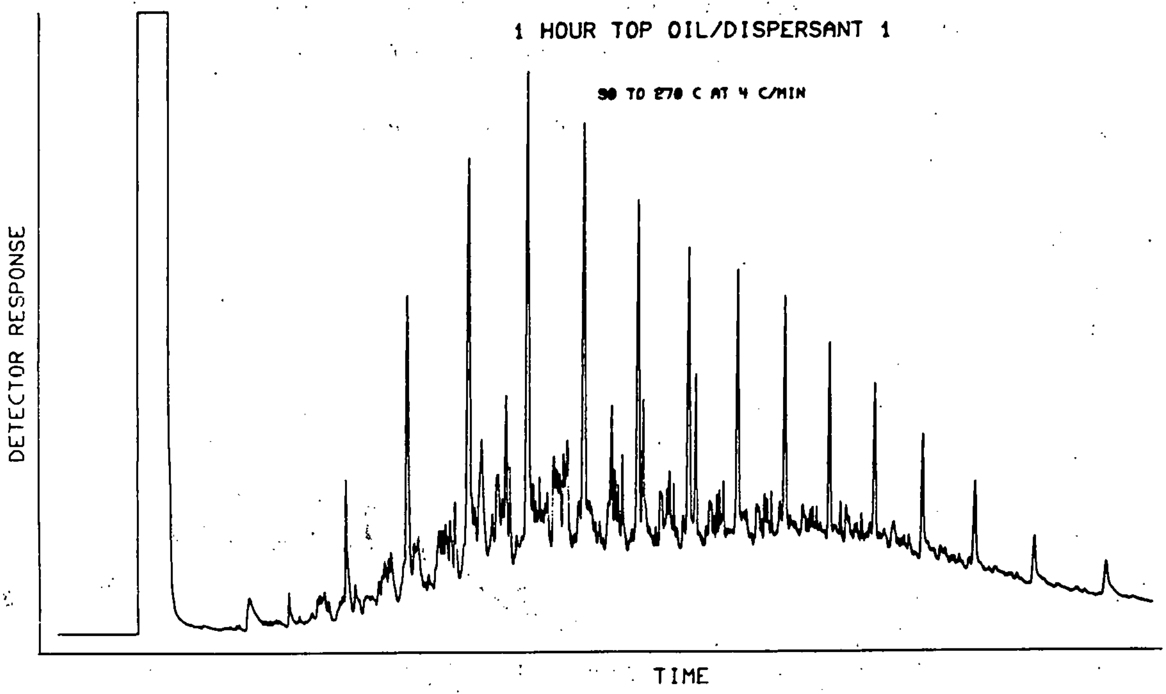


Figure 7.4.26 GC of Middle Oil/Dispersant after 1 hr. (Trial 1)

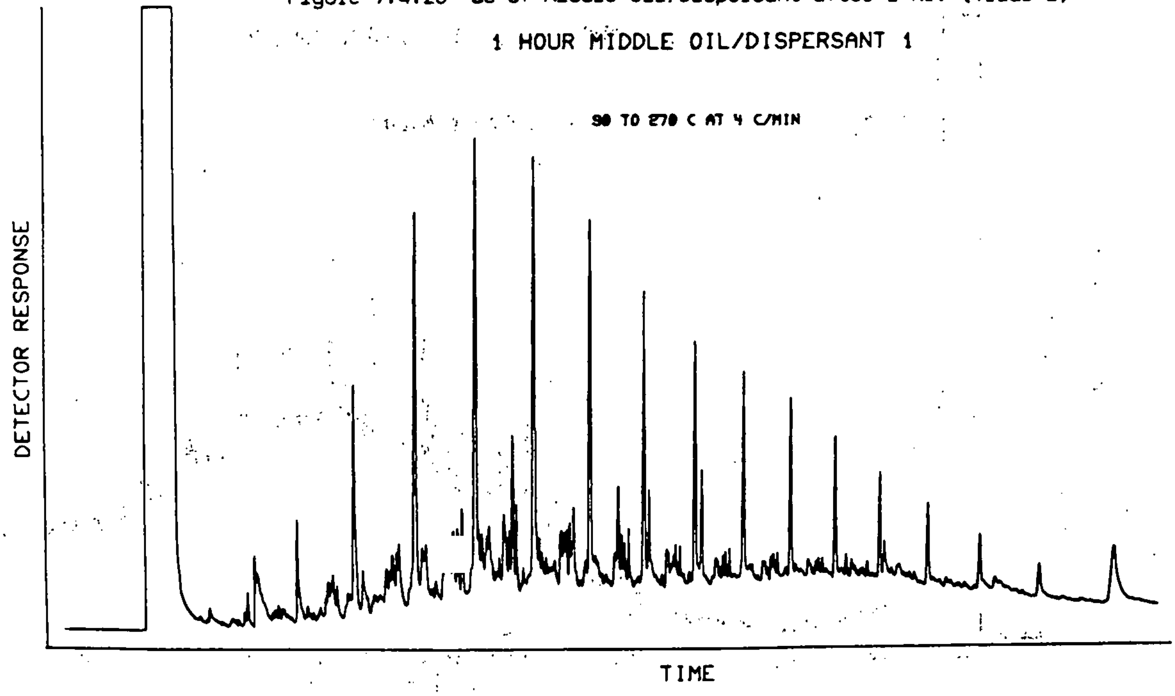


Figure 7.4.27 GC of Top Oil/Dispersant after 24 hrs. (Trial 1)

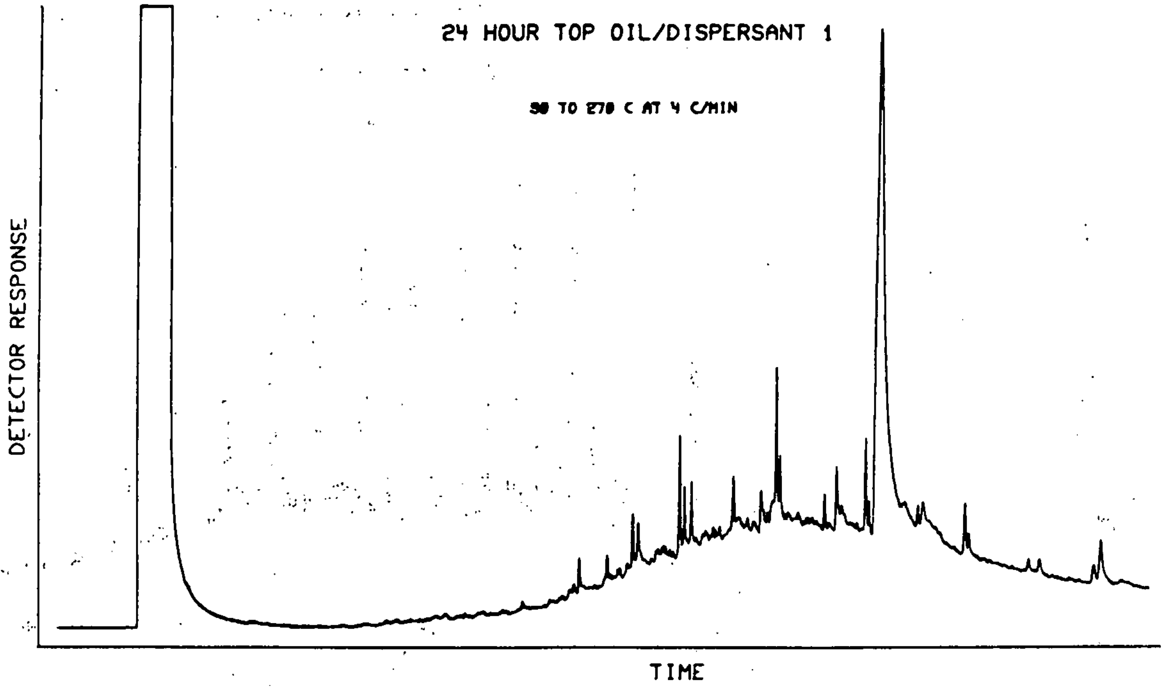


Figure 7.4.28 GC of Middle Oil/Dispersant after 24 hrs. (Trial 1)

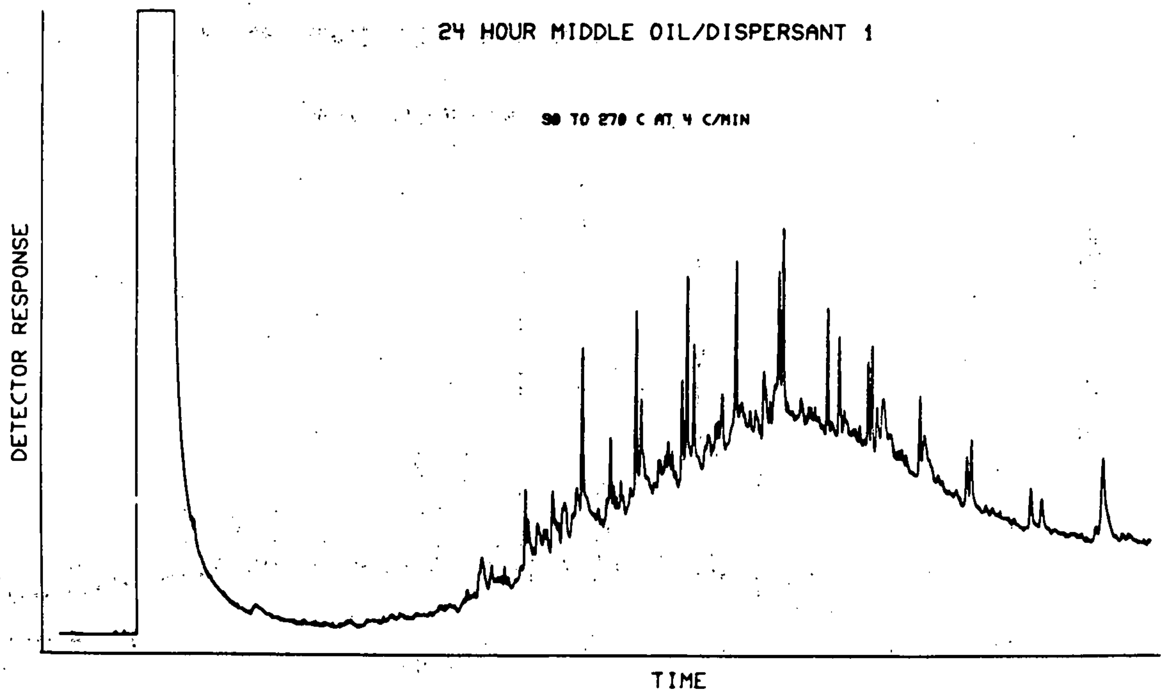


Figure 7.4.29 GC of Middle Control at 0 hr. (Trial 2)

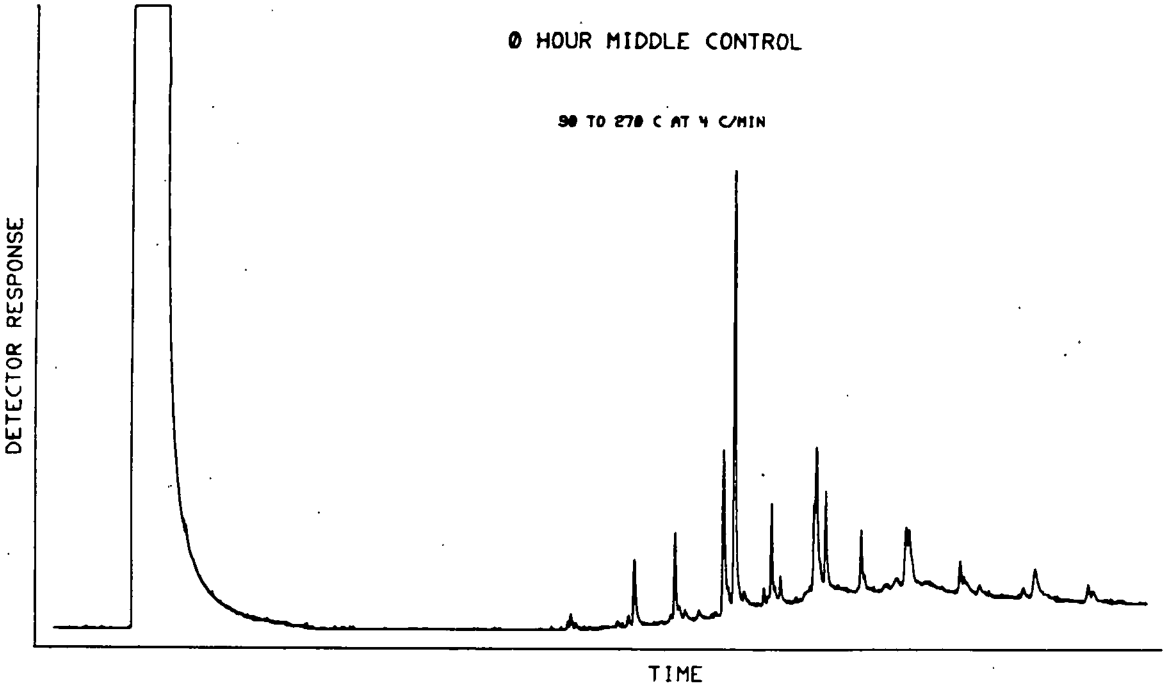


Figure 7.4.30 GC of Top Control after 1 hr. (Trial 2)

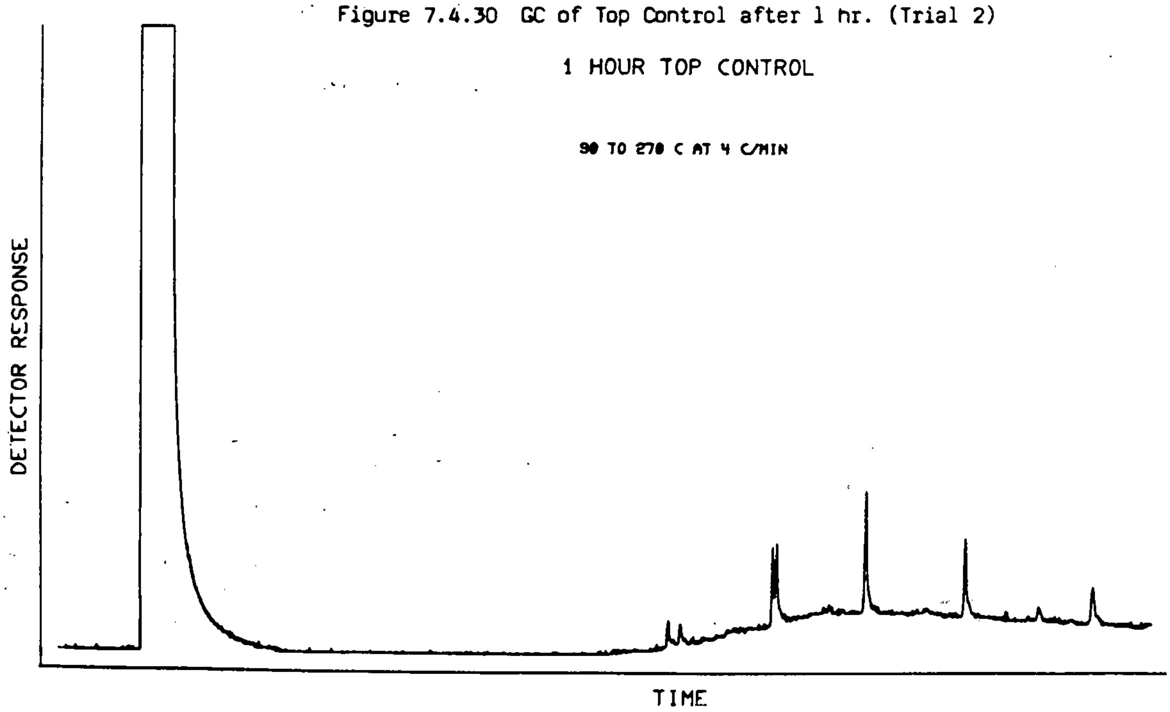


Figure 7.4.31 GC of Bottom Control after 1 hrs. (Trial 2)

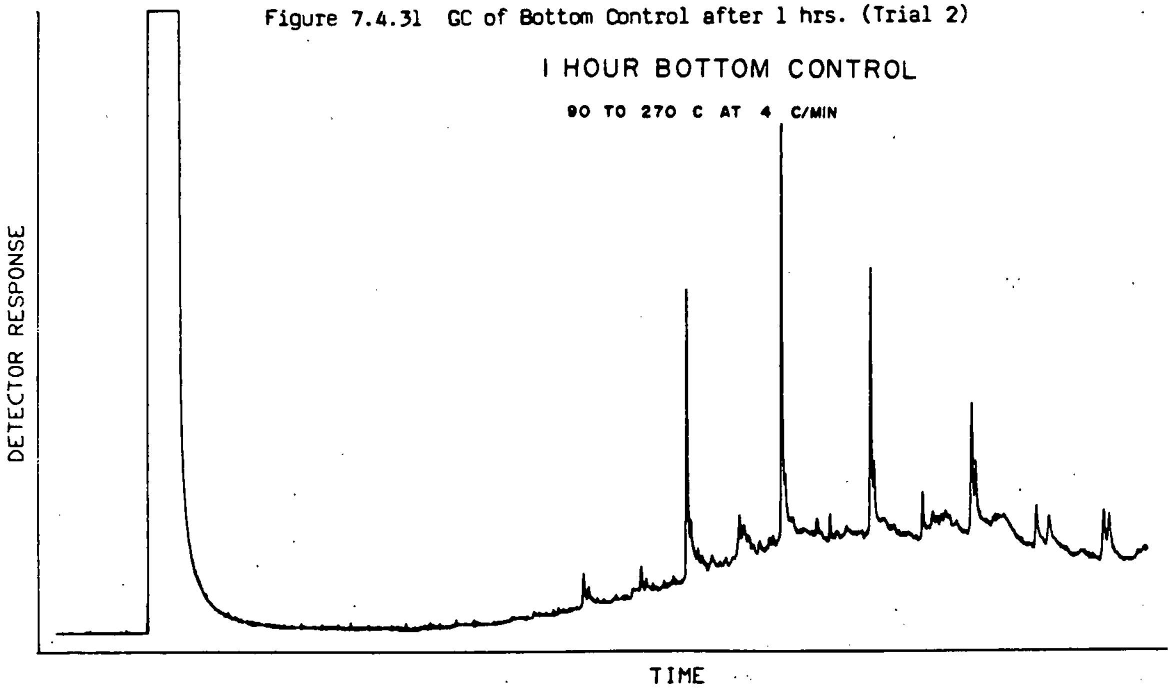


Figure 7.4.32 GC of Top Control after 48 hrs. (Trial 2)

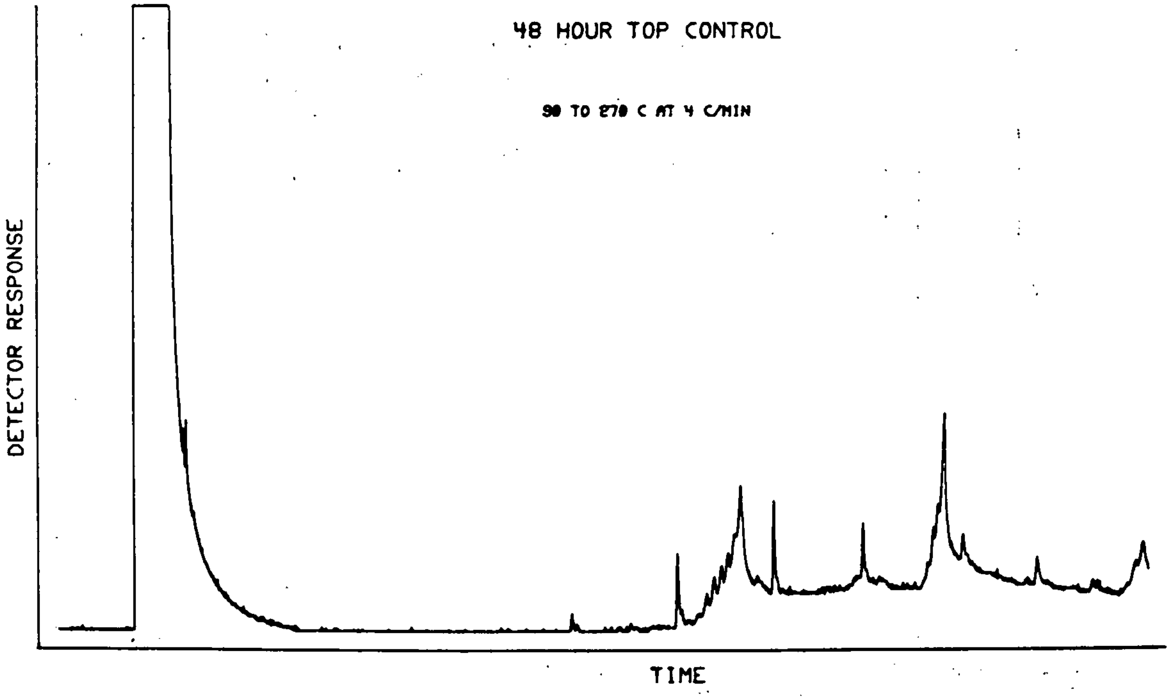


Figure 7.4.33 GC of Middle Control after 48 hrs. (Trial 2)

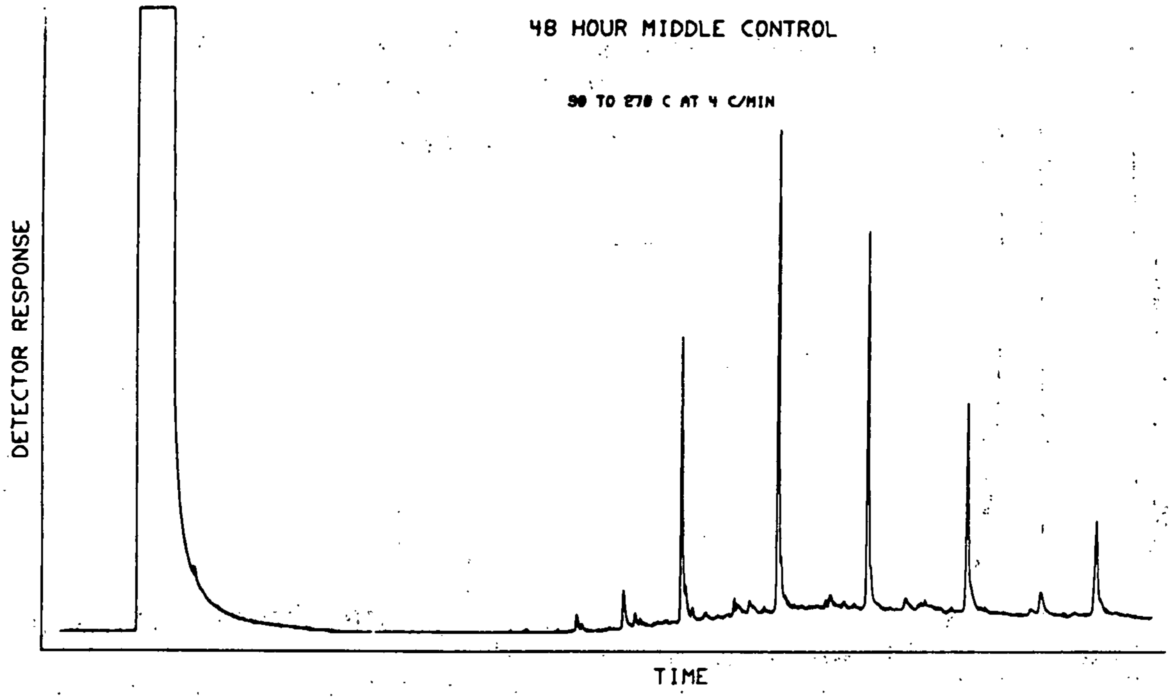


Figure 7.4.34 GC of Top Control after 72 hrs. (Trial 2)

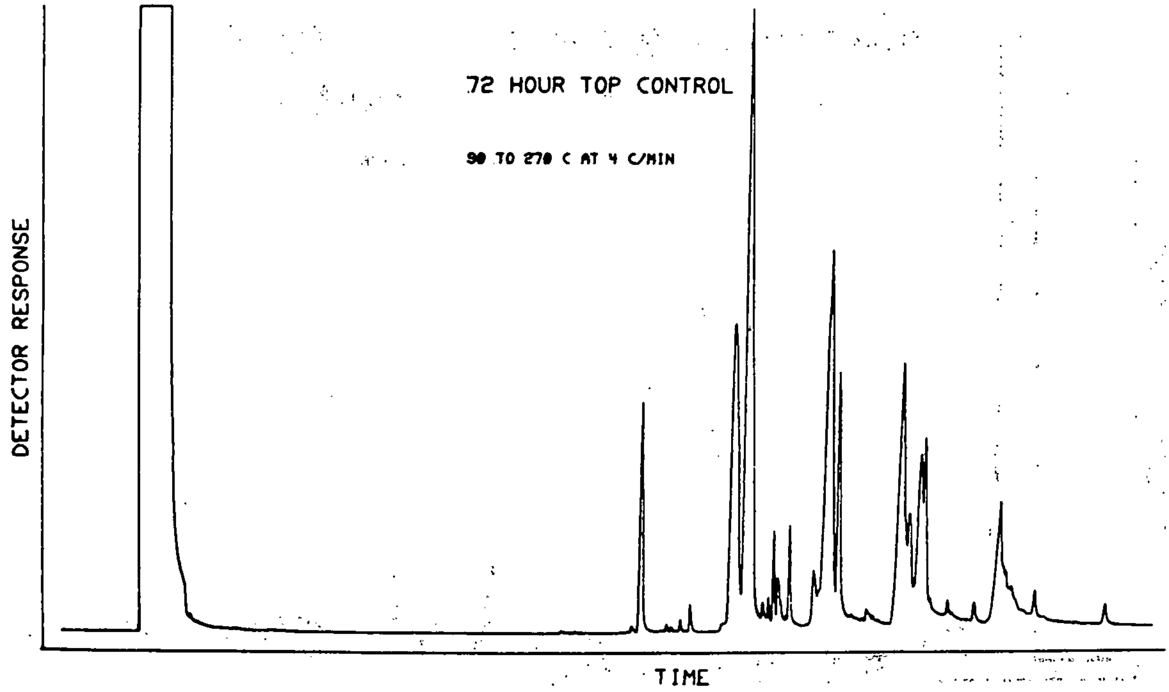


Figure 7.4.35 GC of Bottom Control after 72 hrs. (Trial 2)

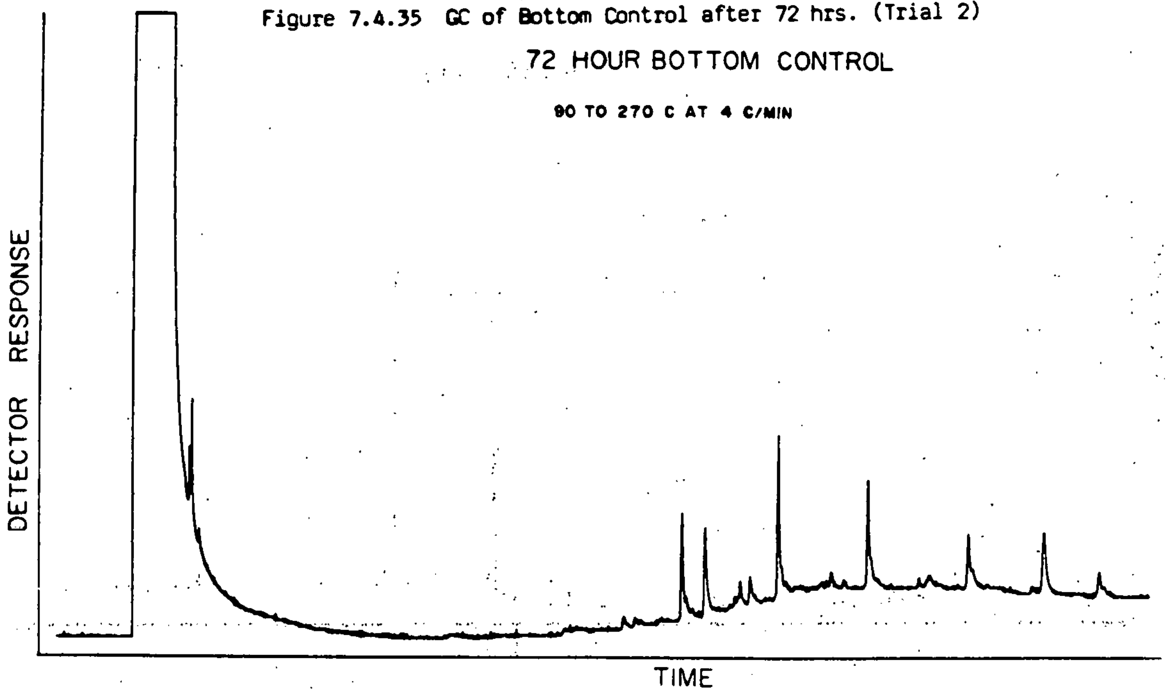


Figure 7.4.36 GC of Top Control after 192 hrs. (Trial 2)

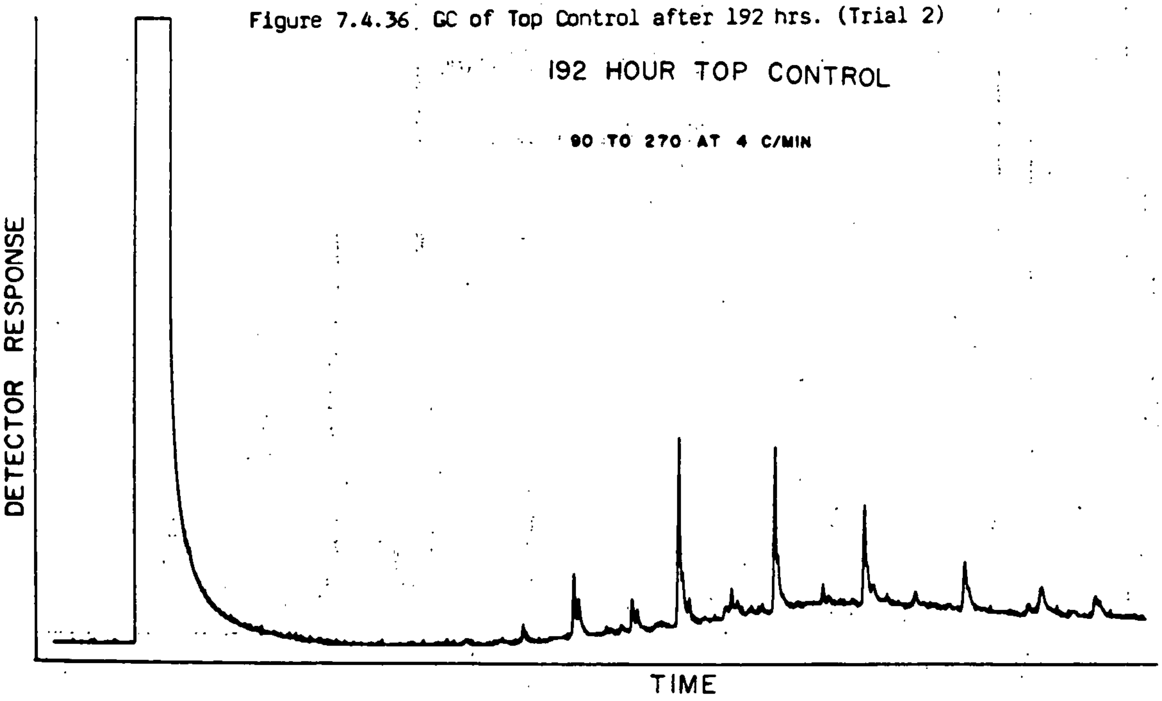


Figure 7.4.37 GC of Bottom Control after 192 hrs. (Trial 2)

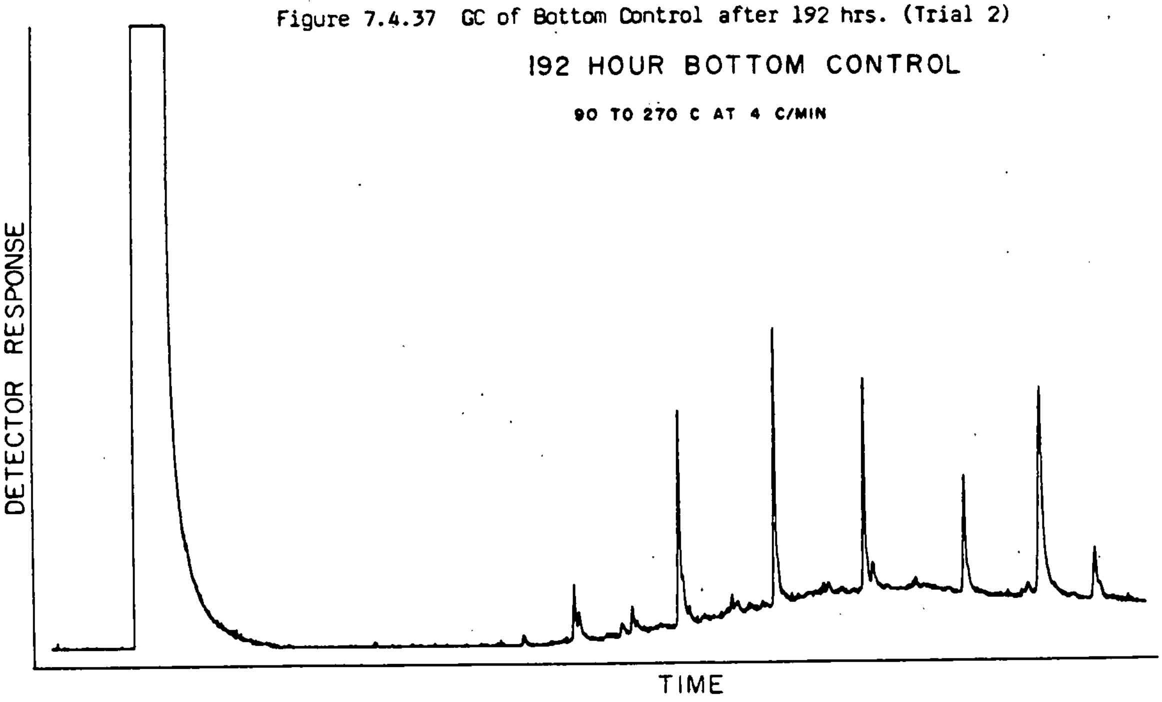


Figure 7.4.38 GC of Top Control after 350 hrs. (Trial 2)

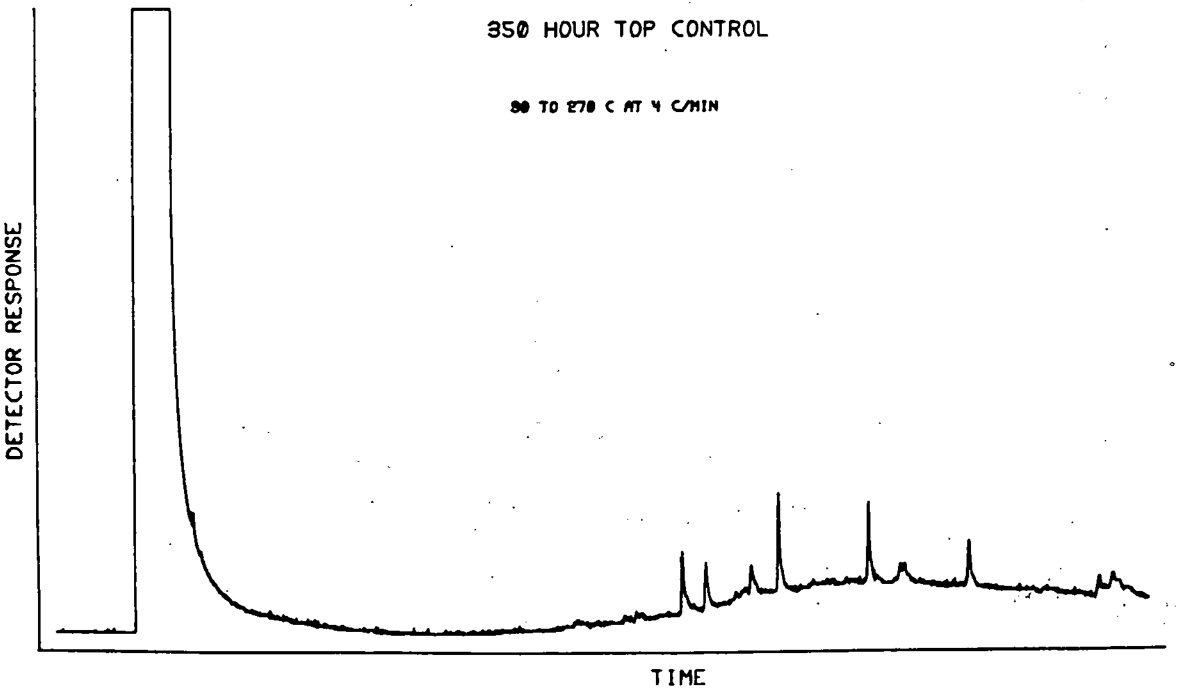


Figure 7.4.39 GC of Middle Control after 350 hrs. (Trial 2)

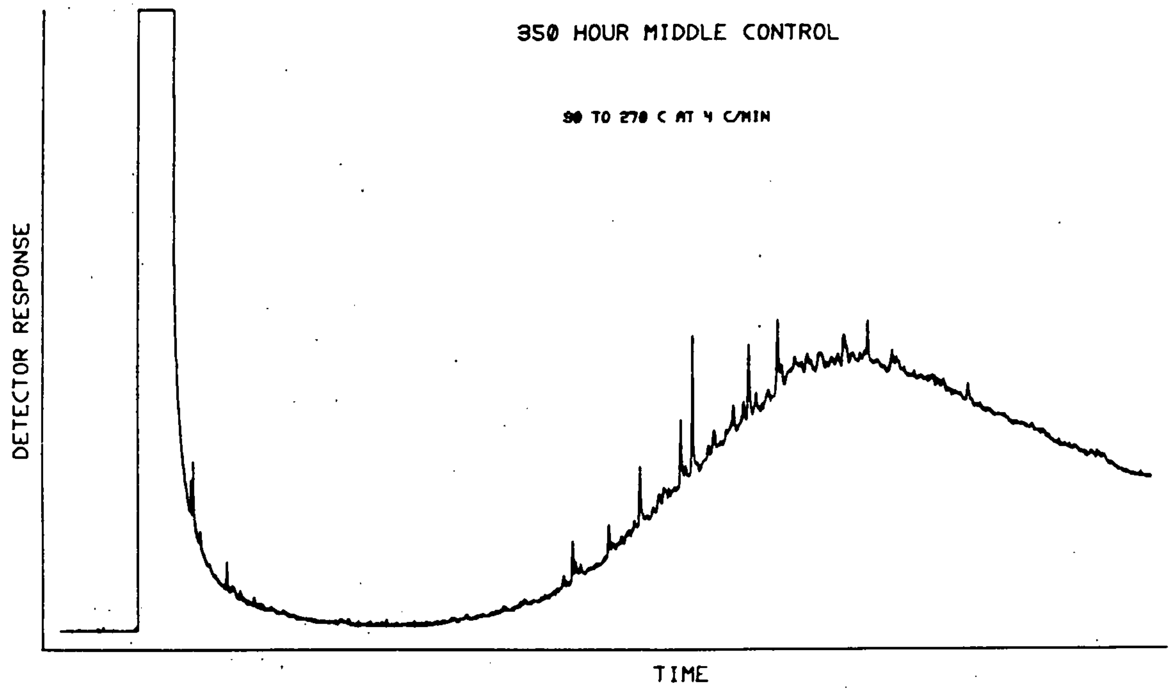
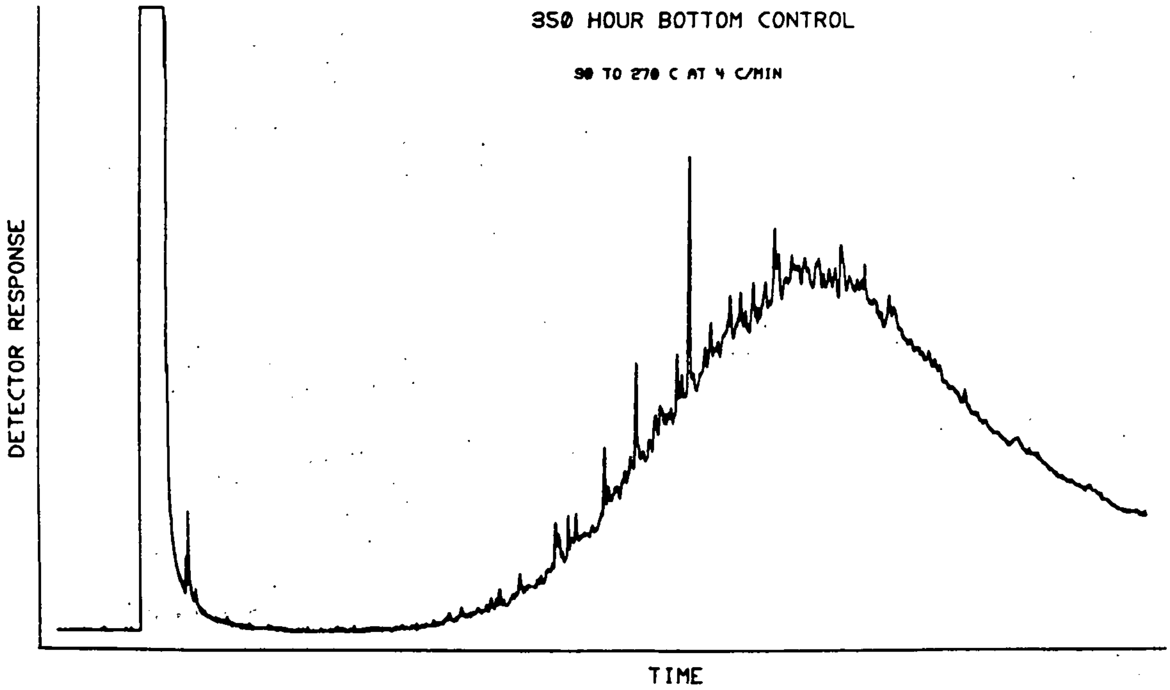


Figure 7.4.40 GC of Bottom Control after 350 hrs. (Trial 2)



peaks. This series of peaks is also observed in a number of the gas chromatograms from the oil contaminated tanks when petroleum hydrocarbons are not observed. These peaks appear to be due to chemicals of biological origin. The large quantitative values from the 350 hour middle and bottom samples are supported by the large unresolved envelope in the GC's of the two samples shown in Figures 7.4.29 and 7.4.40. The origin of the chemicals giving rise to their envelope are unknown; however, a similarly high quantitative value and unresolved envelope were observed for the sample from the bottom of the oil tank collected at 350 hours (Figure 7.4.56).

Oil Tank:

GC's of samples from the oil contaminated tank are shown in Figures 7.4.41-7.4.56. Prior to addition of the oil, the GC of a sample from the middle of the tank, Figure 7.4.41 is almost identical to that from the middle of the control tank (Figure 7.4.24). Samples from the oil tank at 1 and 24 hours do not show an appreciable increase in extractable organics over the control amounts and the GC's (Figures 7.4.32-7.4.34) are very similar to those of the control sample.

The GC of the sample from the oil tank taken from the top at 48 hours (Figure 7.4.35) shows a distribution of normal paraffins that are typical of petroleum and the quantitative value is over 1,000 ppb. The GC is interesting in that only the normal paraffins between C_{14} and C_{22} are observed. Moreover, the amounts of pristane and phytane relative to the normal paraffins are much larger than in the neat oil (see Figure 7.4.76).

The GC of the sample taken from the top (Figure 7.4.48) and bottom (Figure 7.4.50) at 72 hours also indicates a distribution of petroleum similar to that discussed above. It is interesting to note that the oil seems to be migrating to the bottom. At 192 hours, petroleum hydrocarbons appear in the GC (Figure 7.4.51) from the top of the tank, but they could not be discerned in the GC of the samples from the other two levels.

At 350 hours, GC of the samples (Figures 7.4.54-7.4.56) are very similar to those of the control tanks. As mentioned previously, the GC of the bottom sample has a large unresolved envelope. However, since samples from the control tank had a very similar GC, this large envelope is probably not due to petroleum.

Oil/Dispersant tank:

GC's of samples from the oil/dispersant tank are shown in Figures 7.4.57-7.4.75. Again, the GC of the sample from the middle of this tank prior to addition of the oil-dispersant is very similar to that of the control tank. GC's of the top and middle samples at 1 hour (Figures 7.4.58-7.4.59) and 24 hours (Figures 7.4.61-7.4.62) indicate a distribution of petroleum hydrocarbons very similar to the neat oil. It should be noted that the GC's of the samples from the top port contain more of the light components (C_{10}-C_{12}) than those from the middle port. Moreover, there is an increase in the amounts of pristane and phytane relative to the normal paraffins between the 1 and 24 hour samples.

Figure 7.4.41 GC of Middle Oil at 0 hr. (Contaminated Tank)

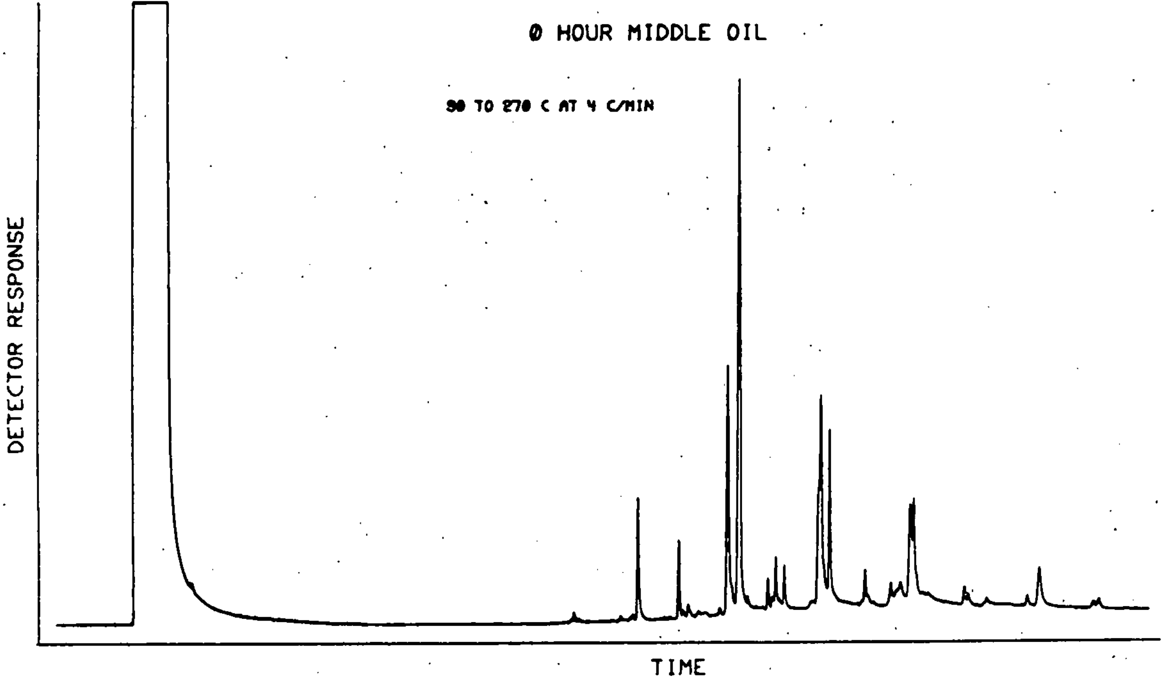


Figure 7.4.42 GC of Middle Oil after 1 hr.

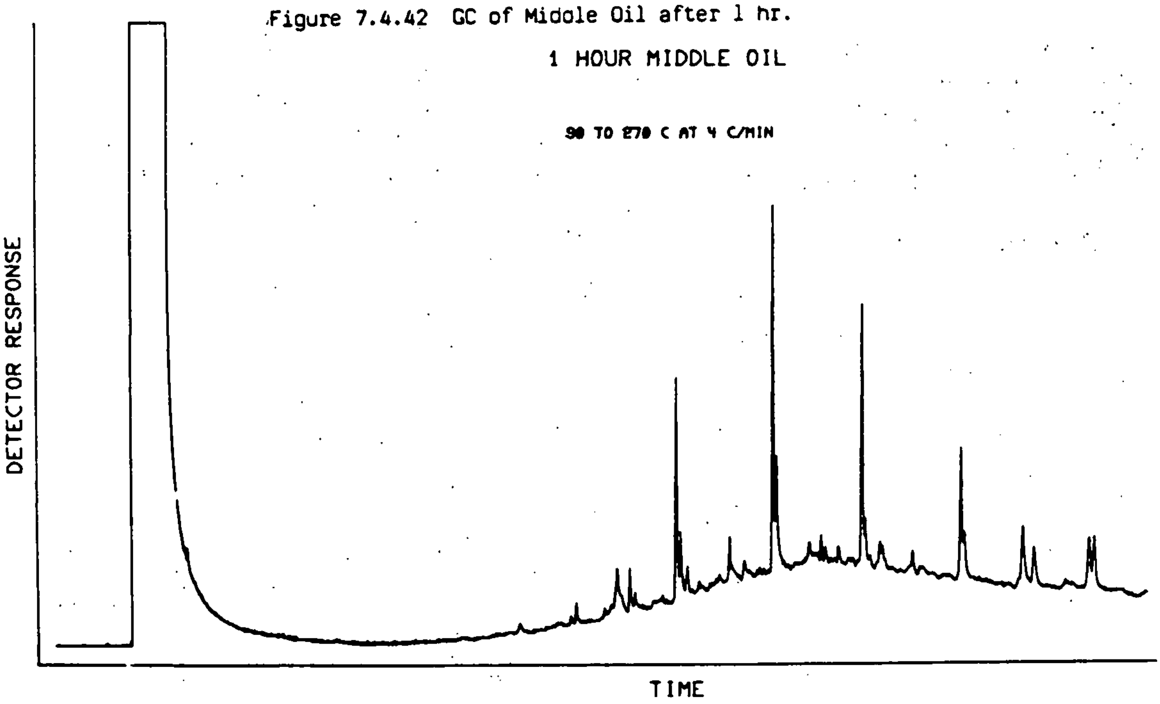


Figure 7.4.43 GC of Top Oil after 24 hrs.

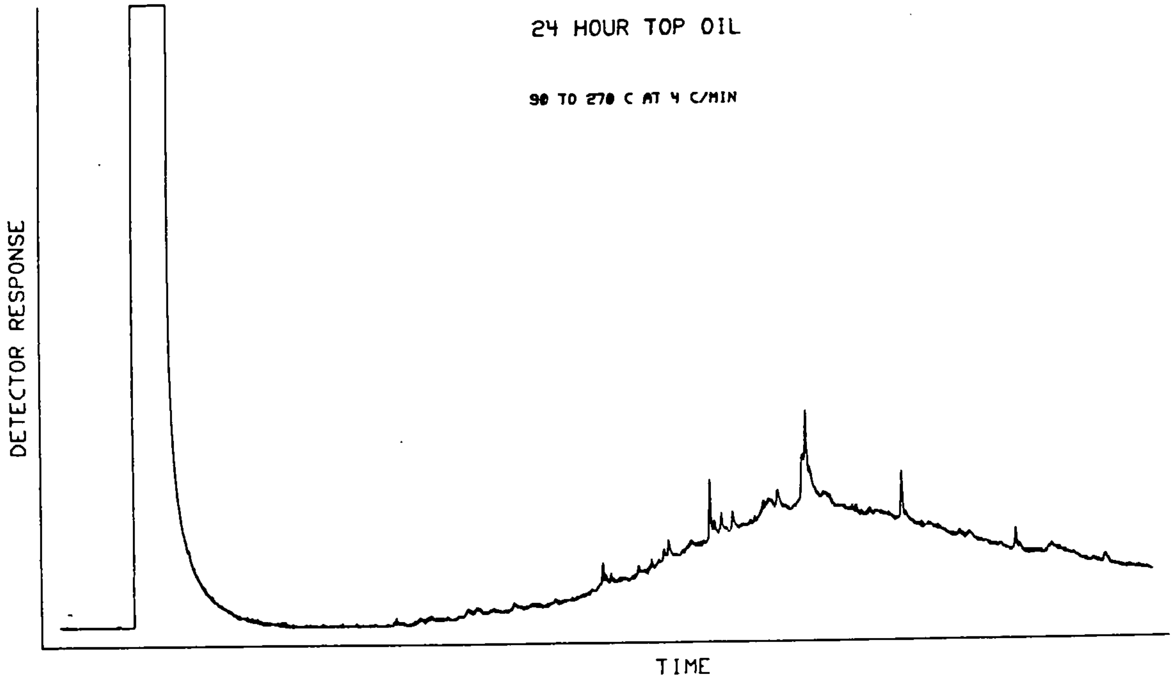


Figure 7.4.44 GC of Middle Oil after 24 hrs.

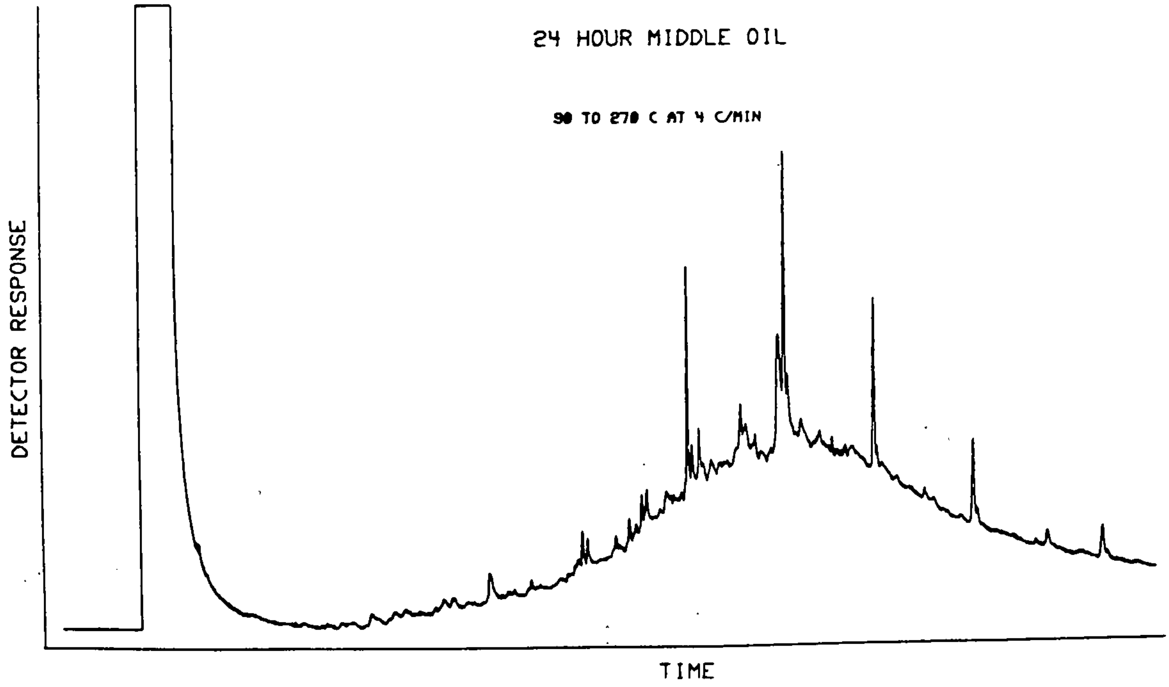


Figure 7.4.45 GC of Top Oil after 48 hrs.

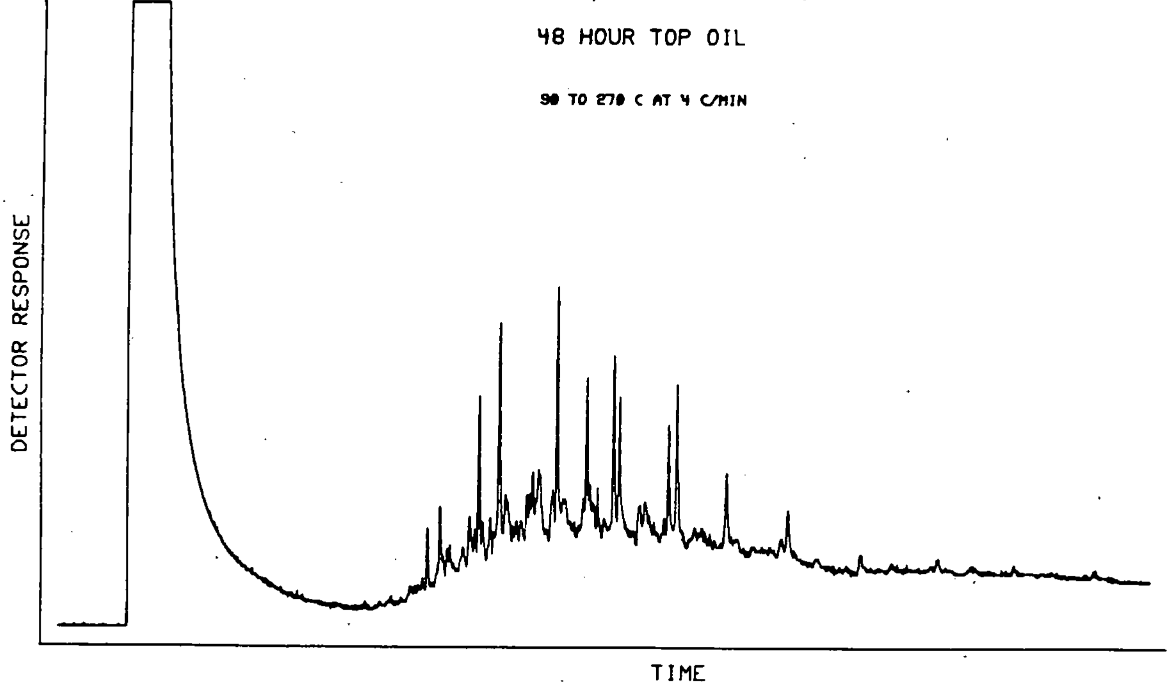


Figure 7.4.46 GC of Middle Oil after 48 hrs.

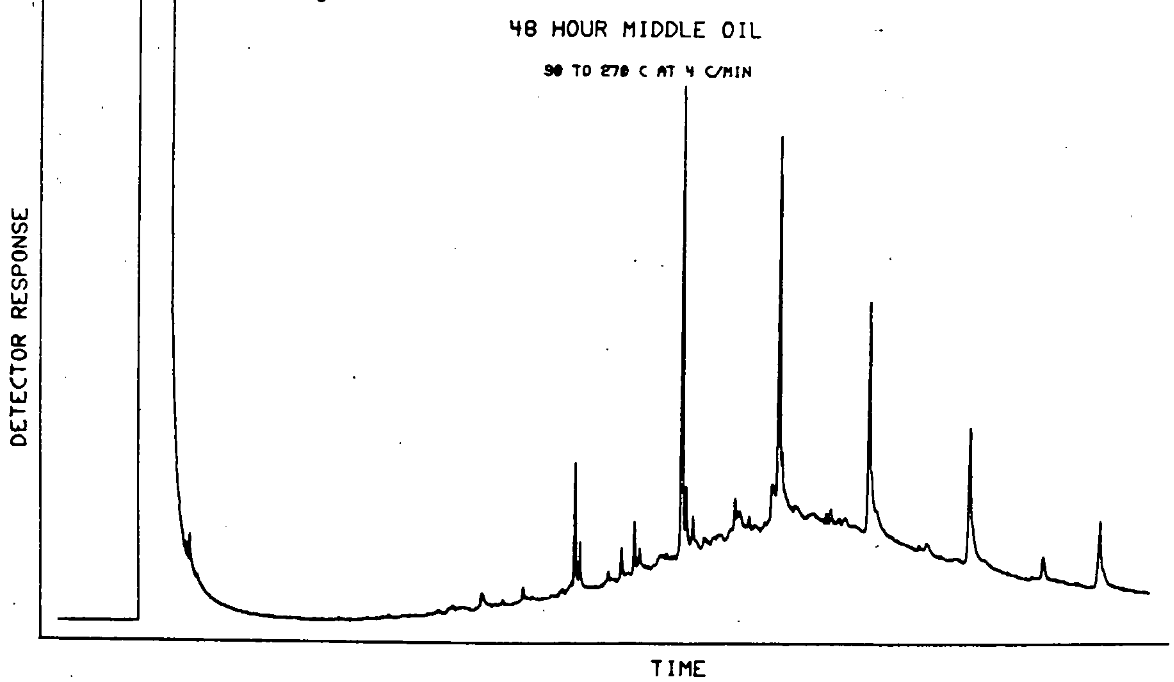


Figure 7.4.47 GC of Bottom Oil after 48 hrs.

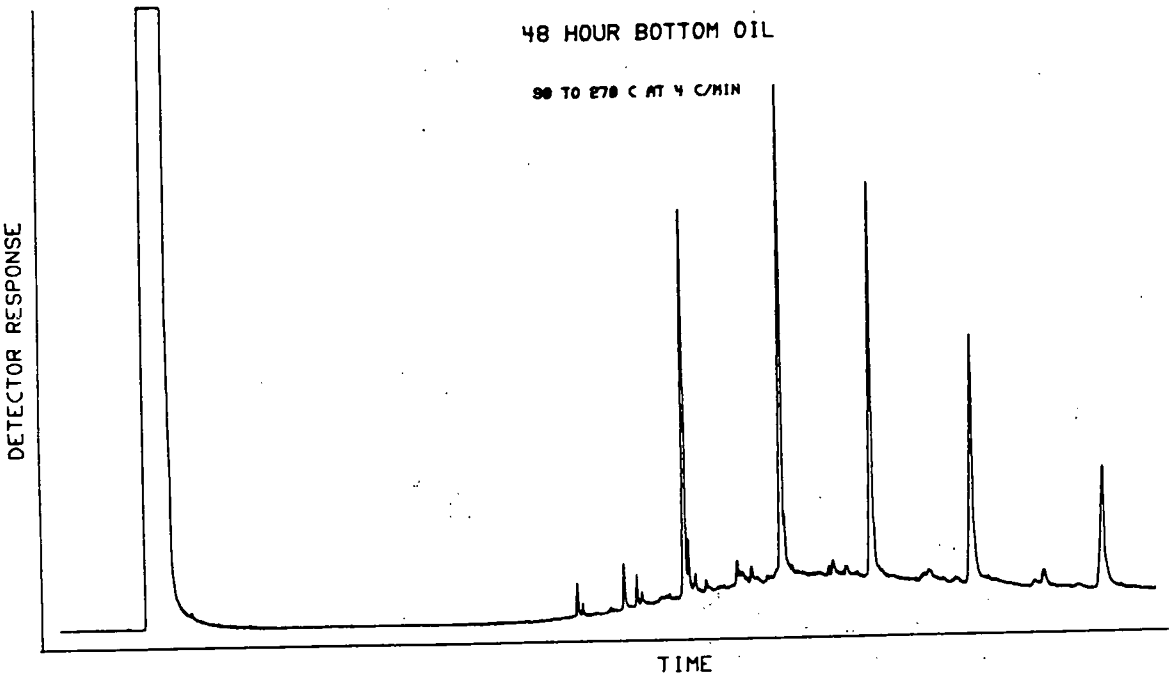


Figure 7.4.48 GC of Top Oil after 72 hrs.

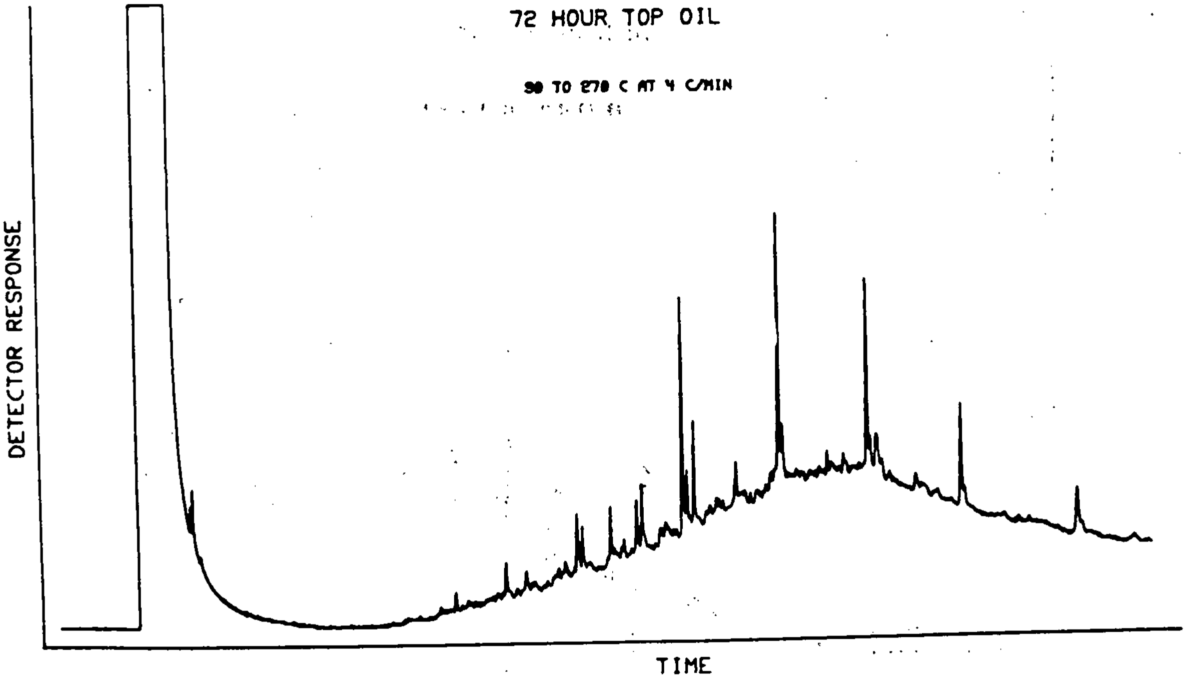


Figure 7.4.49 GC of Middle Oil after 72 hrs. (Contaminated Tank)

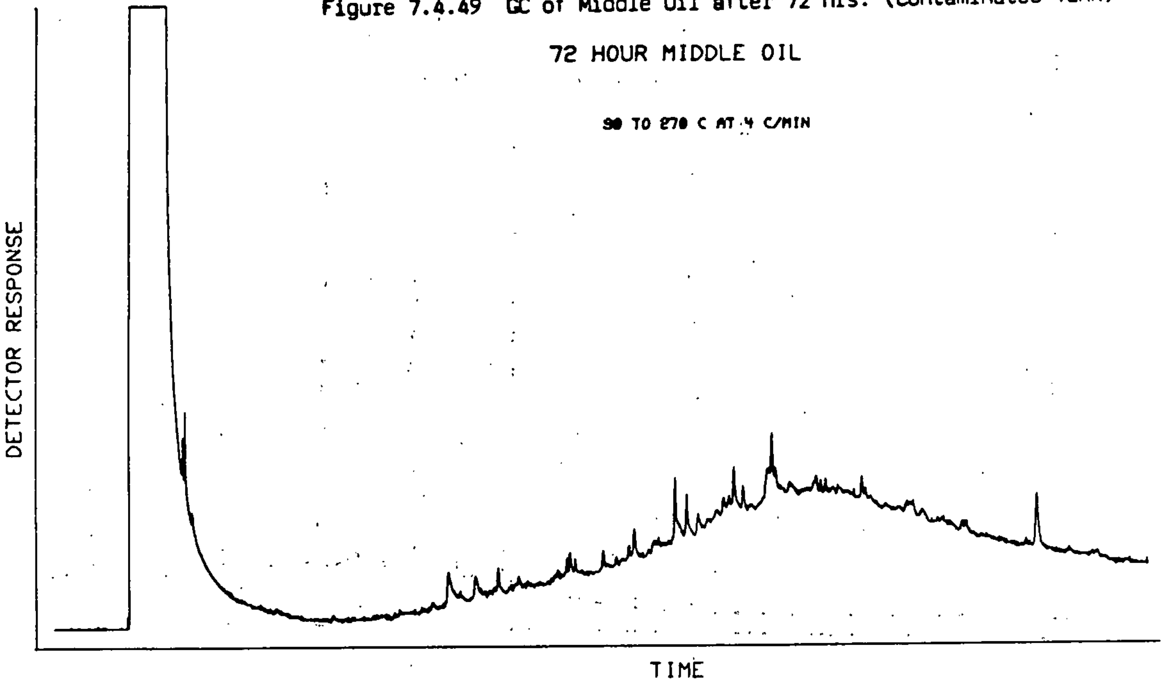


Figure 7.4.50 GC of Bottom Oil after 72 hrs.

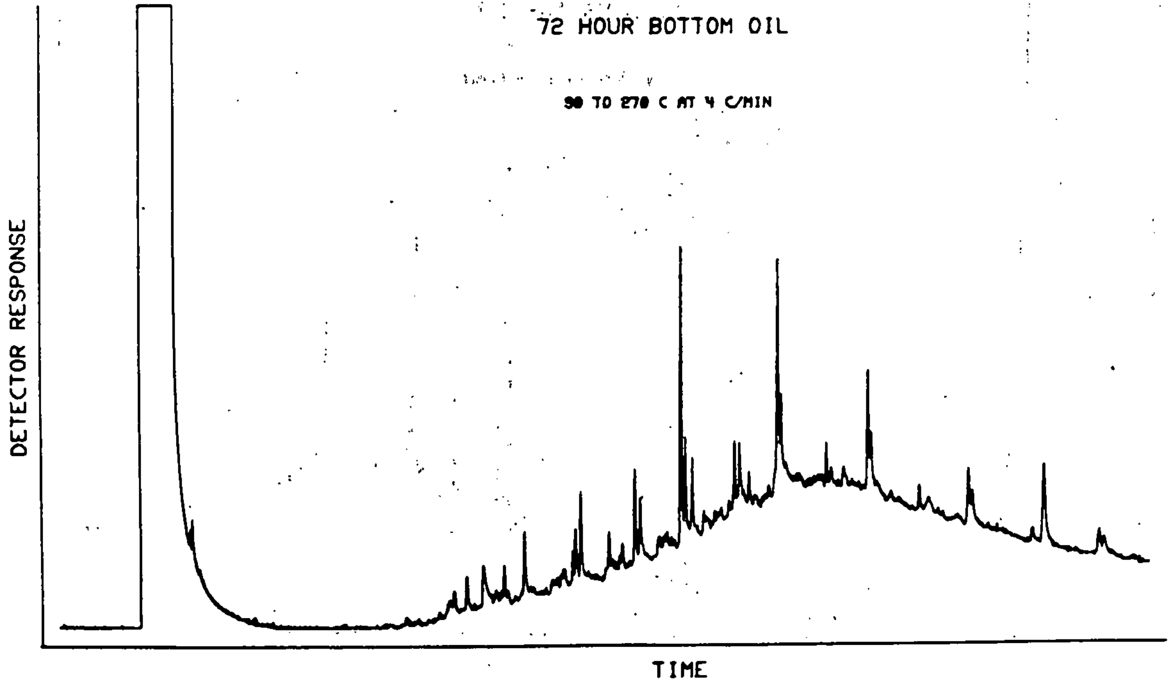


Figure 7.4.51 GC of Top Oil after 192 hrs.

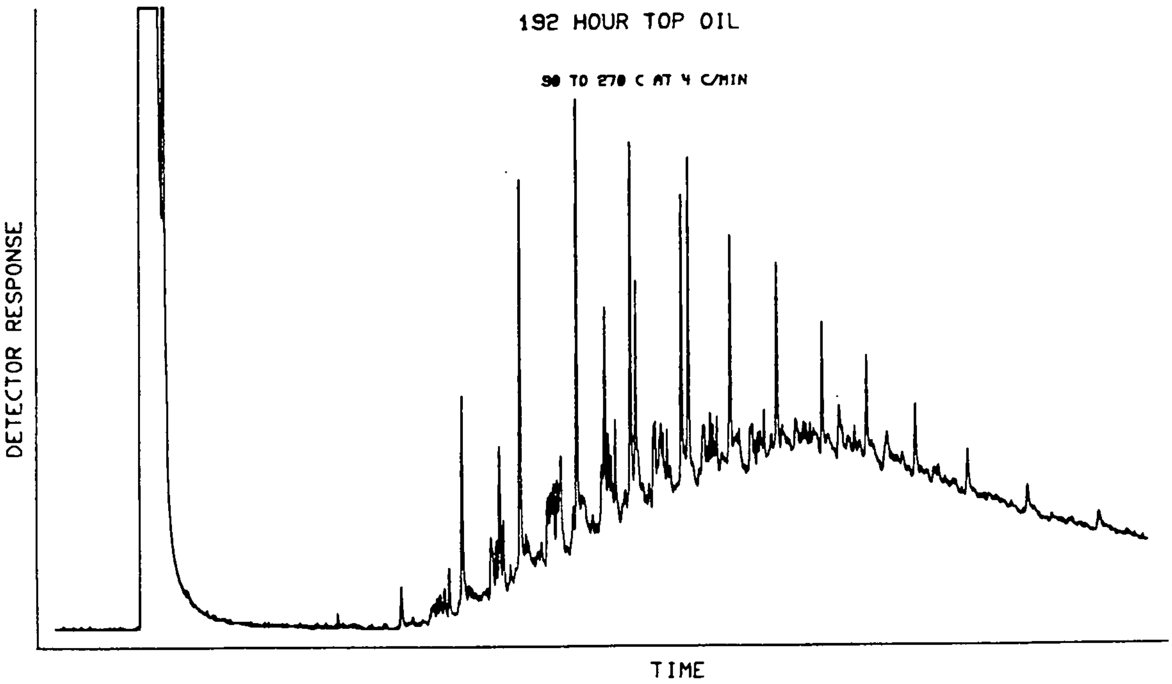


Figure 7.4.52 GC of Middle Oil after 192 hrs.

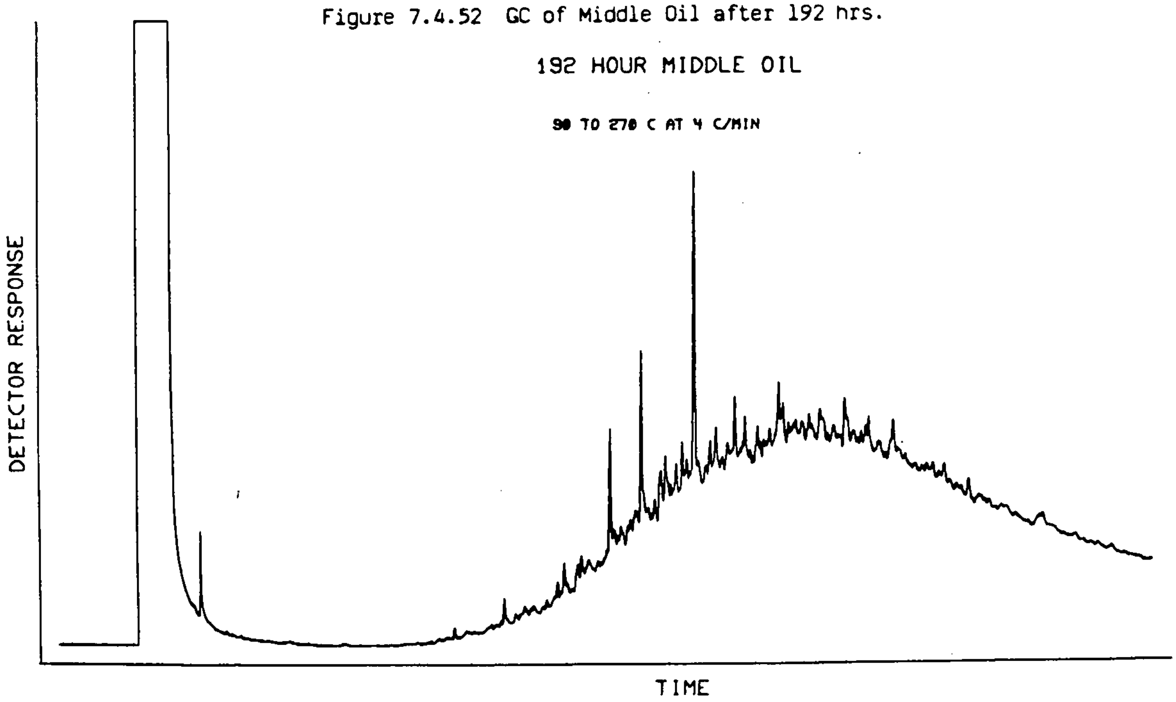


Figure 7.5.53 GC of Bottom Oil after 192 hrs.

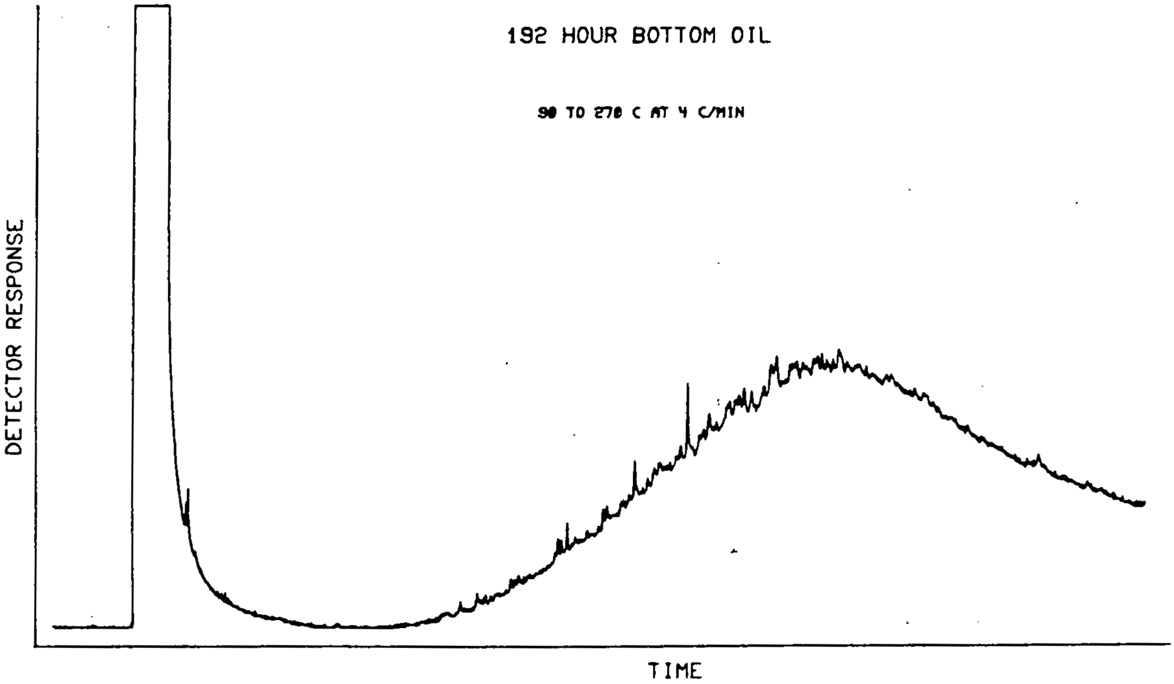


Figure 7.4.54 GC of Top Oil after 350 hrs.

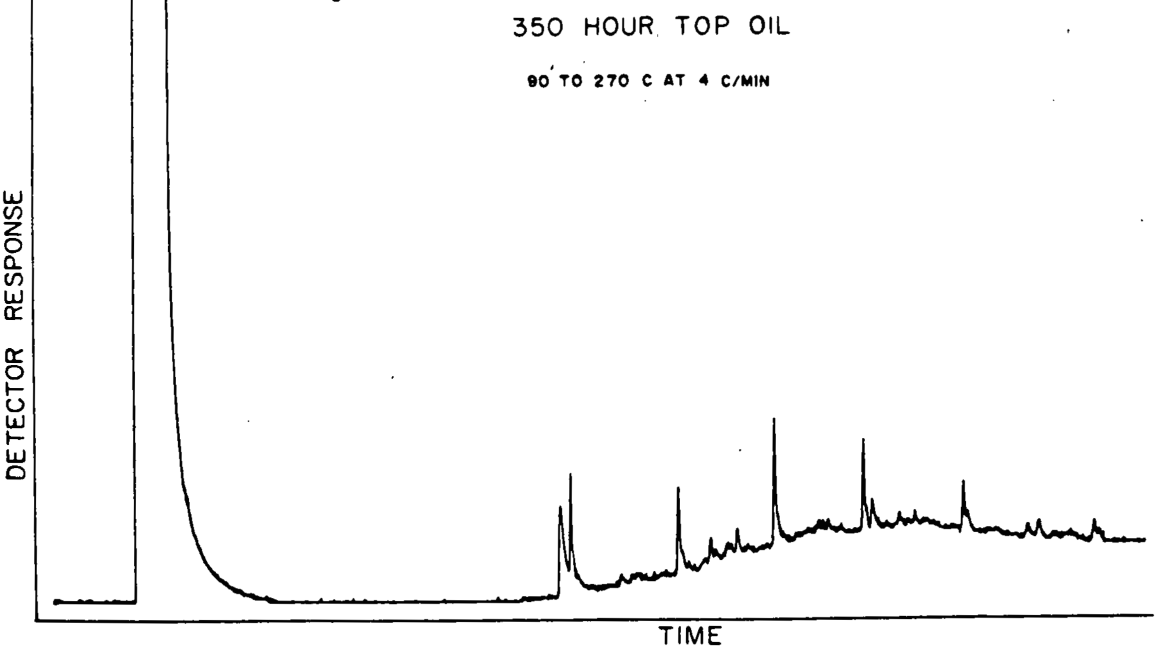


Figure 7.4.55 GC of Middle Oil after 350 hrs.

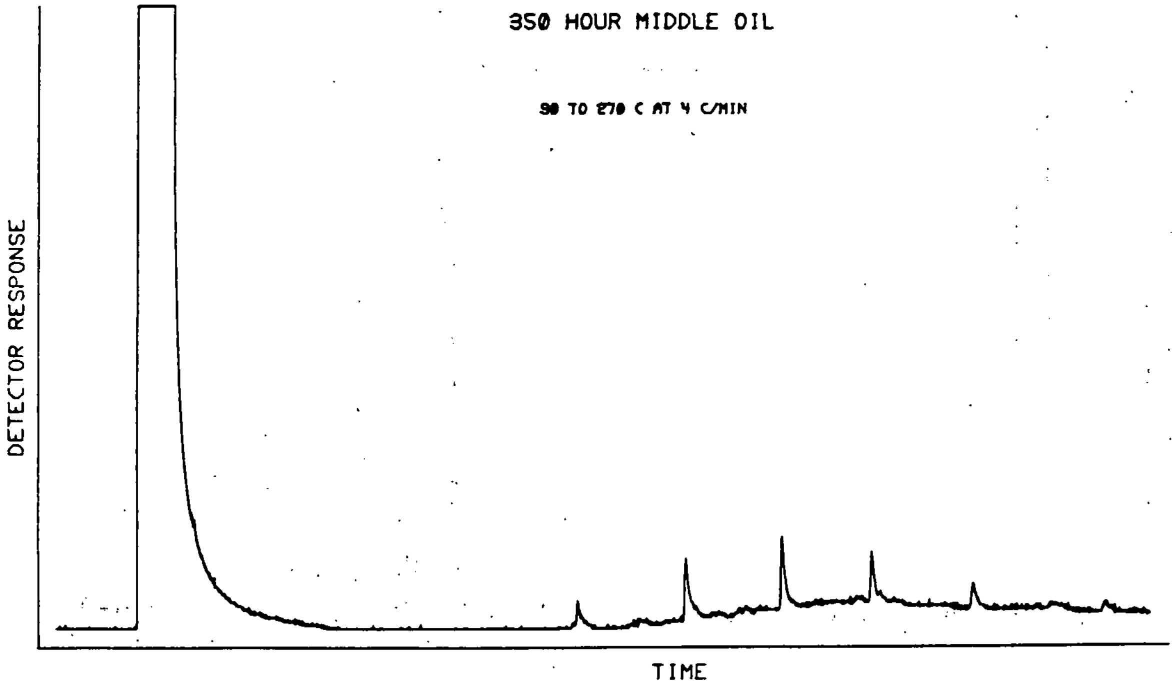


Figure 7.4.56 GC of Bottom Oil after 350 hrs.

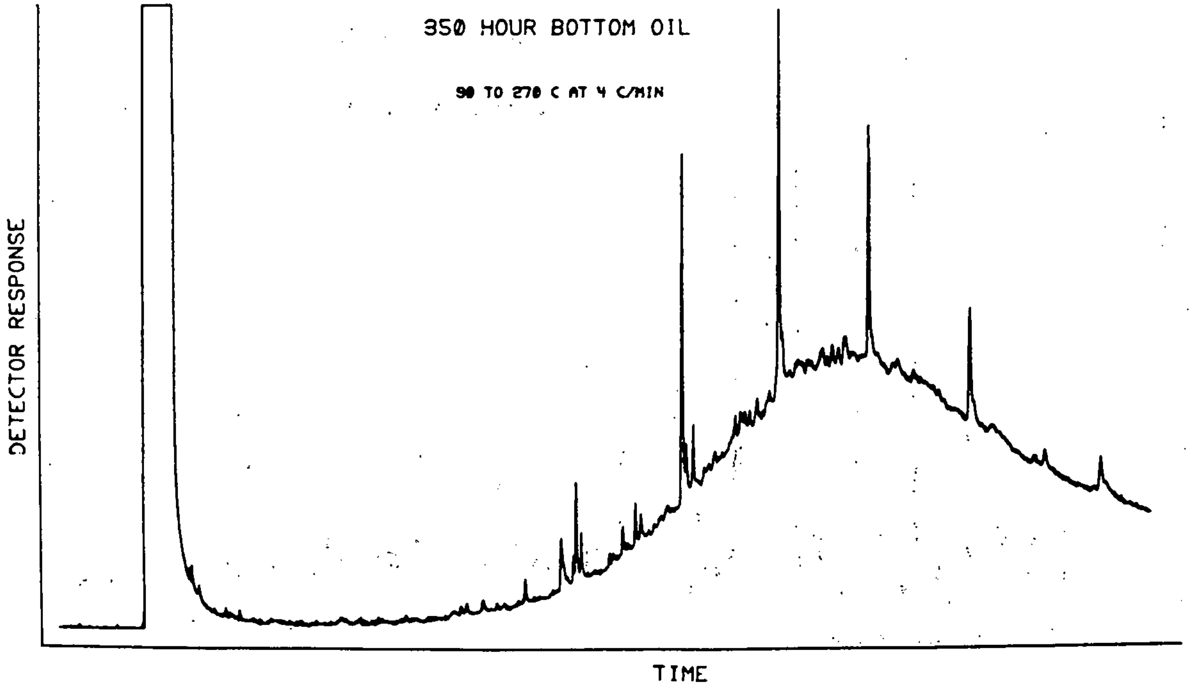


Figure 7.4.57 GC of Middle of Oil/Dispersant Tank at 0 hrs.

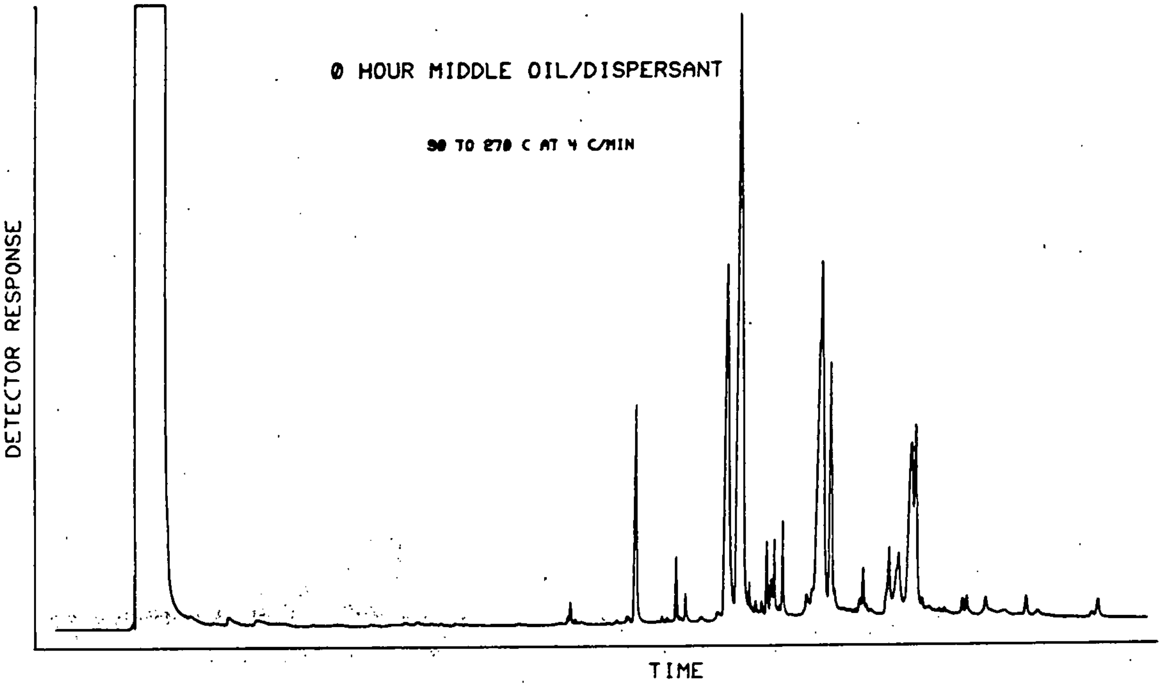


Figure 7.4.58 GC of Top of Oil/Dispersant Tank at 1 hr.

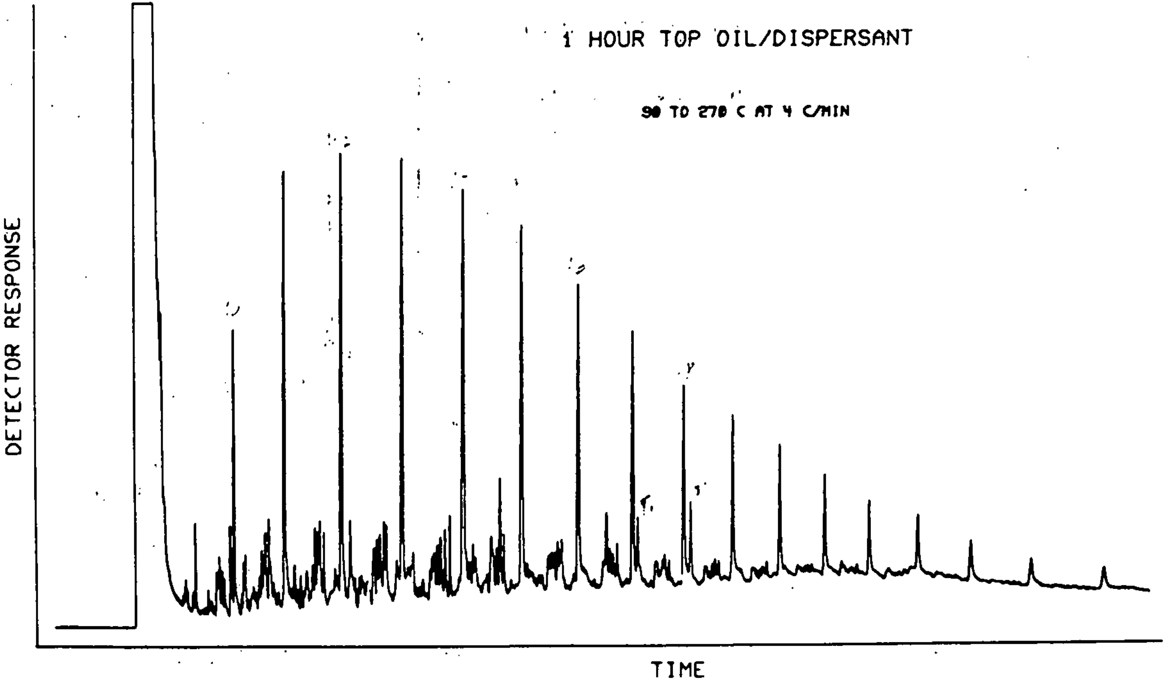


Figure 7.4.59 GC of Middle of Oil/Dispersant Tank at 1 hr.

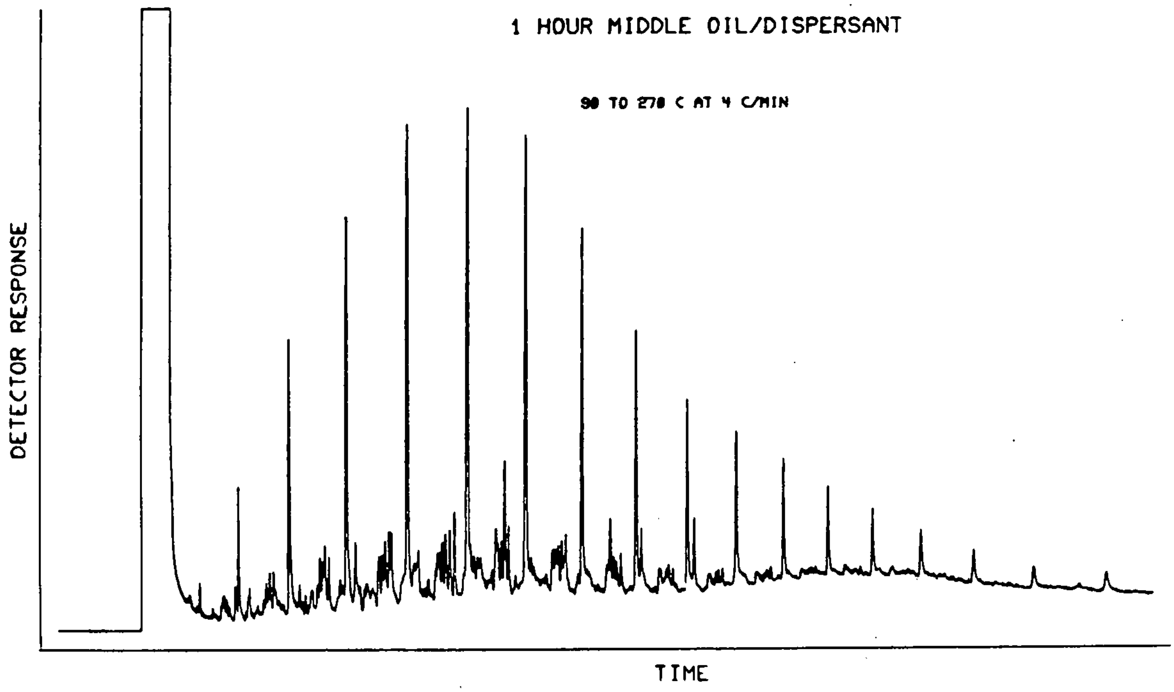


Figure 7.4.60 GC of Bottom of Oil/Dispersant Tank at 1 hr.

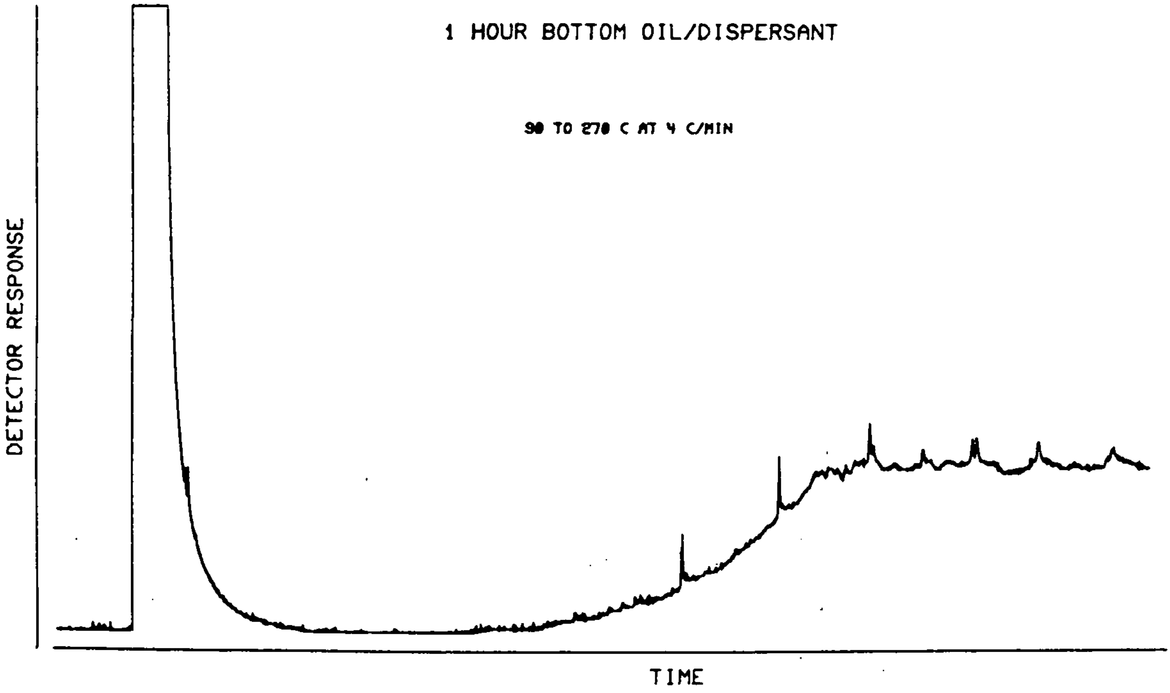


Figure 7.4.61 GC of Top of Oil/Dispersant Tank at 24 hrs.

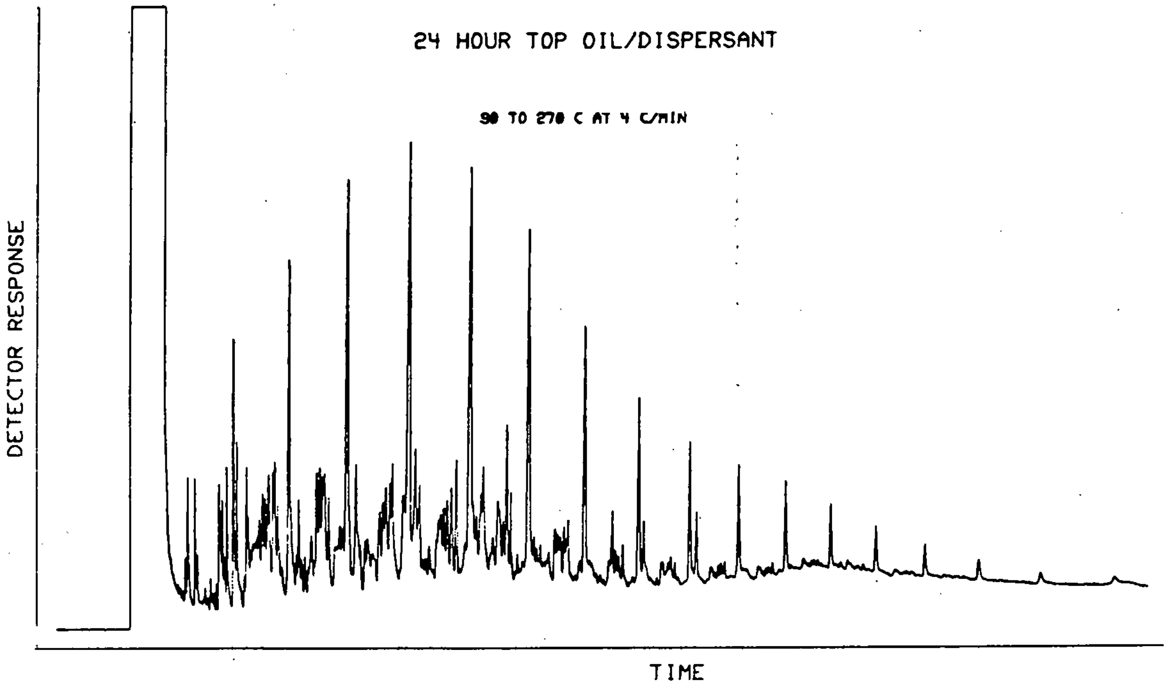


Figure 7.4.62 GC of Middle of Oil/Dispersant Tank at 24 hrs.

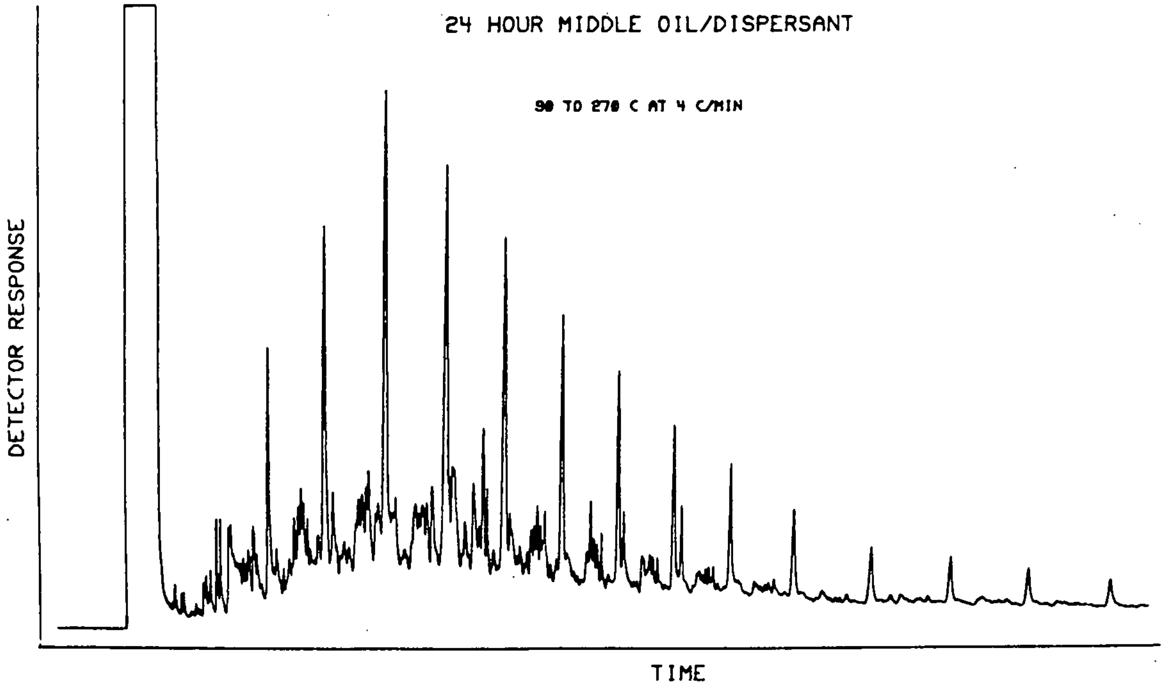


Figure 7.4.63 GC of Bottom of Oil/Dispersant Tank at 24 hrs.

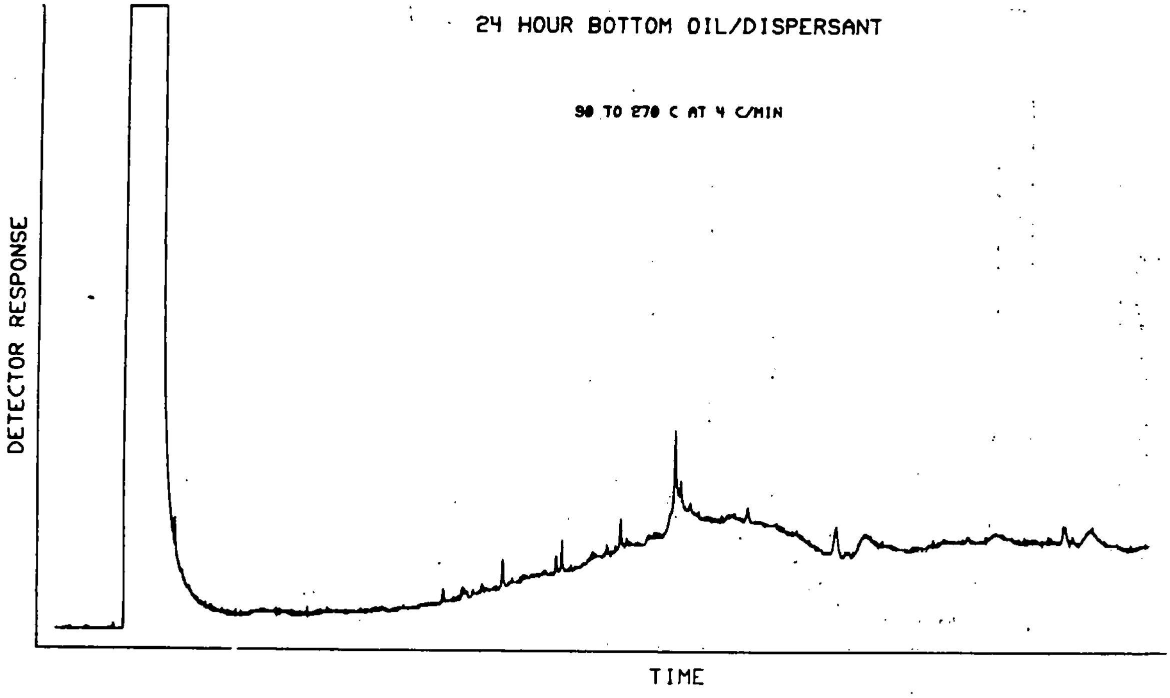


Figure 7.4.64 GC of Top of Oil/Dispersant Tank at 48 hrs.

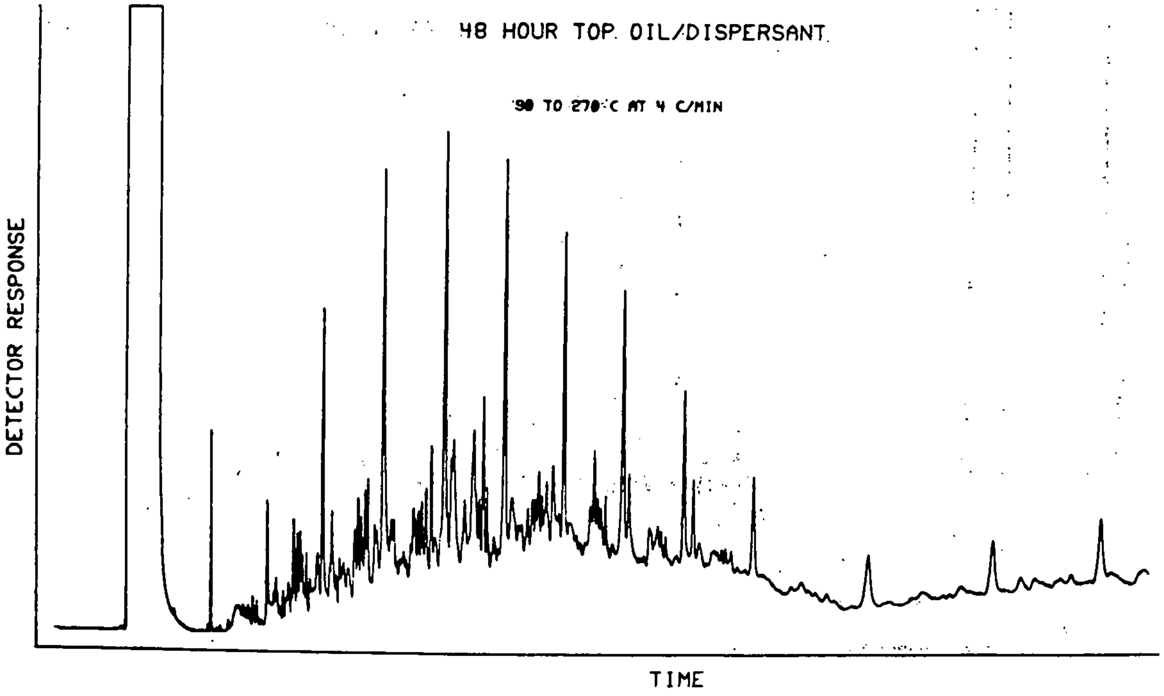


Figure 7.4.65 GC of Middle of Oil/Dispersant Tank at 48 hrs.

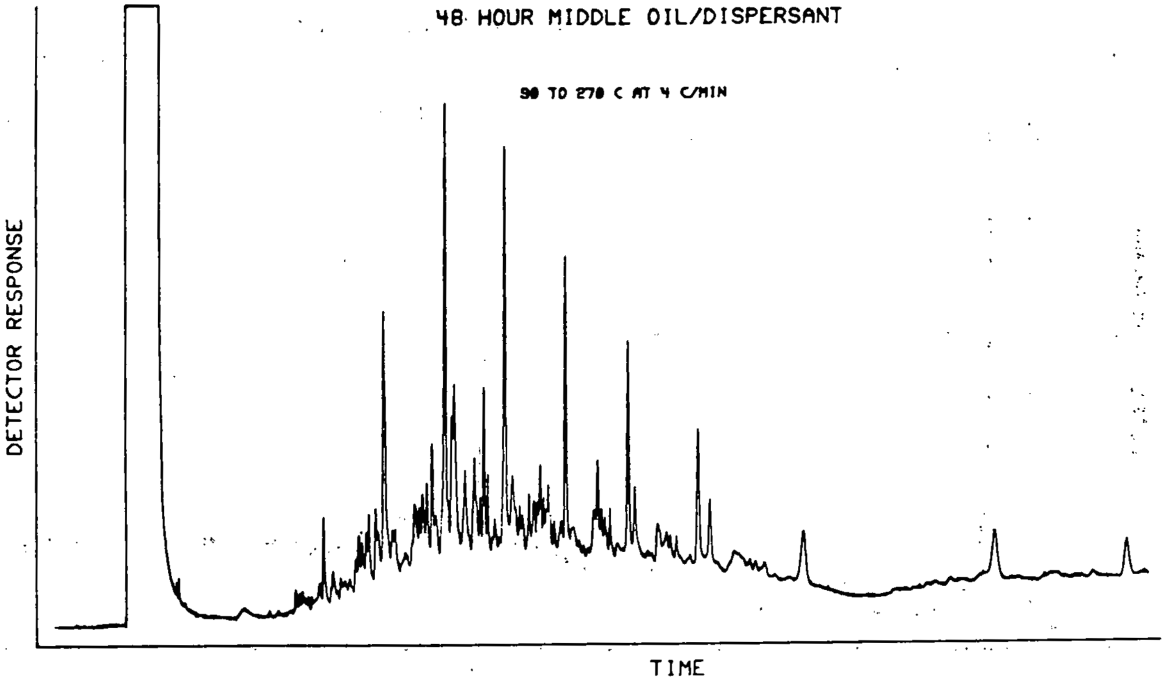


Figure 7.4.66 GC of Bottom of Oil/Dispersant Tank at 48 hrs.

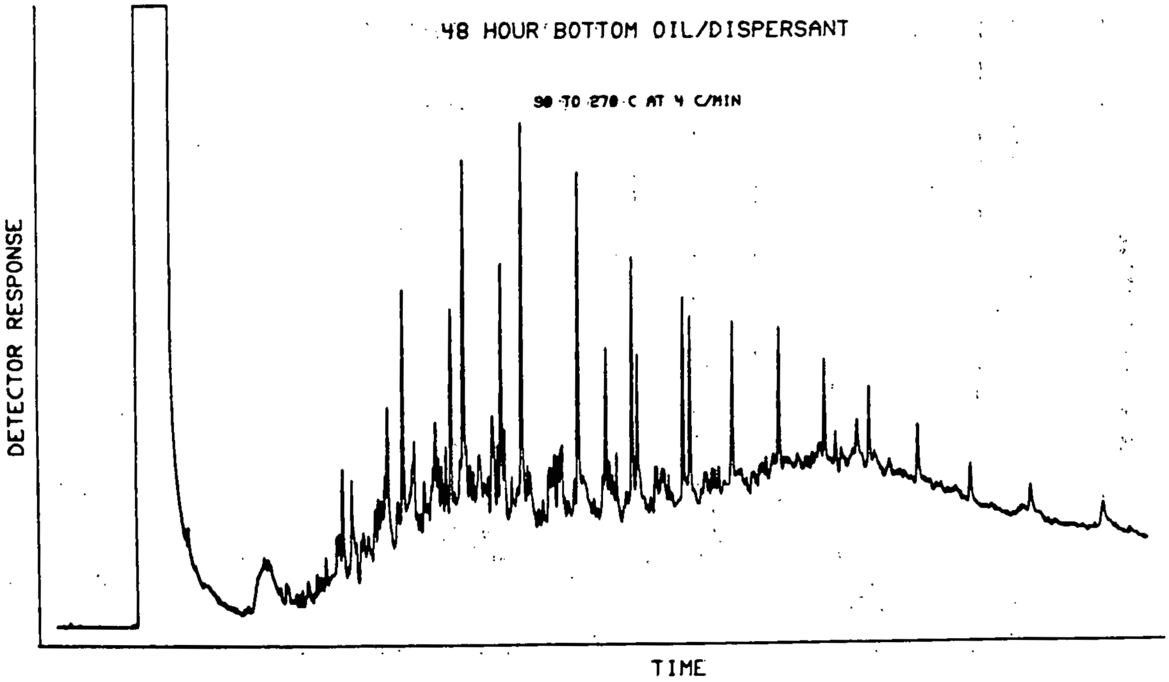


Figure 7.4.67 GC of Top of Oil/Dispersant Tank at 72 hrs.

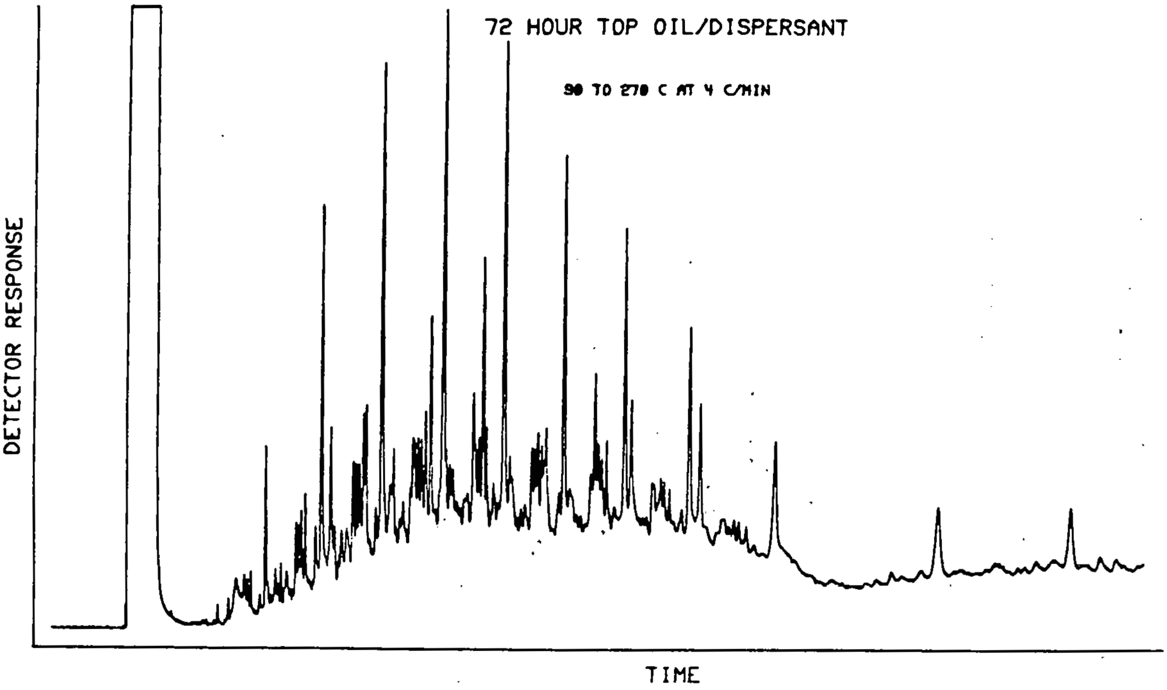


Figure 7.4.68 GC of Middle of Oil/Dispersant Tank at 72 hrs.

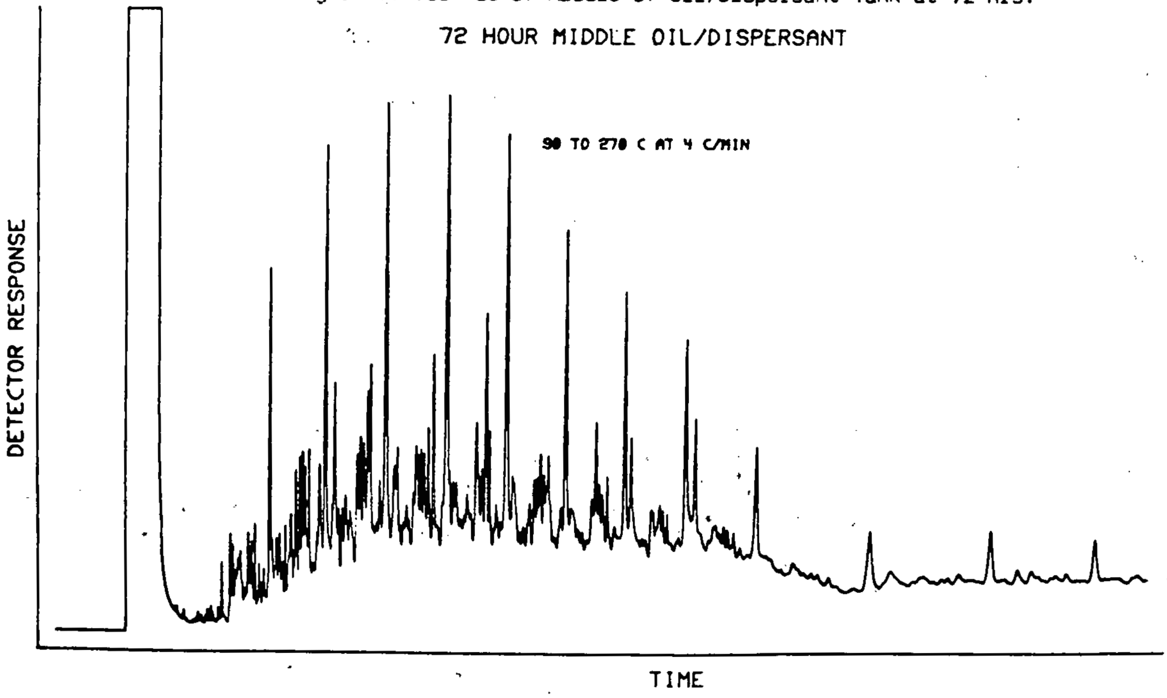


Figure 7.4.69 GC of Bottom of Oil/Dispersant Tank at 72 hrs.

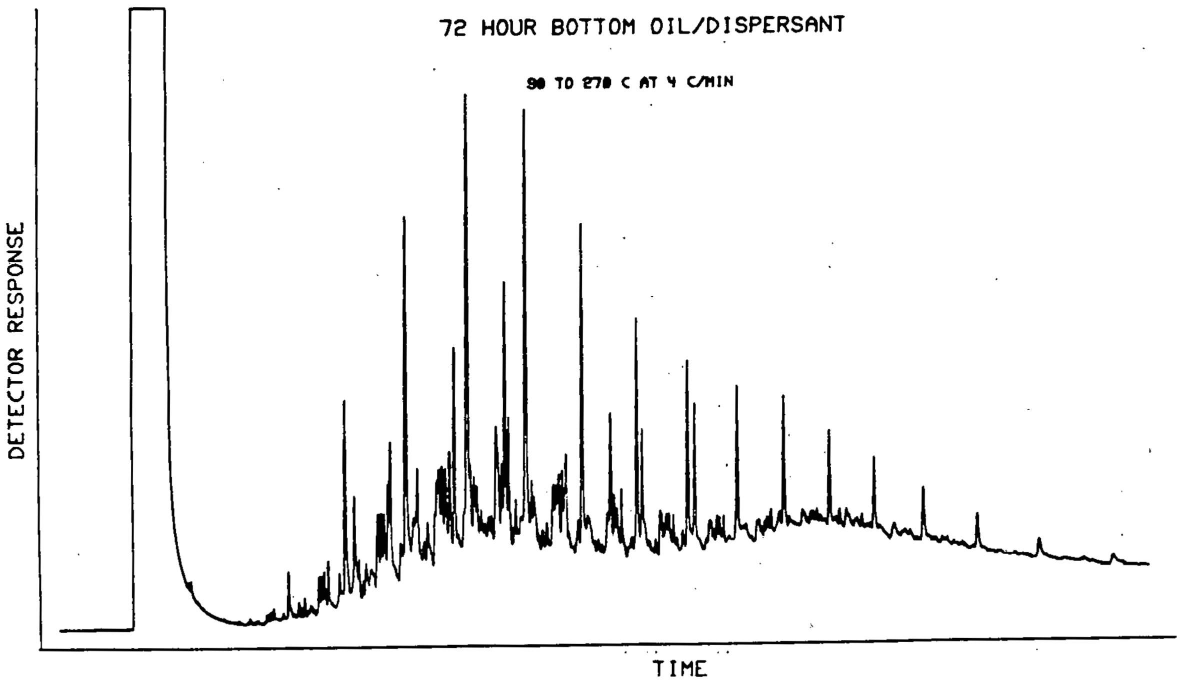
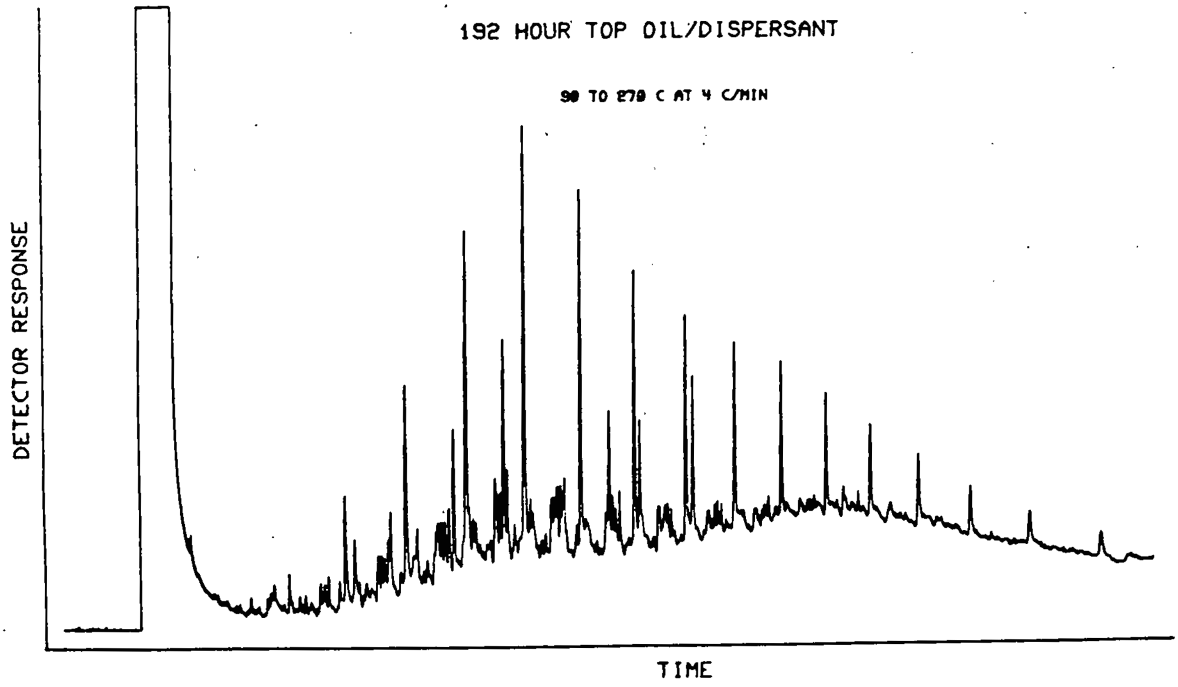


Figure 7.4.70 GC of Top of Oil/Dispersant Tank at 192 hrs.



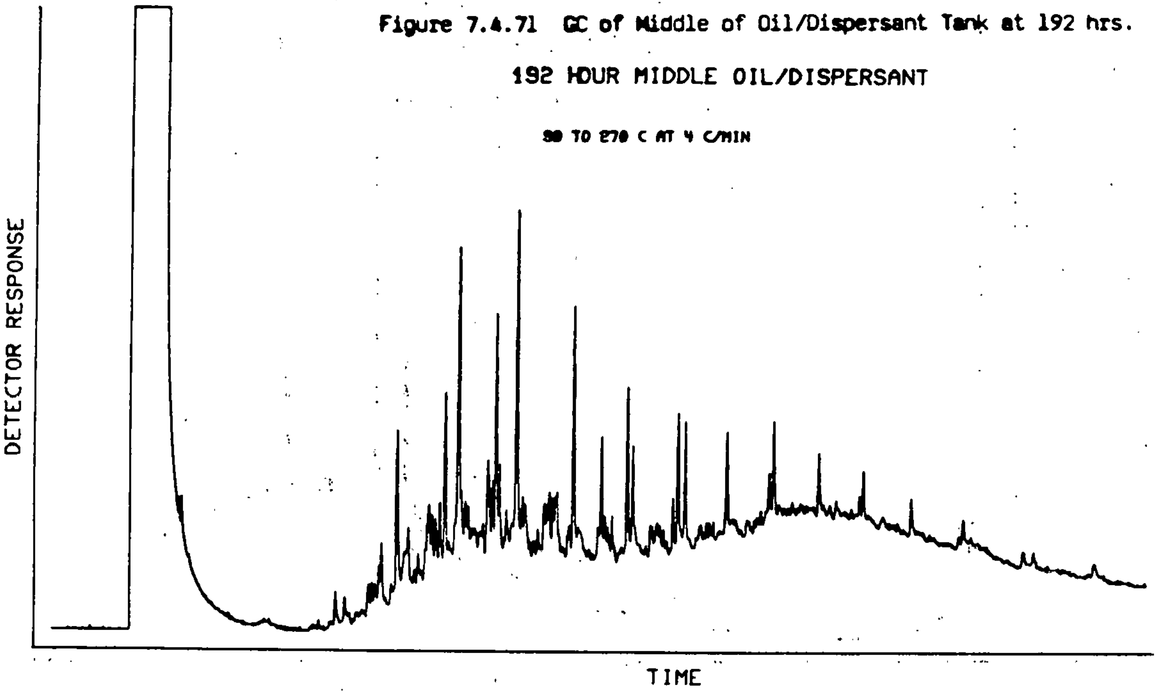


Figure 7.4.71 GC of Middle of Oil/Dispersant Tank at 192 hrs.

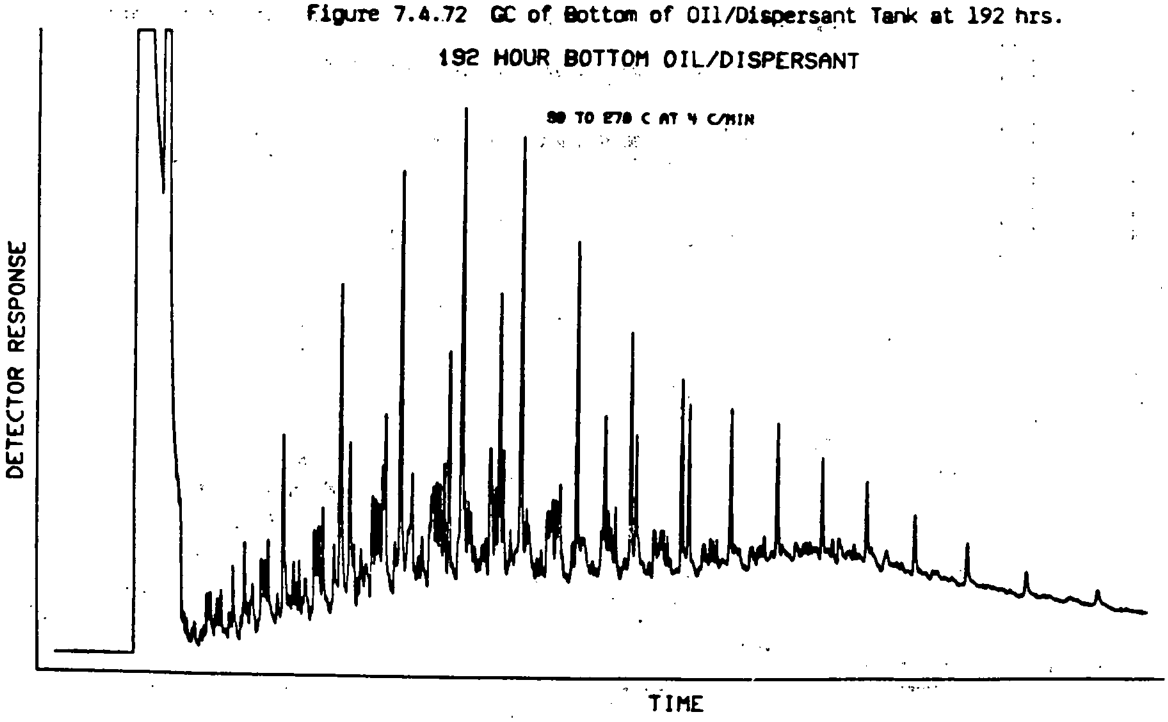


Figure 7.4.72 GC of Bottom of Oil/Dispersant Tank at 192 hrs.

Figure 7.4.73 GC of Top of Oil/Dispersant Tank at 350 hrs.

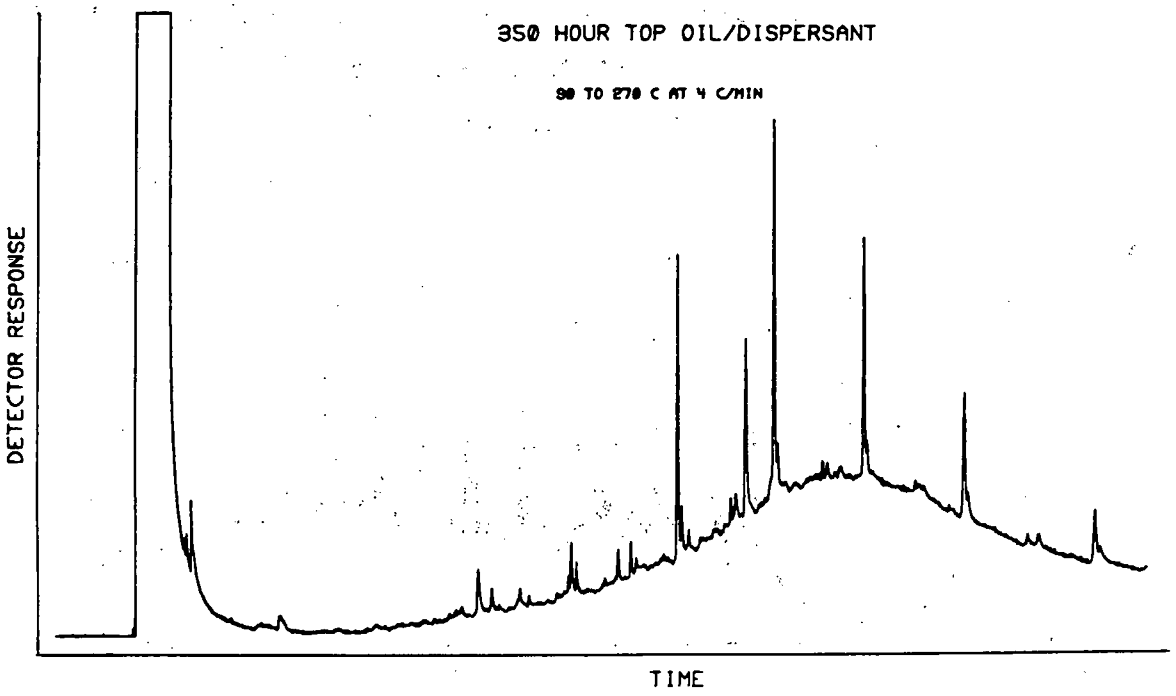
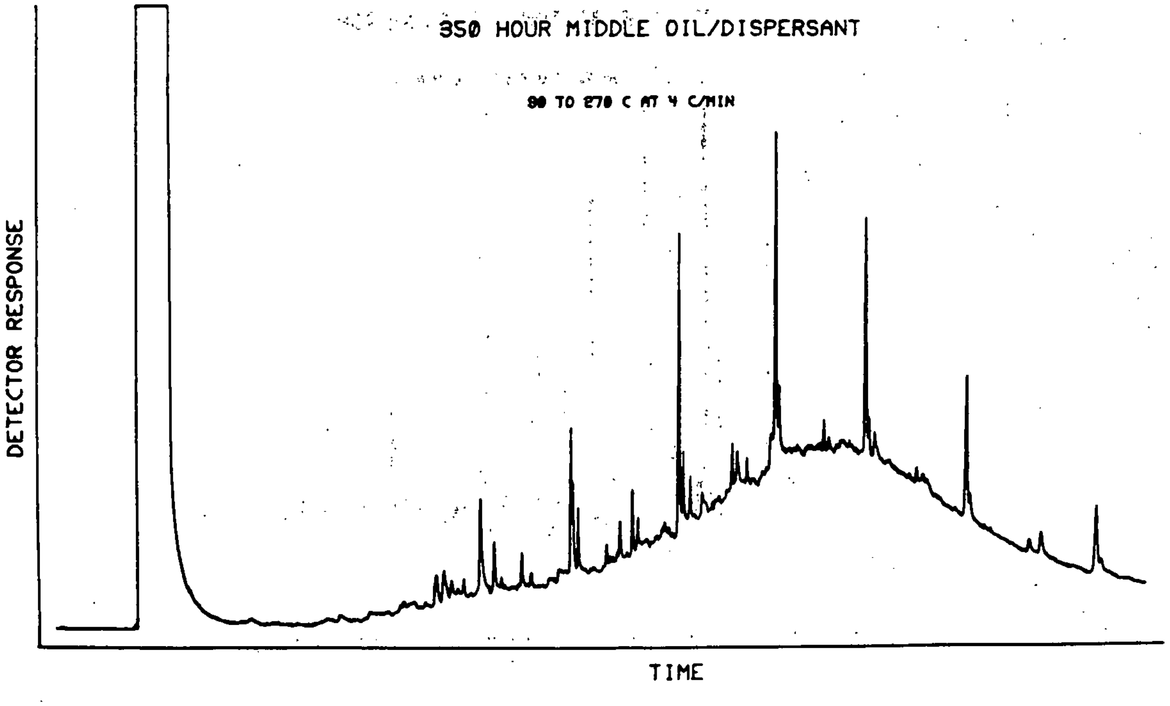


Figure 7.4.74 GC of Middle of Oil/Dispersant Tank at 350 hrs.



At 48 hours, petroleum hydrocarbons are observed in the GC's (Figures 7.4.64-7.4.66) of samples from all three ports. The relative amounts of light hydrocarbons decreases from the top to the bottom of the tank. Furthermore, the GC of the sample from the bottom of the tank shows a dramatic increase in the amounts of pristane and phytane relative to the normal paraffins. Moreover, there appears to be only one broad unresolved envelope centered at about the retention time of n-C_{15} for the samples from the top and middle ports, whereas there is a second maximum centered at about n-C_{22} in the GC of the sample from the bottom.

The GC of samples collected at 72 hours (Figure 7.4.67-7.4.69) are very similar to those at 48 hours; however, there is an increase in the amounts of pristane and phytane relative to the normal paraffins in the GC of the samples from the top and middle ports.

At 192 hours the GC's of samples from the three ports (Figures 7.4.70-7.4.72) are very similar, and only subtle differences can be detected. All three GC's appear to have a double unresolved envelope, with maxima at n-C_{15} and n-C_{21}. The GC of the sample from the bottom port has a slightly greater amount of the lighter paraffins with a maximum of normal paraffins at n-C_{14} rather than at n-C_{15} as observed in the other two samples.

After 350 hours, the GC's of samples from the three ports have changed dramatically. The amounts of petroleum hydrocarbons relative to peaks found in the GC of control samples is very low in samples from the top two ports and it is difficult to identify them; the concentrations of samples from these two levels are at the control level. However, the sample from the bottom port still contains significant amounts of petroleum hydrocarbons as indicated in the GC shown in Figure 7.4.75. Again, the double unresolved envelope and the relatively high concentration of pristane and phytane are observed.

Fractionation of Samples

Extracts of water samples were separated into three fractions consisting of paraffins, aromatics and polar compounds. A GC of each fraction was measured. The GC of the neat oil is shown in Figure 7.4.76 and of the three fractions of the neat oil in Figure 7.4.77-7.4.79. The GC of the first two fractions contain a number of specific peaks, whereas the GC of the third fraction contains very few characteristic peaks.

GC's obtained by fractionating selected samples from the oil/dispersant tank collected at 24, 48 and 72 hours are shown in Figures 7.4.80 - 7.4.94. At 24 hours the paraffin fraction (Figure 7.4.80) from the top port is very similar to the paraffin fraction of the neat oil (Figure 7.4.77) except for the loss of the more volatile components from n-C_{11} to n-C_{14}. The aromatic fraction (Figure 7.4.81 and 7.4.78) are also similar except for the loss of the lighter fractions. However, the GC of the polar fraction from the oil/dispersant tank (Figure 7.4.82) has no distinctive peaks suggesting that the polars are lost in the flow system.

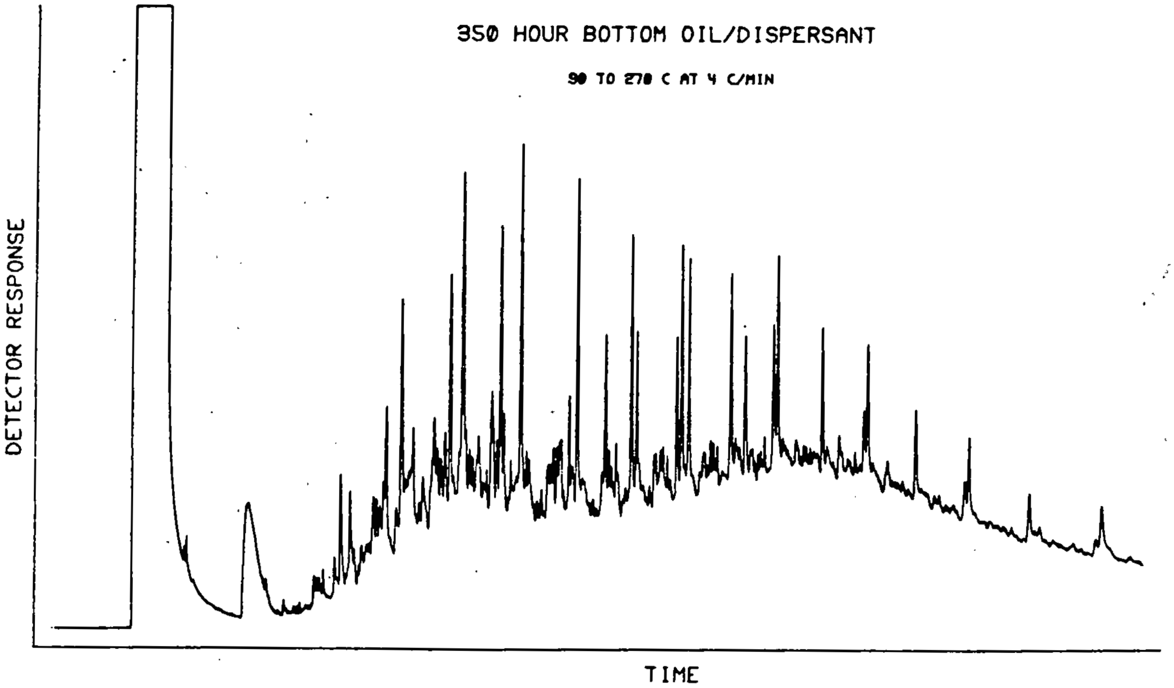


Figure 7.4.75 GC of Bottom of Oil/Dispersant Tank at 350 hrs.

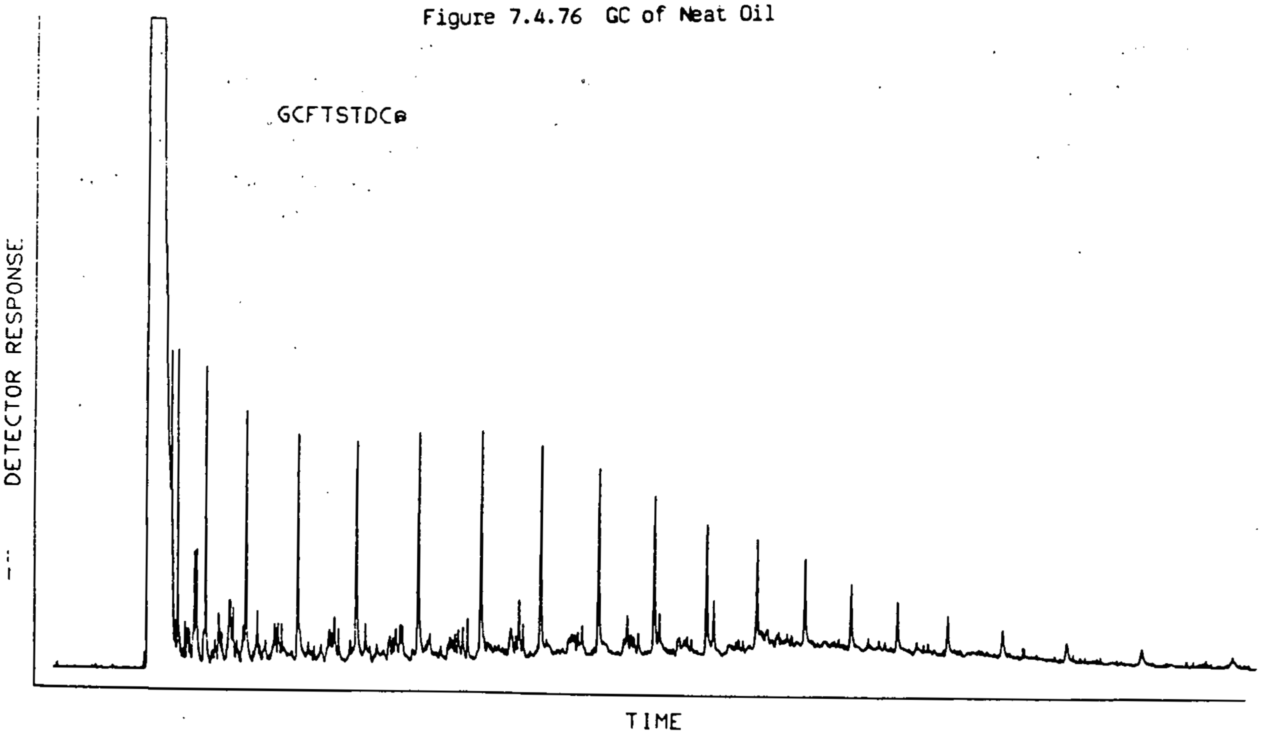


Figure 7.4.76 GC of Neat Oil

Figure 7.4.77 GC of Paraffin Fraction of Neat Oil

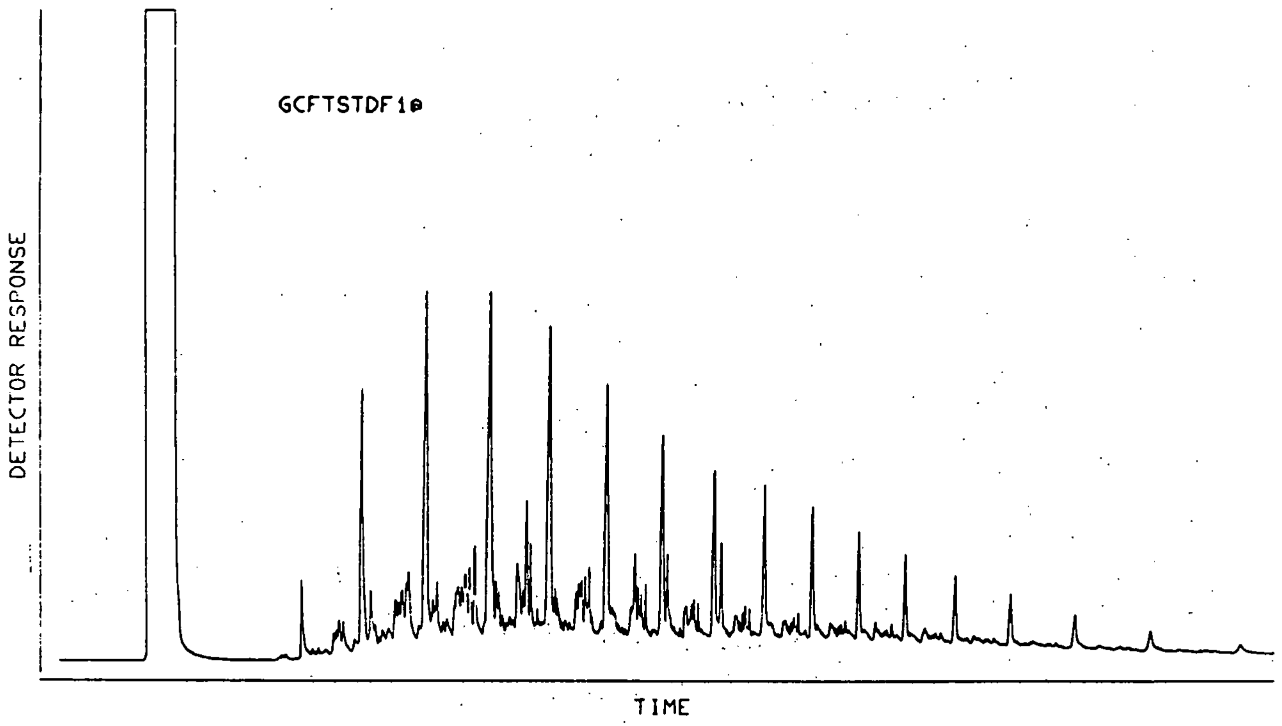


Figure 7.4.78 GC of Aromatic Fraction of Neat Oil

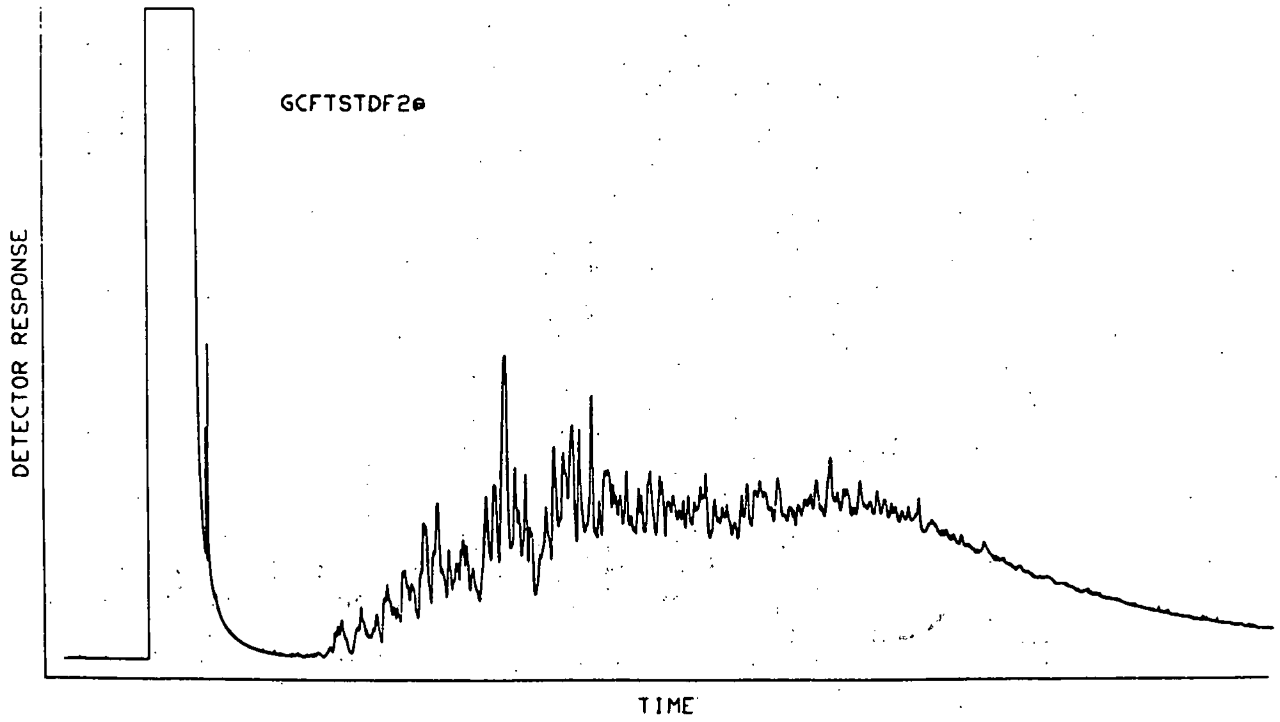


Figure 7.4.79 GC of Polar Fraction of Neat Oil

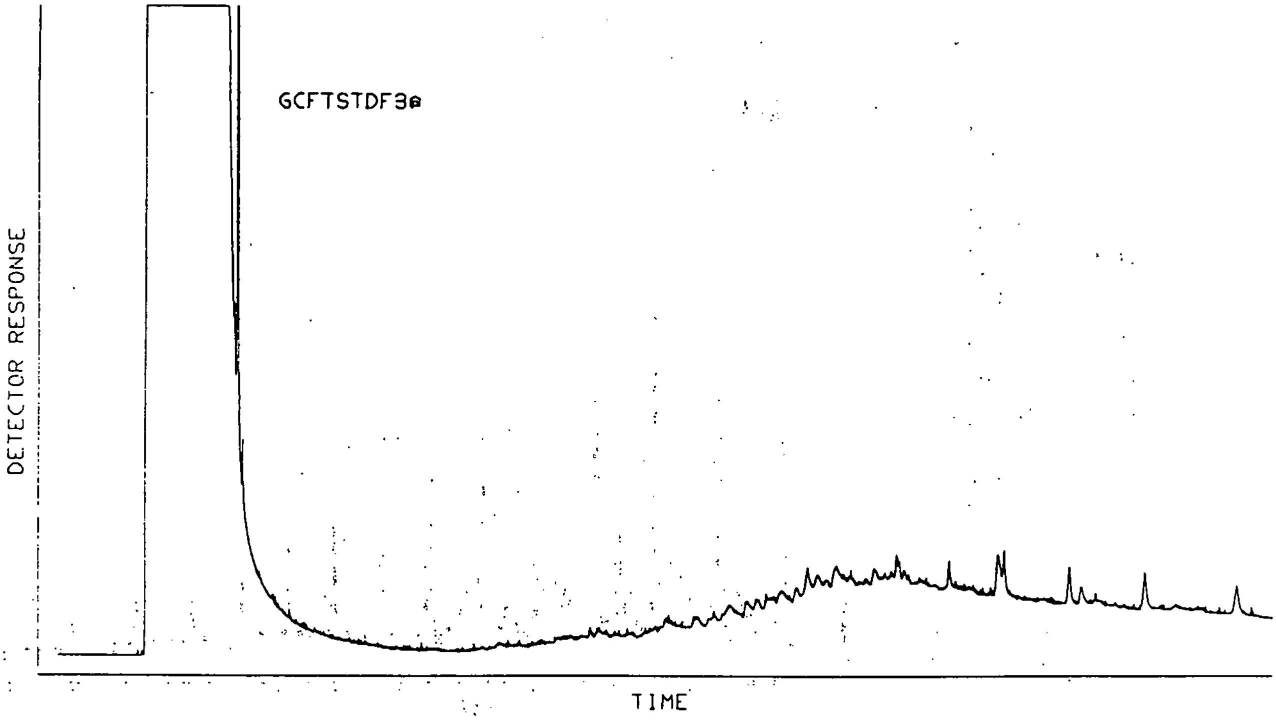


Figure 7.4.80 GC of Paraffin Fraction From Oil Tank at 24 hrs.

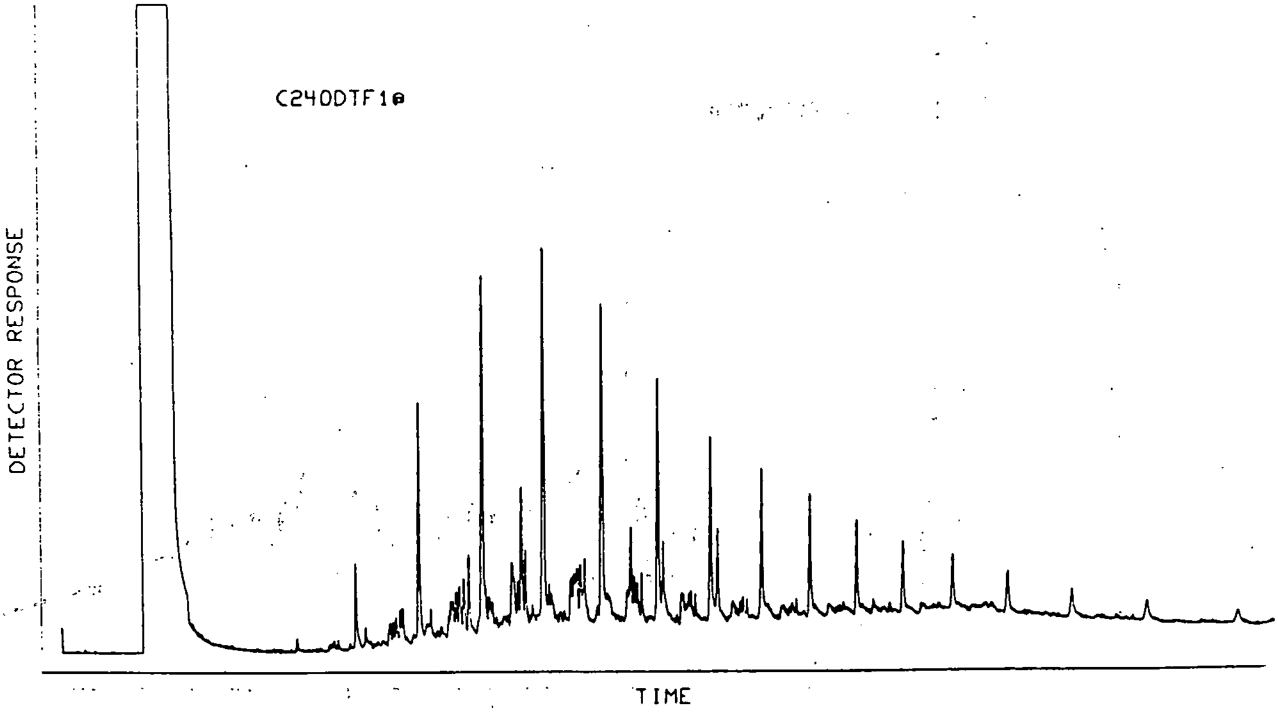


Figure 7.4.81 GC of Aromatic Fraction From Old Tank at 24 hrs.

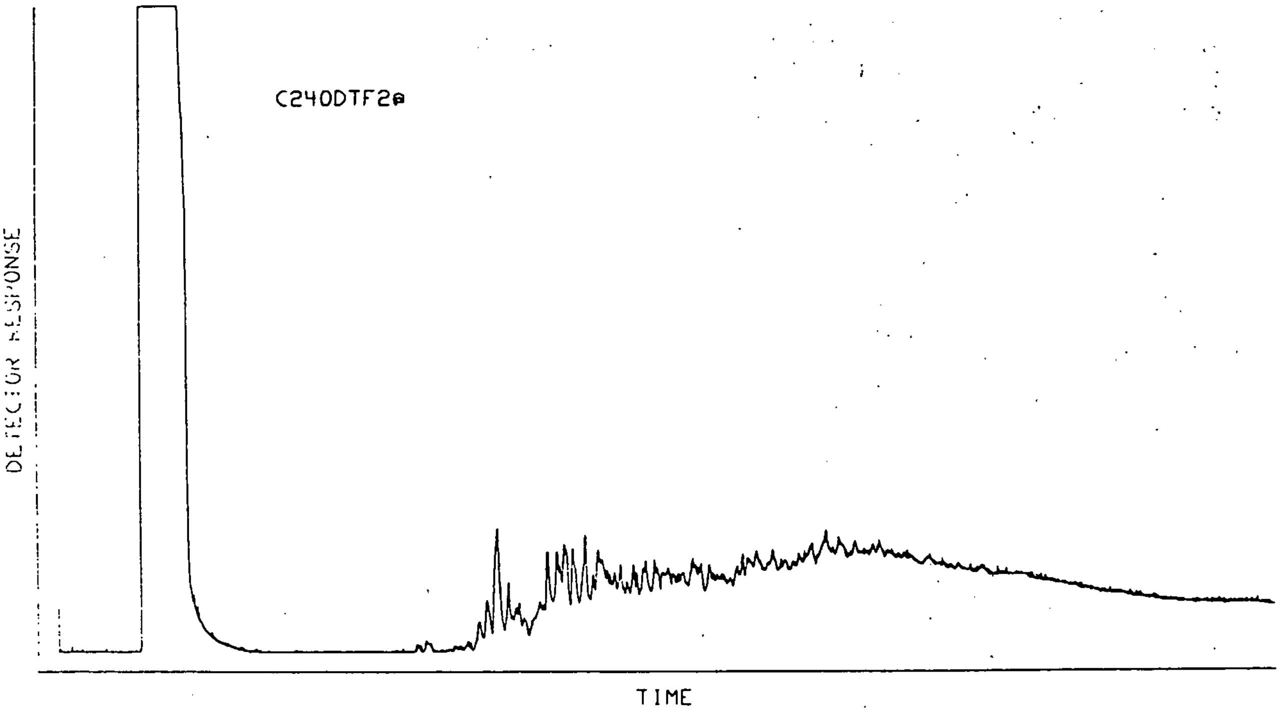
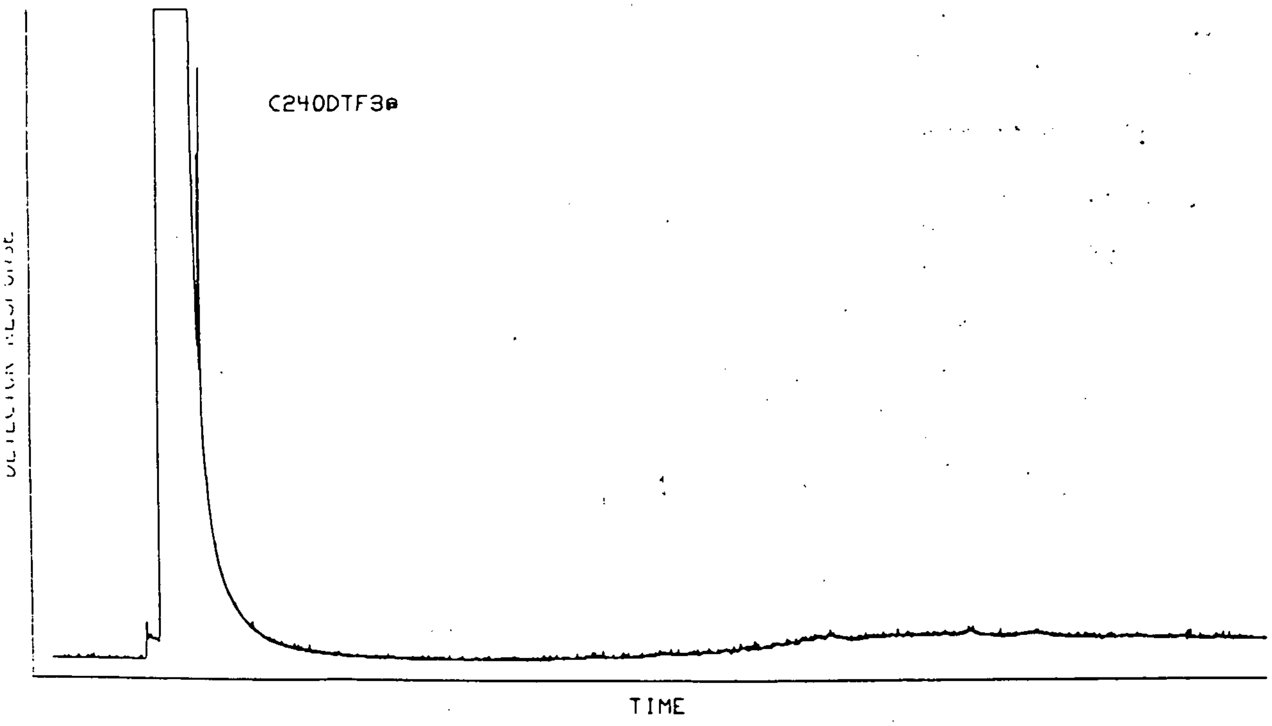


Figure 7.4.82 GC of Polar Fraction From Old Tank at 24 hrs.



The fractions of the sample from the middle of the tank (Figures 7.4.83 and 7.4.84) at 24 hours contained larger relative amounts of the isoprenoids, pristane and phytane, in the paraffin phase, but very small peaks in the aromatic phase. This suggests (but is not conclusive evidence) that aromatics are stratified in the water column and remain near the top of the tank, indicating that the dispersant has a different effect on paraffins and aromatics.

The GC of the paraffin fraction at 48 hours (Figure 7.4.85) shows an odd/even effect with the even chain lengths (n-C_{16}, n-C_{18} and n-C_{20}) found at higher concentrations than the odd chain lengths. This odd/even effect is less pronounced in the GC of the composite sample (Figure 7.4.64); however, the distribution in the GC of the composite is affected by the large unresolved envelope centered at n-C_{15}.

The remaining GC of the fractionated samples do not reveal any new features that are not observed in the GC of the composite samples.

(3) Conclusions

In this experiment, useful conclusions can be drawn from the gas chromatograms of samples from the oil dispersant tank. As shown by the quantitative results from this experiment and from previous experiments, the oil (petroleum hydrocarbons) appear to migrate with time to the bottom of the tank. This is supported by the gas chromatograms. However, in this experiment, the chromatograms show that not all of the components of the oil appear equally distributed at all three sampling levels. At 1 and 24 hours more of the lighter components (C_{10}-C_{12} are found in the sample from the top port. The fractionation procedure indicates that the heavier aromatics never reach the center of the tank.

After 192 hours there appears to be more of the lower molecular weight paraffins in the bottom of the tank than at the other two levels. This could reflect greater degradation of the heavier paraffins at the bottom. In the same way, there is a general increase in the relative amounts of the isoprenoids, pristane and phytane, as a function of time; this could also be due to the degradation of the normal paraffins with time.

III. References

1. Jasper, W.J., Kim, T.J., Wilson, M.P., "Drop-size Distribution in a Treated Oil Water System," ASTM Conference, Chemical Dispersants, Williamsburg, Pa., 1977.

2. Traxler, R.W., Bhattacharya, L.S., "Effect of Chemical Dispersants on Microbial Utilization of Petroleum Hydrocarbons," ASTM Conference, ibid.

3. Wilson, M.P., "The Assessment Problems of Whether or Not to Treat Oil Spills," ibid.

4. Brown, R.A., Elliott, J.J., Searl, T.D., "Measurement and Characterization of Nonvolatile Hydrocarbons in Ocean Water," AID. 4BA.74 (1974).

Figure 7.4.83 GC of Paraffin Fractions From Middle of Old Tank at 24 hrs.

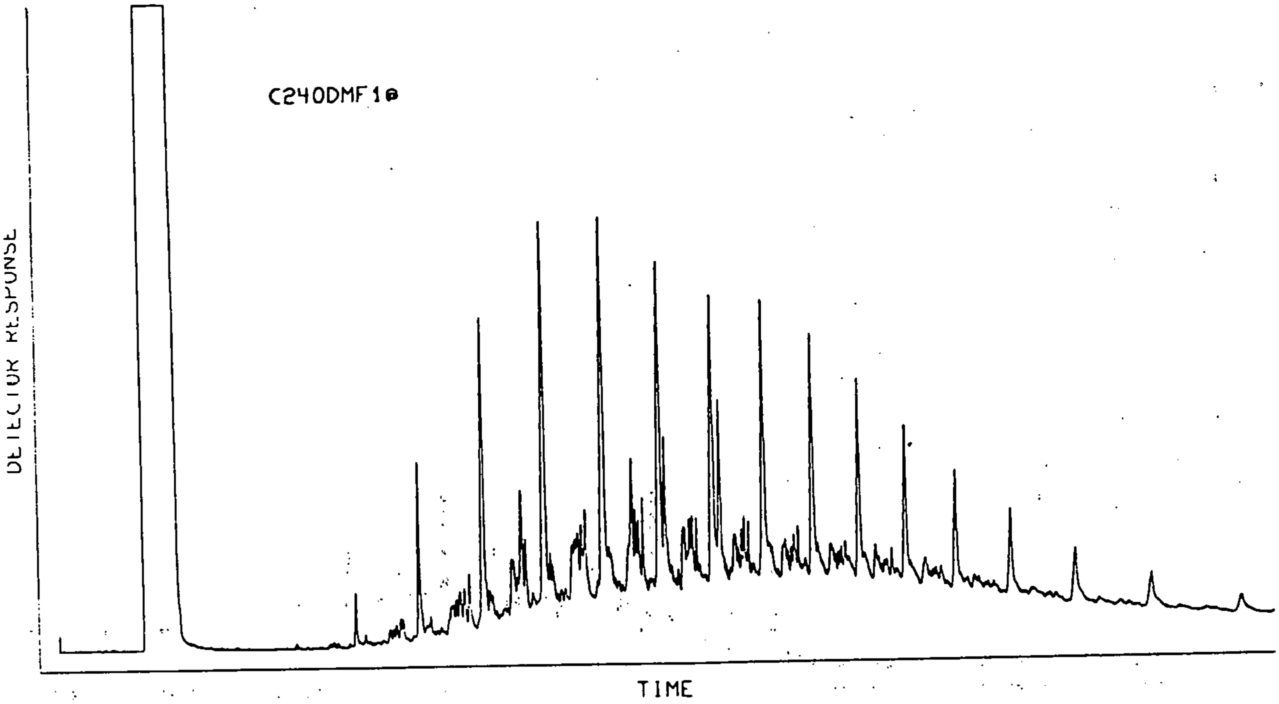


Figure 7.4.84 GC of Aromatic Fractions From Middle of Old Tanks at 24 hrs.

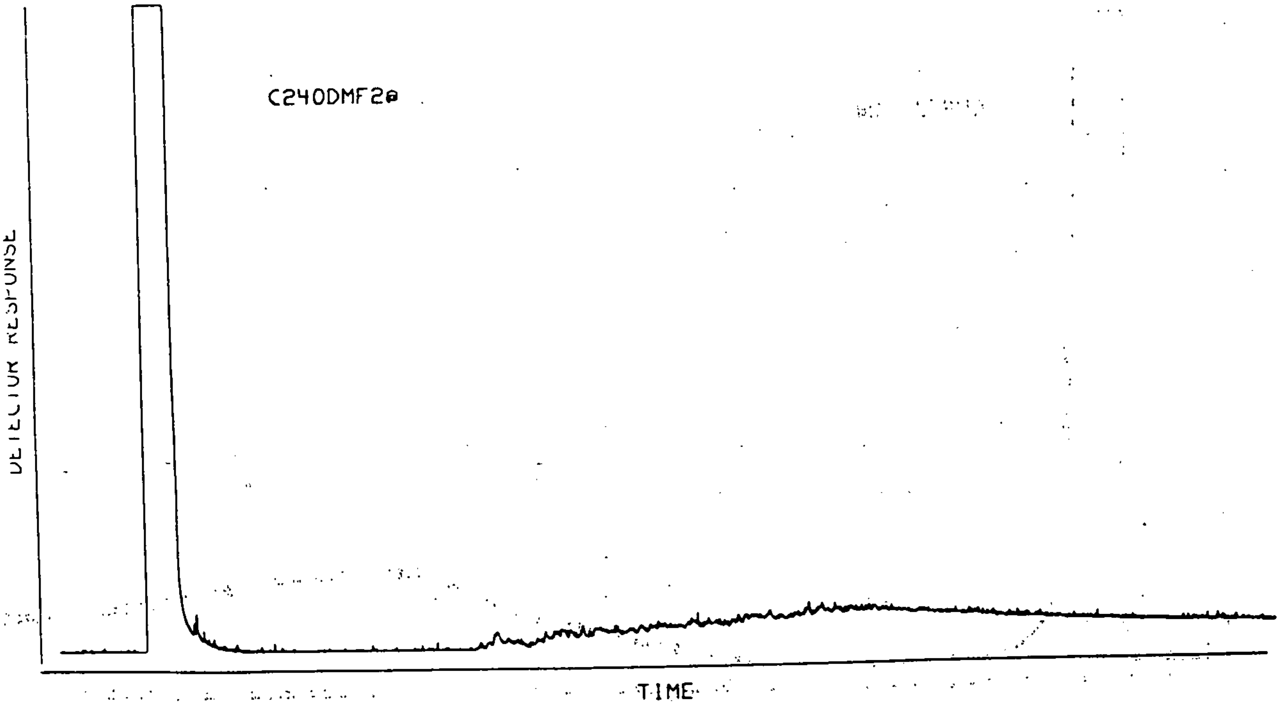


Figure 7.4.85 GC of Paraffin Top Fraction at 48 hrs.

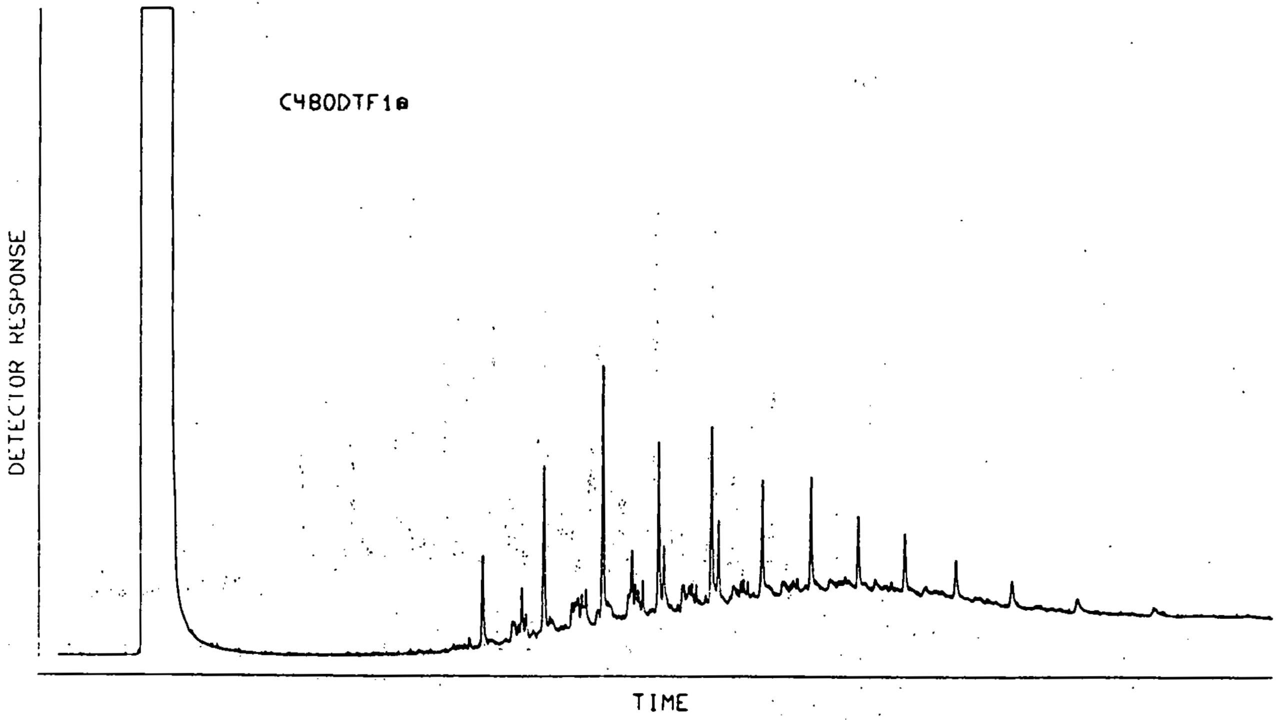


Figure 7.4.86 GC of Aromatic Top Fraction at 48 hrs.

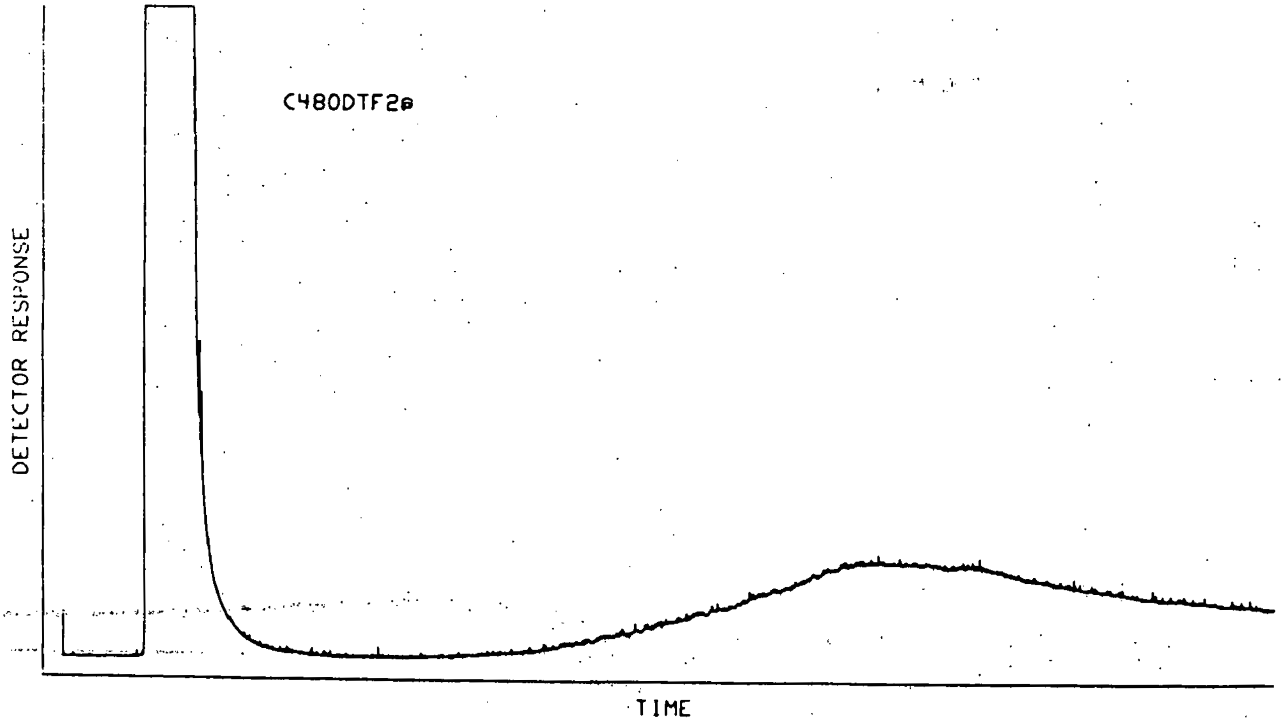


Figure 7.4.87 GC of Polar Fraction Top Fraction at 48 hrs.

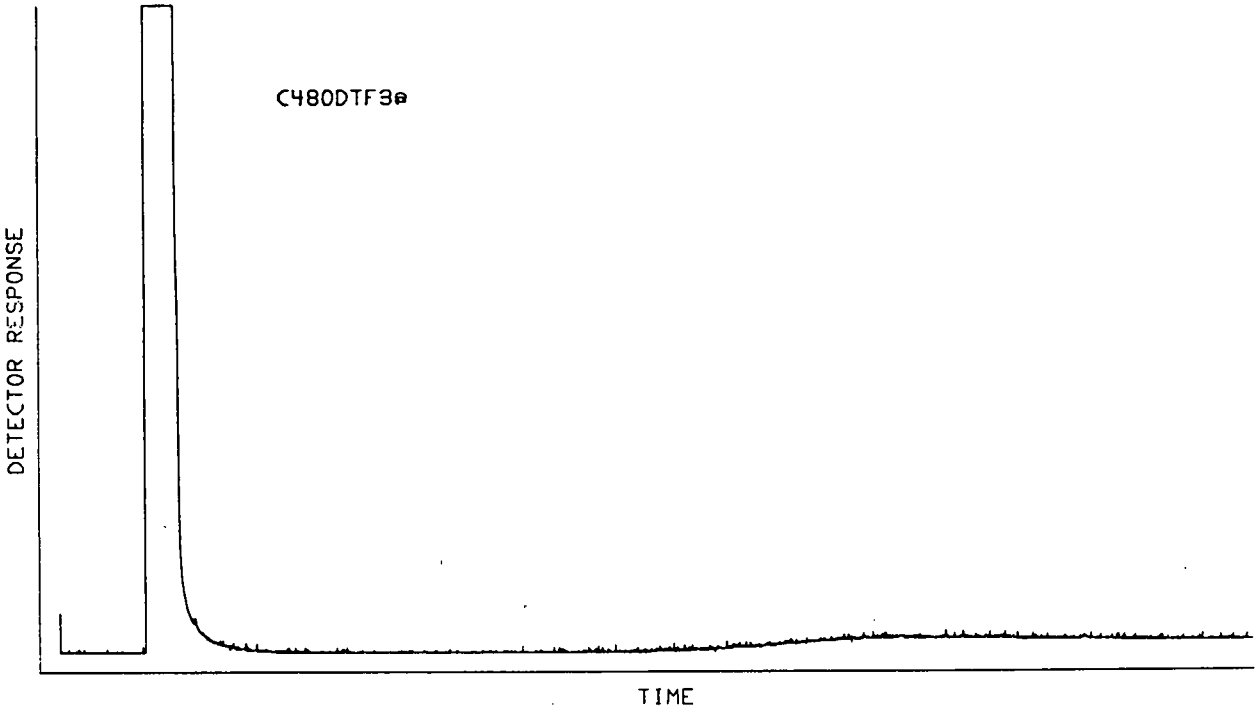


Figure 7.4.88 GC of Paraffin Middle Fraction at 48 hrs.

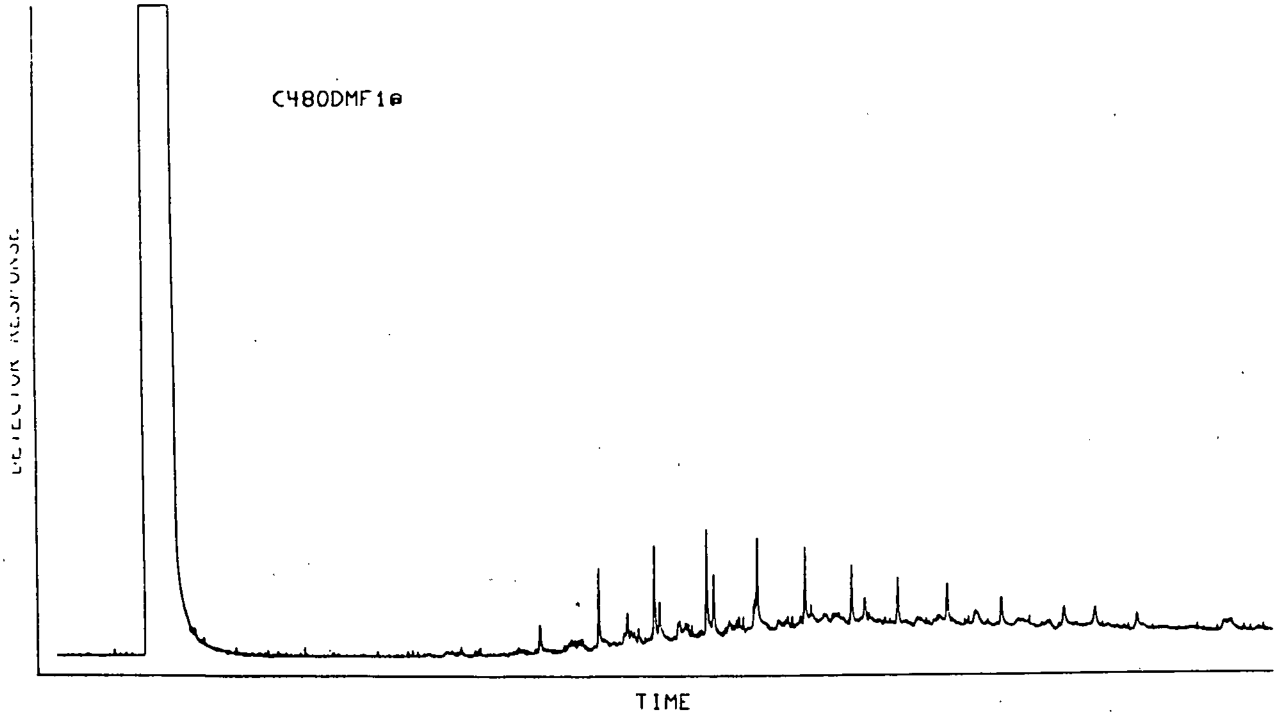


Figure 7.4.89 GC of Aromatic Middle Fraction at 48 hrs.

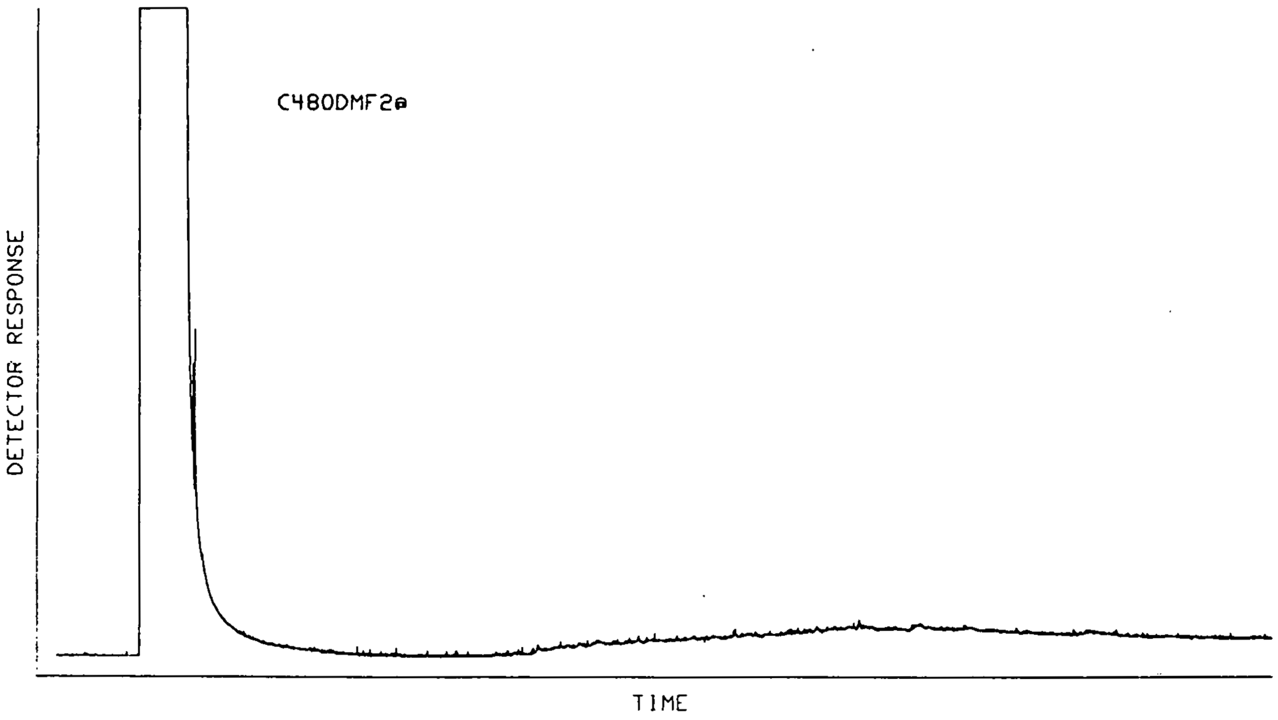


Figure 7.4.90 GC of Paraffin Top Fraction at 72 hrs.

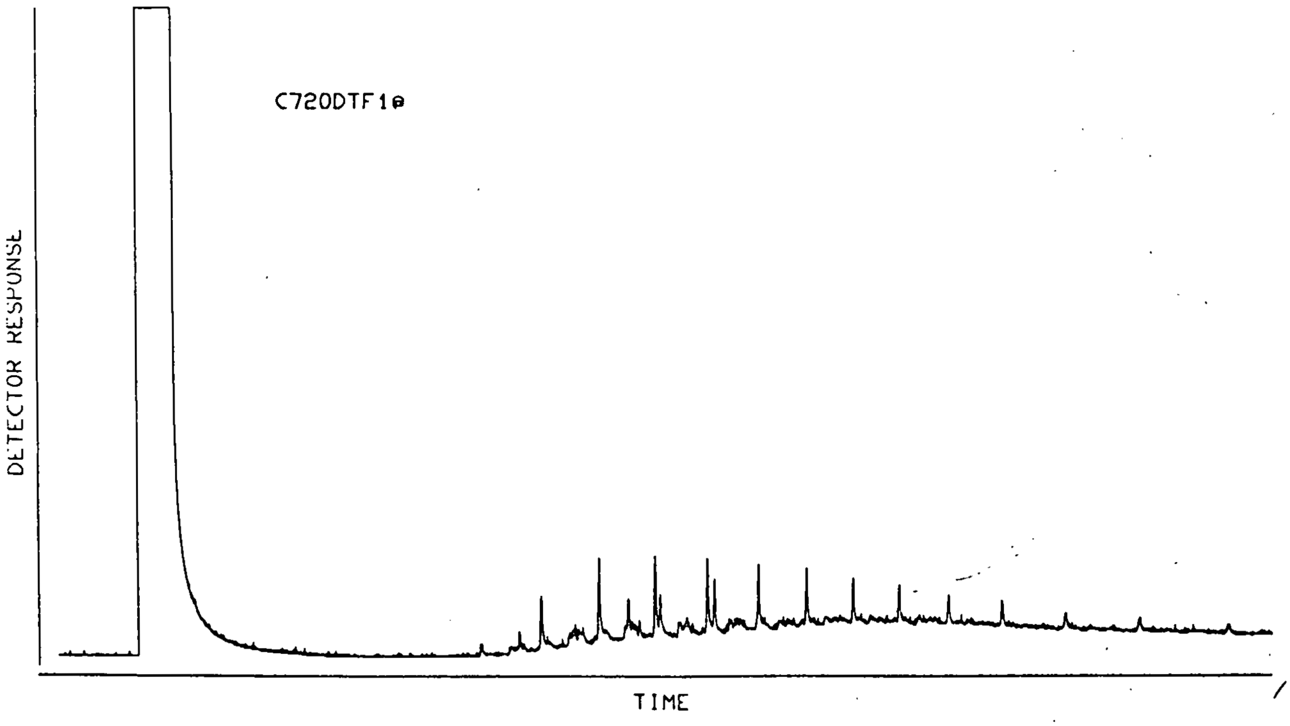


Figure 7.4.91 GC of Polar Top Fraction at 72 hrs.

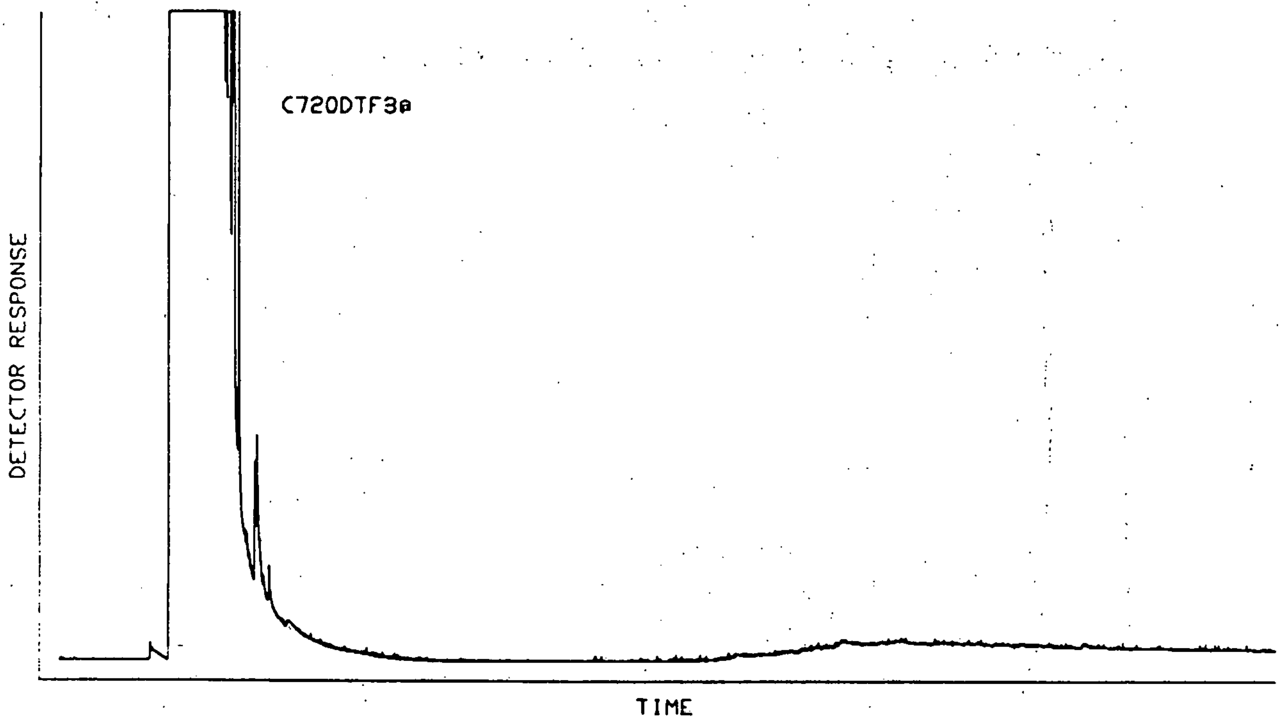


Figure 7.4.92 GC of Aromatic Middle Fraction at 72 hrs.

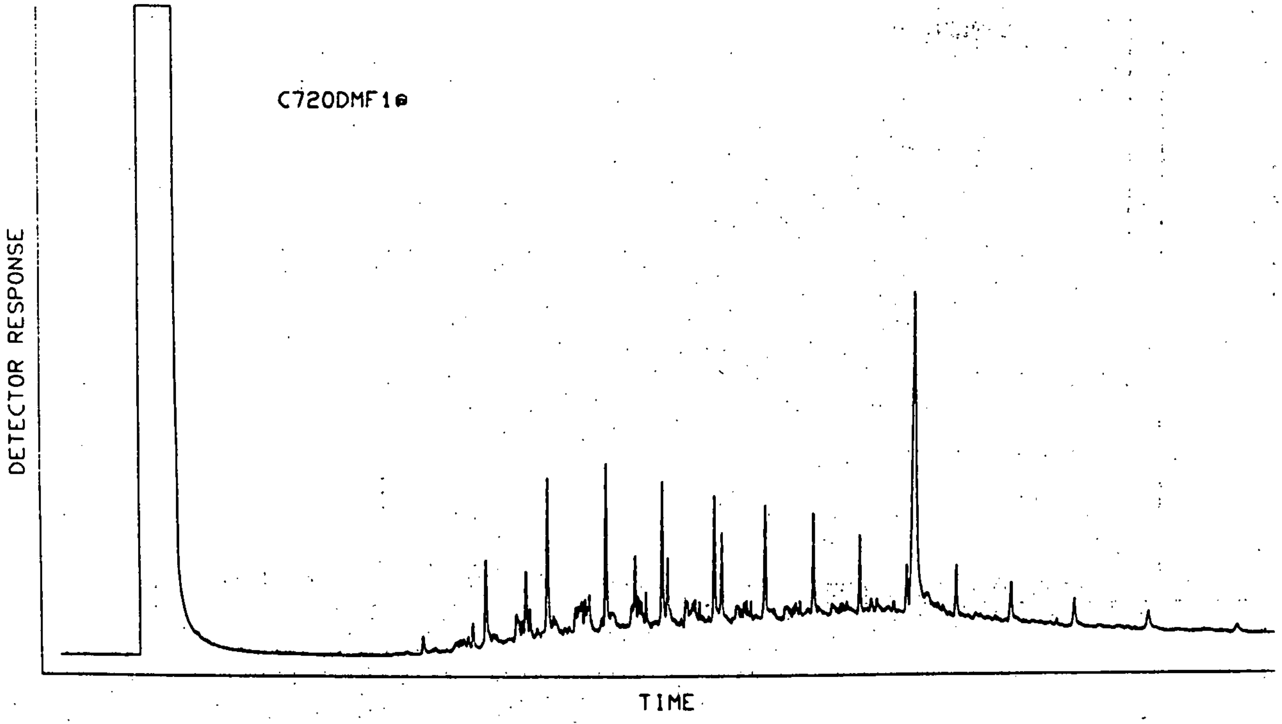


Figure 7.4.93 GC of Paraffin MIddle Fraction at 72 hrs.

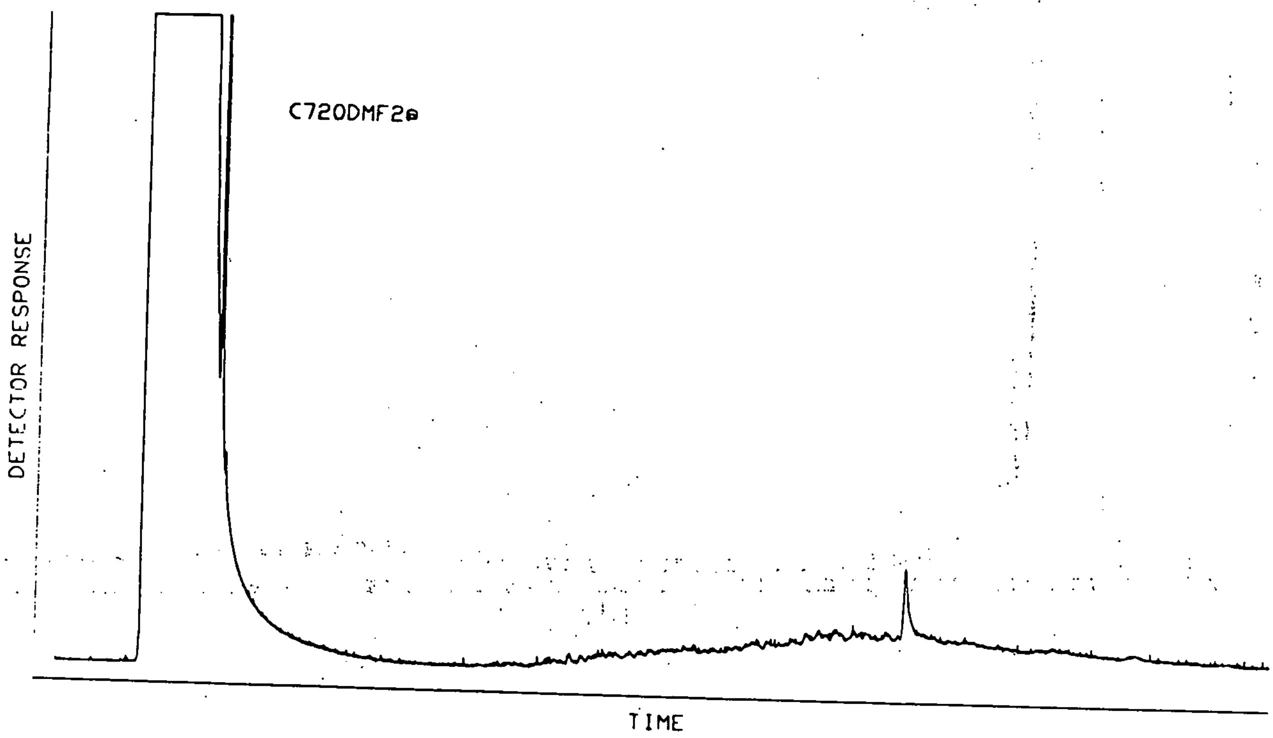
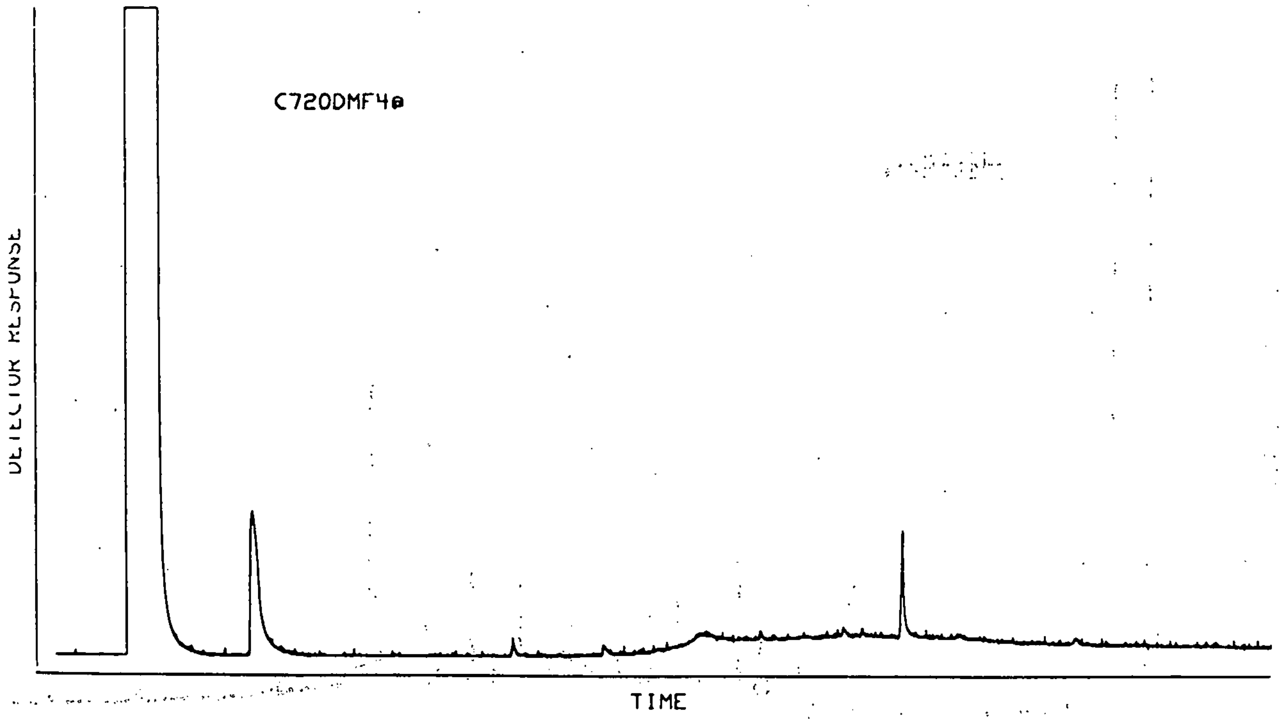


Figure 7.4.94 GC of Polar MIddle Fraction at 72 hrs.



7.5 Jerusalem Flow Thru Experiment

7.5.1 Introduction

The flow-thru experiment consisted of four 55 gallon drums with sea water flowing through each at the rate of 10 gallons/hour. Initially, the following components were added to the surface of the sea water:

1) Control

2) Ten ml of dispersant (Corexit 9527)

3) Two hundred ml oil (Kuwait crude)

4) Two hundred ml of Kuwait crude and 10 ml of Corexit 9527

Water samples were collected every week from the top, middle and bottom of each tank. Sediment samples were collected from tanks 1, 3, and 4 at week 1 (first day of the experiment) and week 4.

7.5.2 Experimental

(A) Quantitative Analysis of Water Samples

One-liter water samples were extracted with two 15 ml aliquots of CS_2. The aliquots were combined and the volume adjusted to 25 ml. The infrared spectrum was recorded from 3200 to 2800 cm^{-1} using 6 mm AgCl matched cells, and the absorbance of the C-H stretching band at 2930 cm^{-1} was used to determine the concentration of extractable organics from plots of concentration vs. absorbance measured using known amounts of the Kuwait crude oil, Kuwait and Corexit, or Corexit. An extraction efficiency of 65% (previously determined) was used for samples from tanks 1, 3 and 4. An extraction efficiency of 22% was used for tank 2 (dispersant) when it was found that the dispersant was present in the extract by qualitative infrared spectroscopy; however, if the dispersant was not present, a 65% efficiency was used.

(B) Qualitative Analysis of Water Samples Collected from the Tanks.

During the 1st, 4th and 6th weeks, 3.5 liter water samples were collected from the tanks. These larger samples were collected in order to perform complete qualitative analyses. The samples from the fourth week did not contain enough hydrocarbons to warrant qualitative analysis; however, samples from the other two weeks were analyzed.

All samples were extracted with CS_2 and the extracts concentrated to 1 or 2 ml. Infrared spectra between 1950 and 660 cm^{-1} were measured using 6 mm AgCl cells. After measuring the infrared spectra, the CS_2 was completely removed from each of the extracts by evaporation and the residue was taken up in 20 μl of hexane. Two μl samples were injected into a gas chromatograph equipped with a glass capillary column (Supelco SP 2100). Three samples were also separated into multiple fractions containing aliphatics, small and large ring aromatics and polar components using a column of alumina and eluting with pentane, toluene and methanol. Each fraction was analyzed on a glass capillary column GC.

(C) Analysis of Sediment Samples

Sediment samples were subjected to a saponification-extraction using a KOH-toluene-methanol reflux. The organic layer was collected and passed through a silica gel column to remove natural polar components. Both qualitative and quantitative infrared spectra of the extracts were measured. The extracts were further separated by thin-layer chromatography and all of the hydrocarbons running above the standard, phenanthrene, were dissolved in hexane and injected into the capillary column gas chromatograph.

7.5.3 Results

(A) Qualitative GC of Water Samples

(a) Week One

Water samples were collected one hour after addition of the oil and dispersant.

i. Control Tank

Gas chromatograms of water samples from the top, middle and bottom of the control tank are shown in Figures 7.5.1, 2 and 3. Gas chromatograms of the top and bottom (CT and CB) suggest the presence of normal paraffins from n-C_{16} to n-C_{24}, which is indicative of petroleum.

ii. Dispersant Tank

GC of the top, middle and bottom water extracts are shown in Figures (7.5.4, 5 and 6). A number of relatively intense peaks are observed in all three GCs; however, peaks at short retention times found in the GC of the oil/dispersant (Figure 7.5.10) are not observed.

iii. Oil Tank

GC of extracts of water from the top, middle and bottom of the oil tank are shown in Figures 7.5.7, 8 and 9. A number of relatively intense peaks are observed in the GC of the top sample. The normal paraffin peaks are relatively weak compared to the other components which suggests that the more soluble aromatics and polar compounds are present. Two prominent peaks are observed in the GC of the middle sample and these two peaks are also present in the GC of the top sample.

iv. Oil/Dispersant Tank

GC of the extracts of water from the top and bottom of the oil/dispersant tank are shown in Figures 7.5.10 and 11; the extract of the middle sample was accidentally destroyed during the analysis procedure. The GC of the top samples is typical of weathered oil with the addition of two peaks at short retention times and several broad peaks at longer retention times; these peaks are undoubtedly due to the dispersant. The interesting feature is that the dispersant takes most of the unweathered components of oil into the water column.

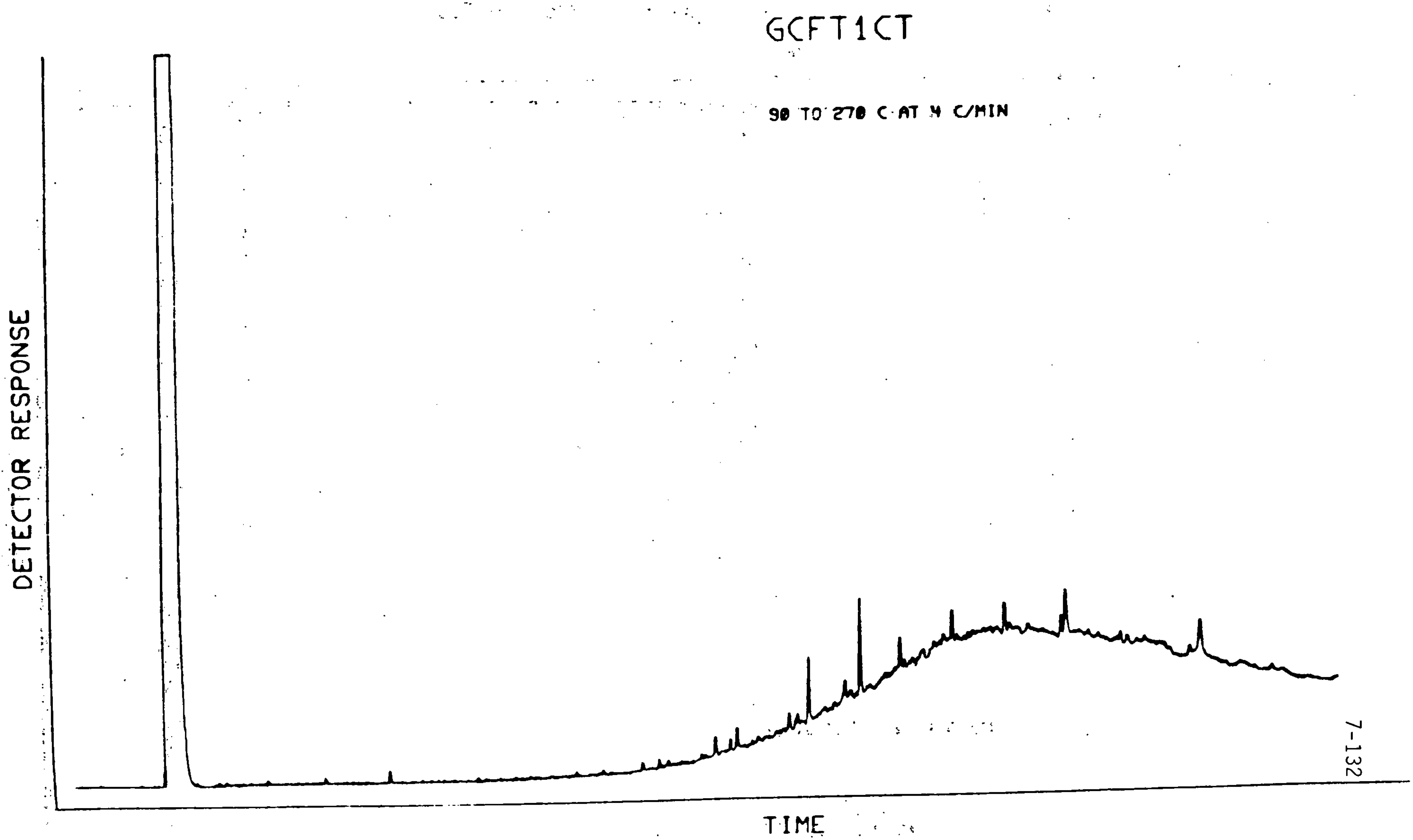


Figure 7.5.1 GC of the Control Tank, top, 1 hr.

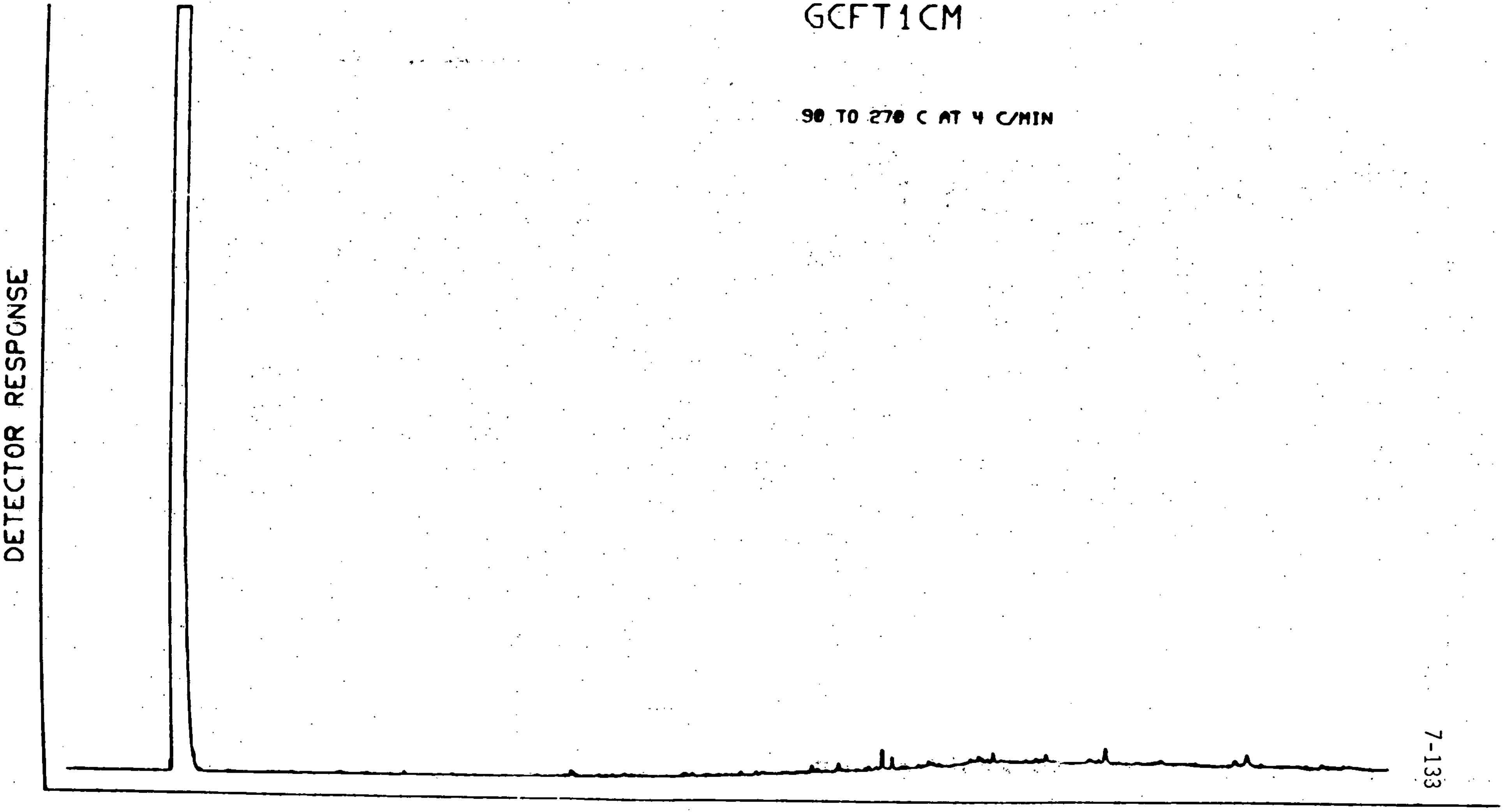


Figure 7.5.2 GC of the Control Tank, middle, 1 hr.

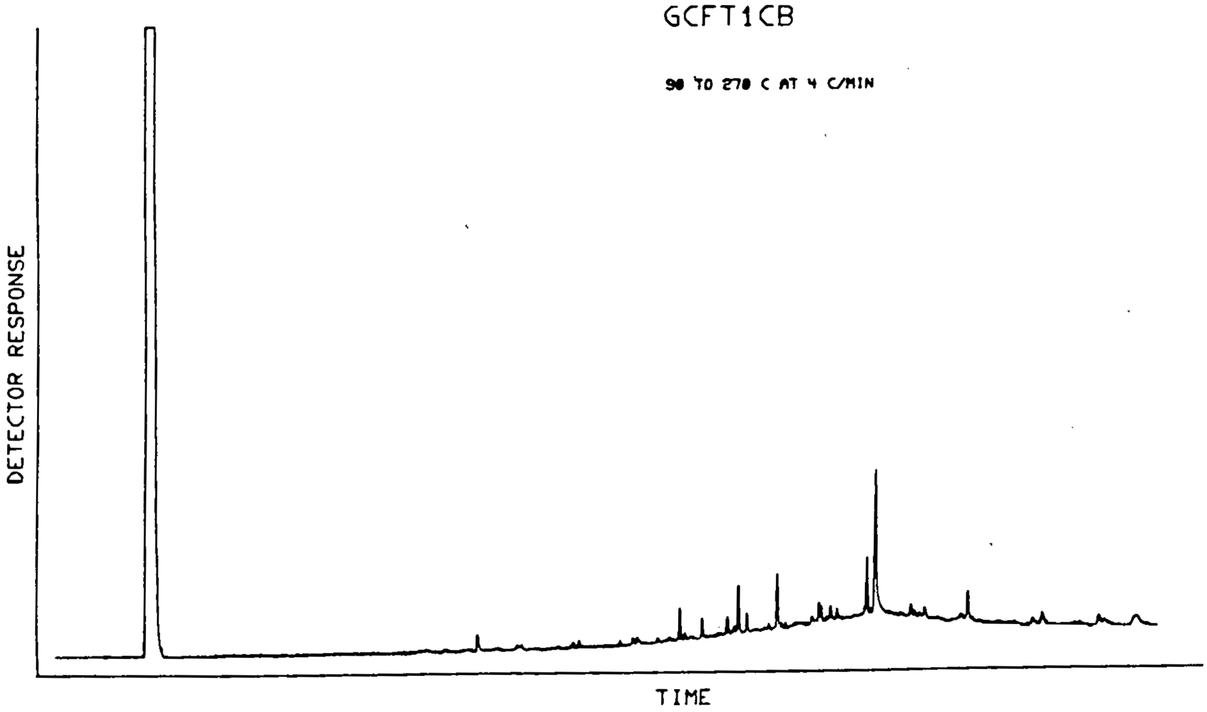


Figure 7.5.3 GC of the Control Tank, bottom, 1 hr.

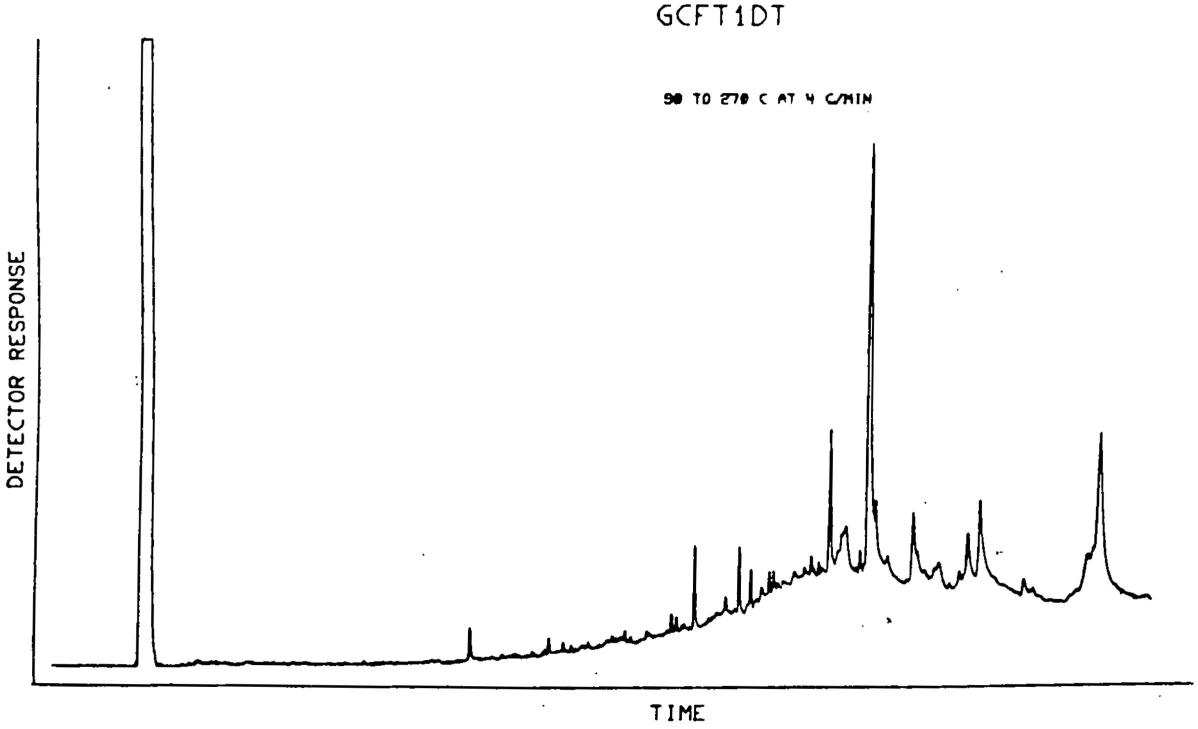


Figure 7.5.4 GC of the Dispersant Tank, top, 1 hr.

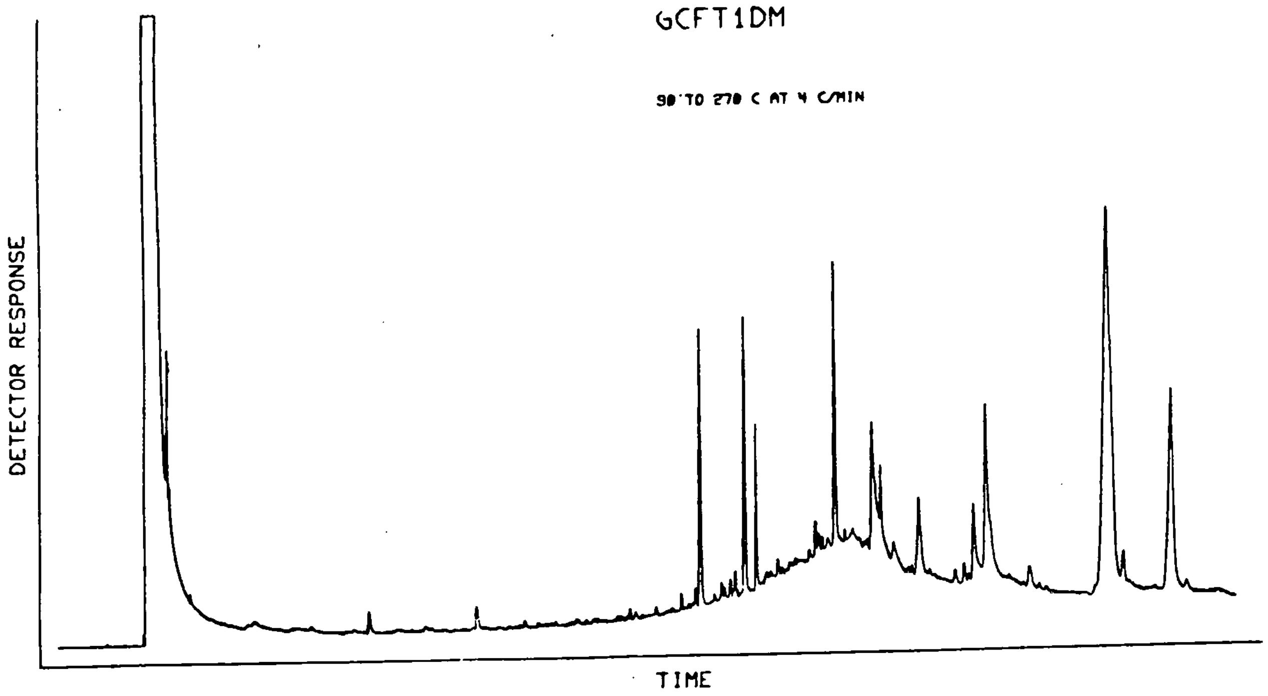


Figure 7.5.5 GC of the Dispersant Tank, middle, 1 hr.

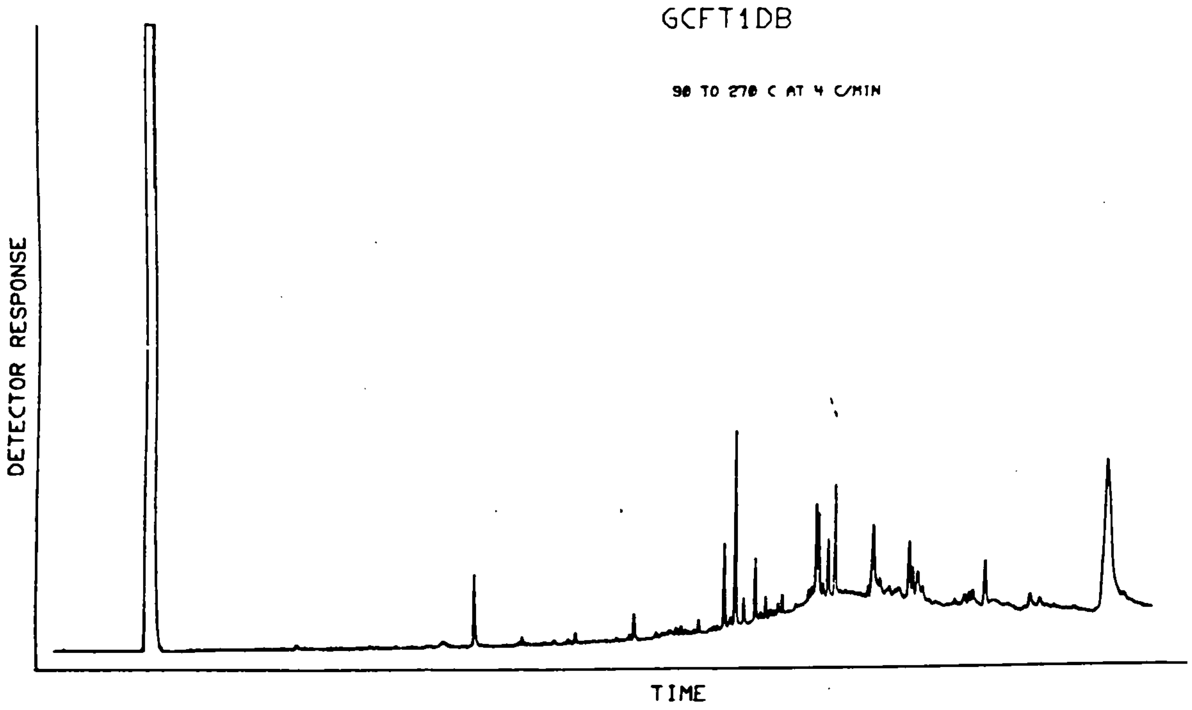


Figure 7.5.6 GC of the Dispersant Tank, bottom, 1 hr.

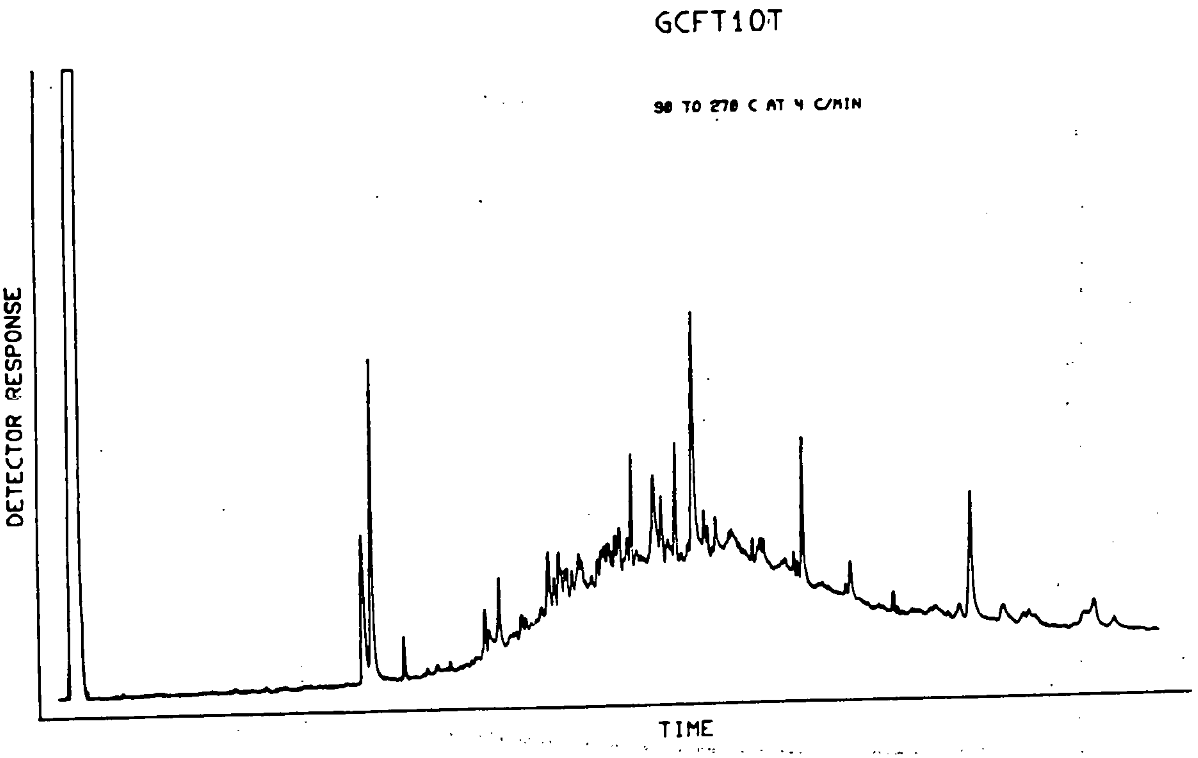


Figure 7.5.7 GC of the Oil Tank, top 1 hr.

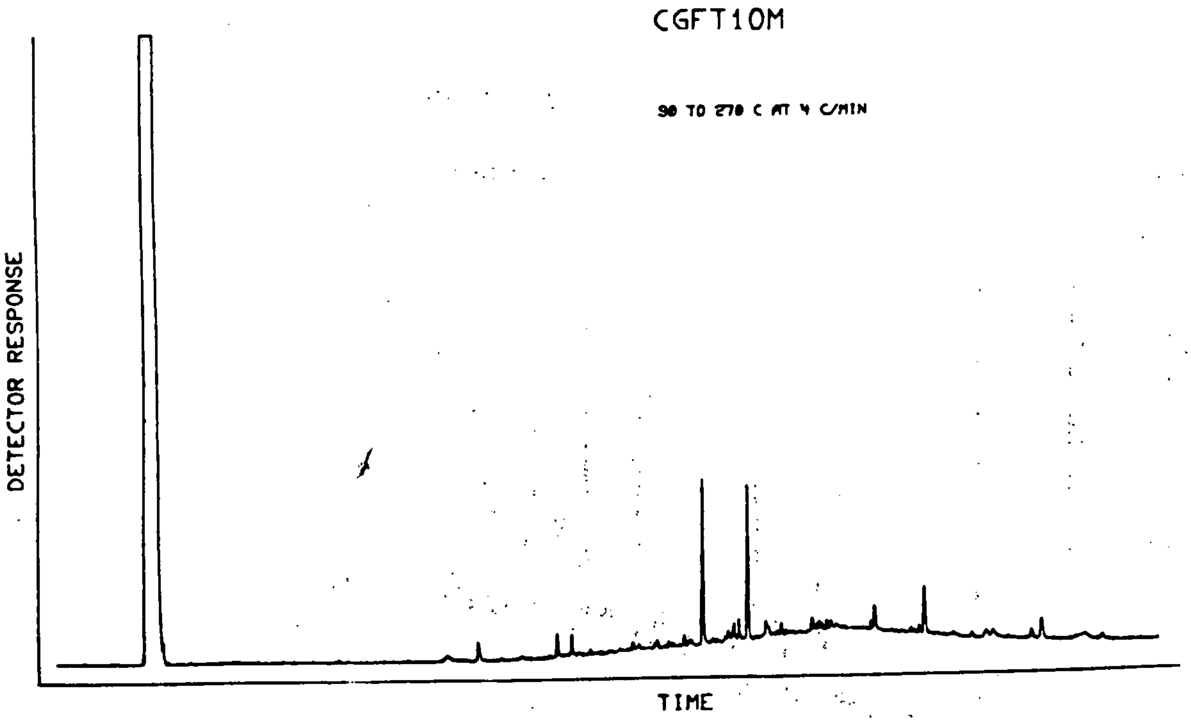


Figure 7.5.8 GC of the Oil Tank, middle, 1 hr.

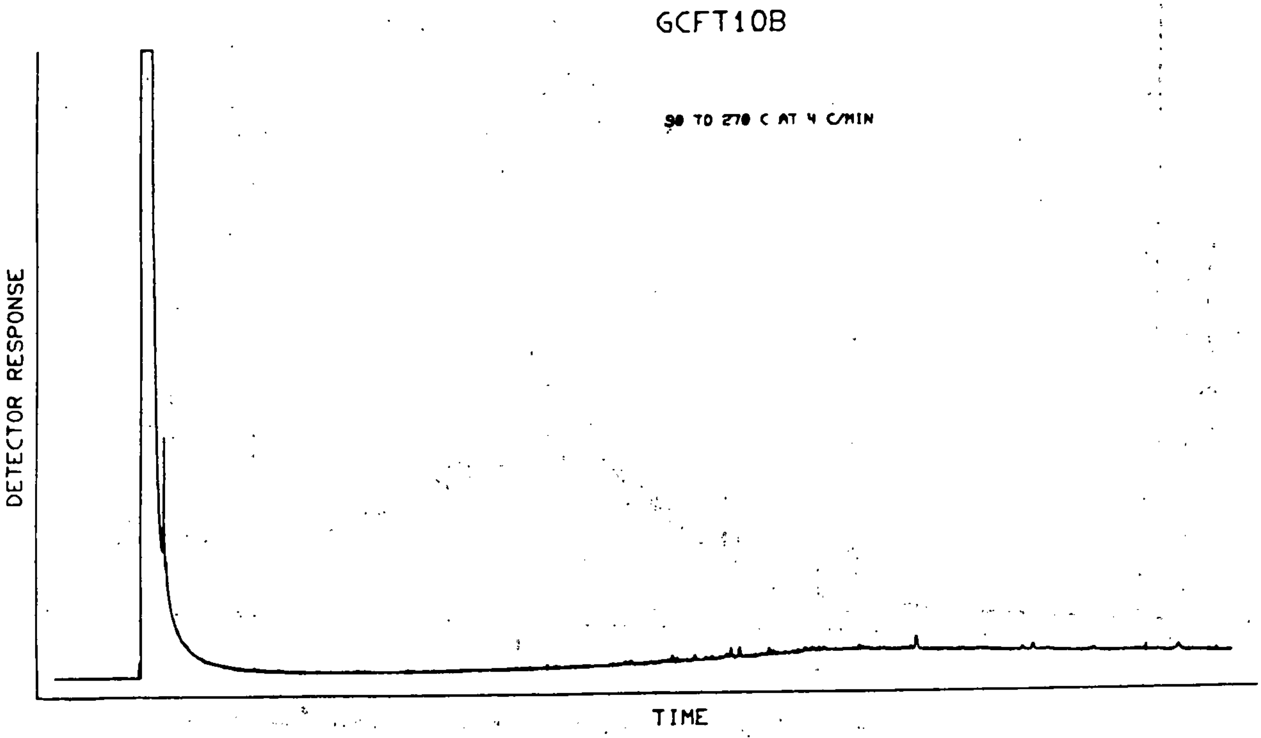


Figure 7.5.9 GC of the Oil Tank, bottom, 1 hr.

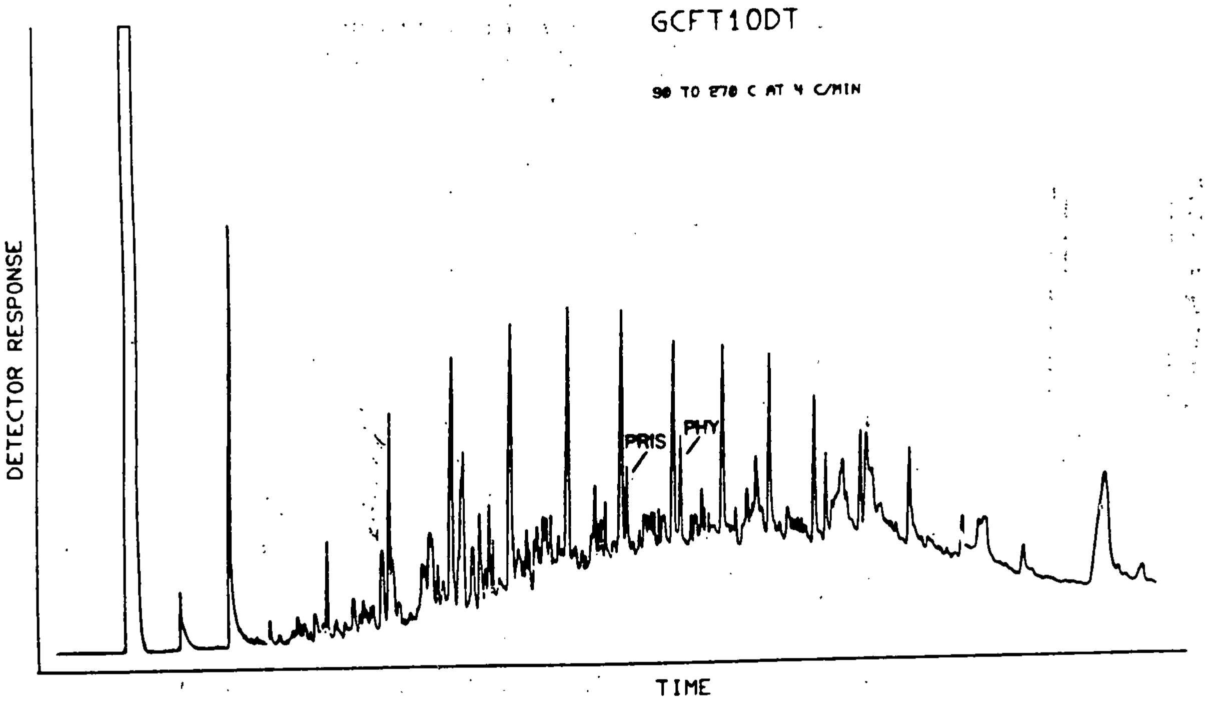


Figure 7.5.10 GC of the Oil/Dispersant Tank, top, 1 hr.

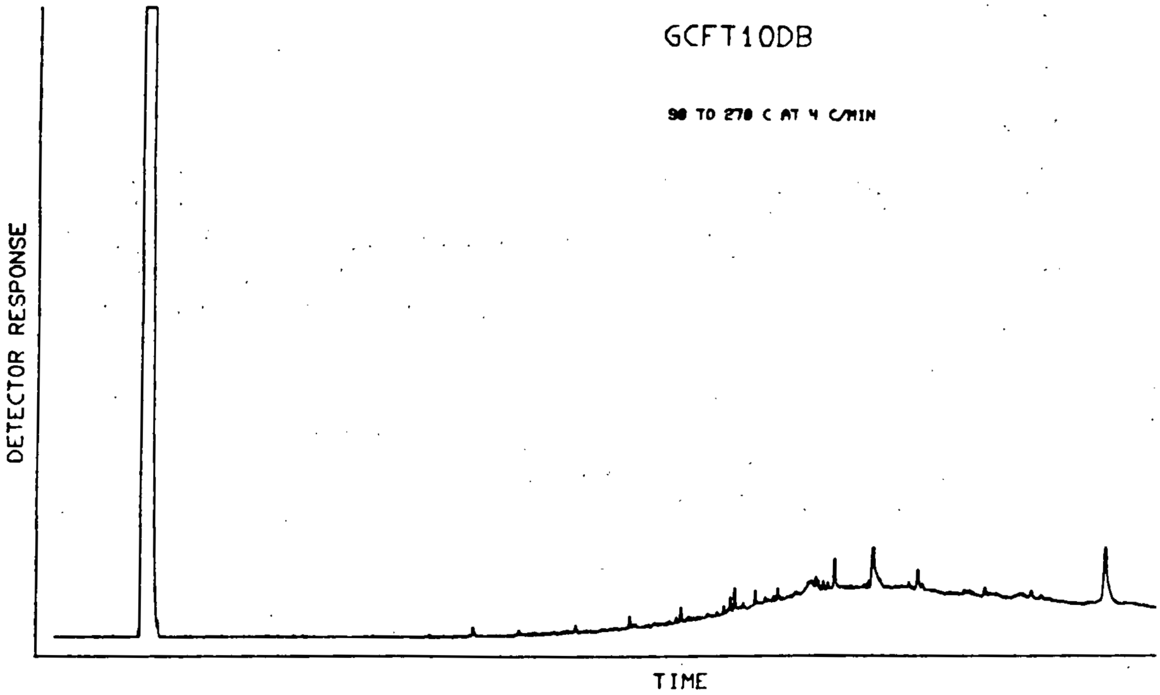


Figure 7.5.11 GC of the Oil/Dispersant Tank, bottom, 1 hr.

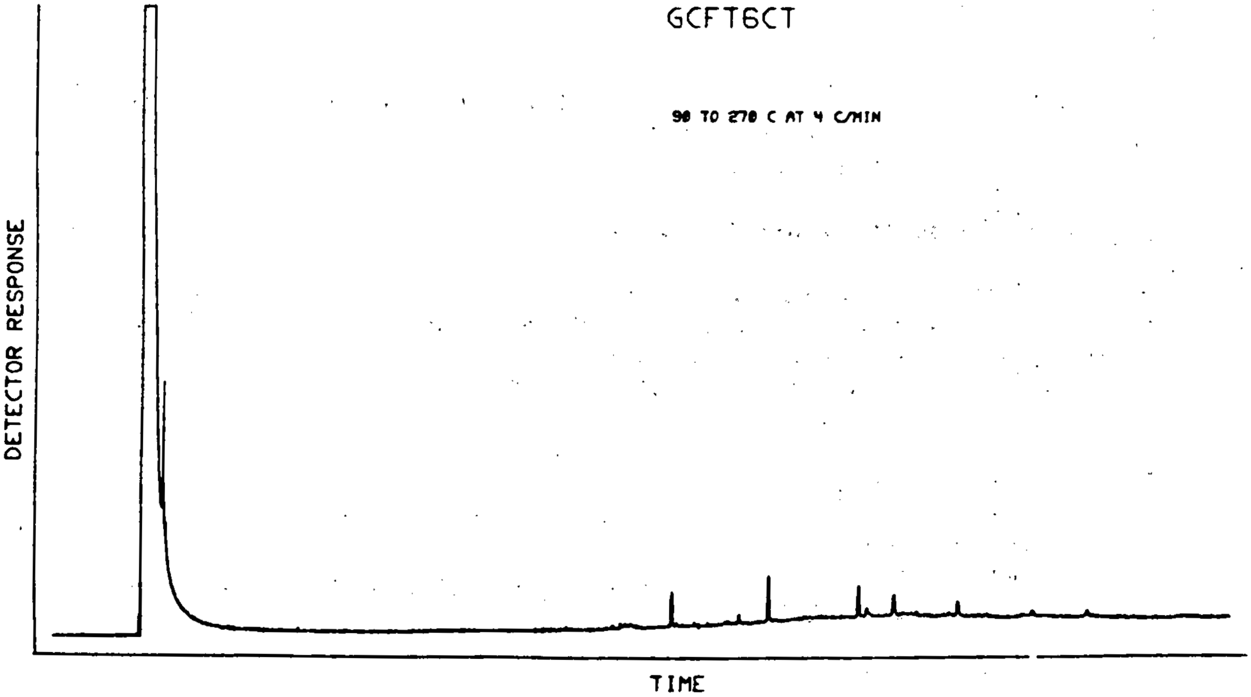


Figure 7.5.12 GC of the Control Tank, top, 6th week.

(b) Week Six

At the beginning of the sixth week, ten ml of dispersant were added to tanks 2, 3 and 4. Water samples were collected for qualitative analysis one hour after the addition of the dispersant.

i. Control Tank

GC of the top, middle and bottom water samples are shown in Figures 7.5.12, 13 and 14. All GC are similar and consist of a series of equally spaced peaks that appear to correspond to the even-numbered normal paraffins. GC of petroleum should consist of a distribution of normal paraffins, whereas biologically produced paraffins are generally odd-numbered.

ii. Dispersant Tank

GC of the top, middle and bottom of the dispersant tank are shown in Figures 7.5.15, 16 and 17. It should be noted that peaks at short retention times are observed after this addition in the top and middle GC, whereas they were not observed after the initial application. The GC of the bottom sample is very similar to that of the controls.

iii. Oil Tank

GC of the top, middle and bottom of the oil tank after dispersant was added, are shown in Figures 7.5.18, 19 and 20. The top and middle are similar, consisting of a number of peaks due to the dispersant. None of the peaks can be definitely assigned to the oil. With the exception of one strong peak, the GC of the bottom is similar to those of the controls.

iv. Oil/Dispersant Tank

GC of the top, middle and bottom samples are shown in Figures 7.5.21, 22 and 23. All three GCs correspond closely to those of the dispersant and oil tanks at the same levels.

(B) Fractionation of Water Extracts

Extracts of the top samples from tanks 1, 3 and 4 collected at the first hour were separated by a liquid column into 7 to 8 fractions. The GC of fractions from the control tank are shown in Figures 7.5.24 to 30. The heavier normal paraffins are observed in fractions 1, 2 and 3; whereas light components (shorter retention times) are observed in 4 thru 7. GC of the fractions from the top of the oil tank are shown in Figures 7.5.31 to 38. In this sequence, paraffins should appear in the first fraction, followed by one ring aromatics, two ring aromatics, multi-ring aromatics, and polar compounds. Fraction 3 (Figure 7.5.33) presents the most interesting GC; the peaks are possibly due to substituted two or three ring aromatics.

Due to the higher concentrations in the oil/dispersant tank, fractionation of this sample produced the strongest GC's as are shown in Figures 7.5.39-46. In the GC of the first fraction, paraffins, both normal and isoprenoids, are clearly separated into individual peaks.

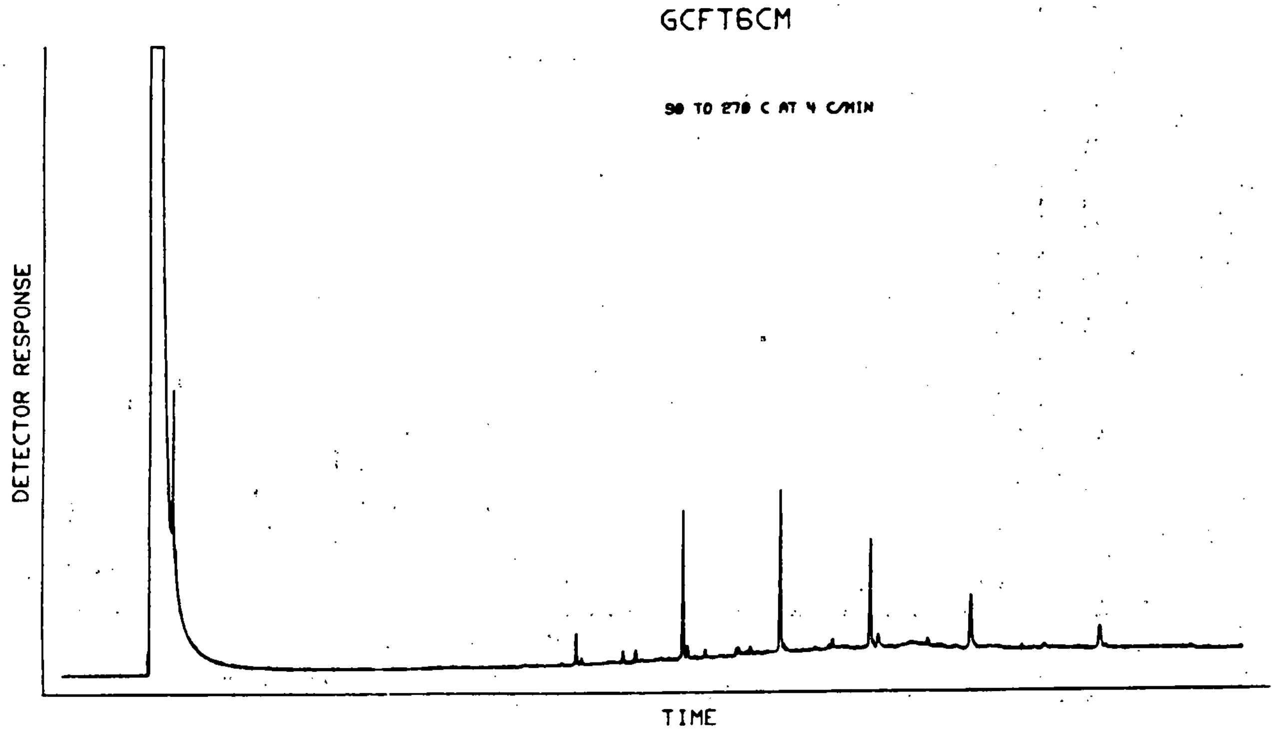


Figure 7.5.13 GC of the Control Tank, middle, 6th week.

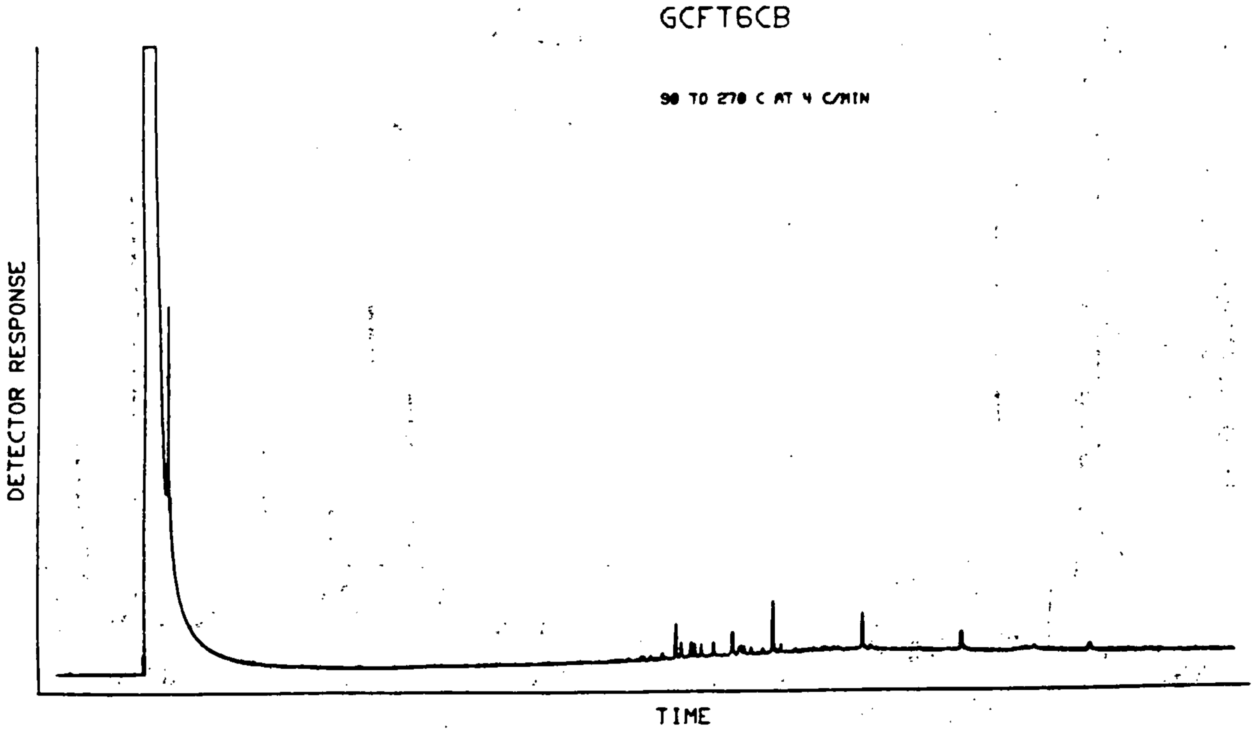


Figure 7.5.14 GC of the Control Tank, bottom, 6th week.

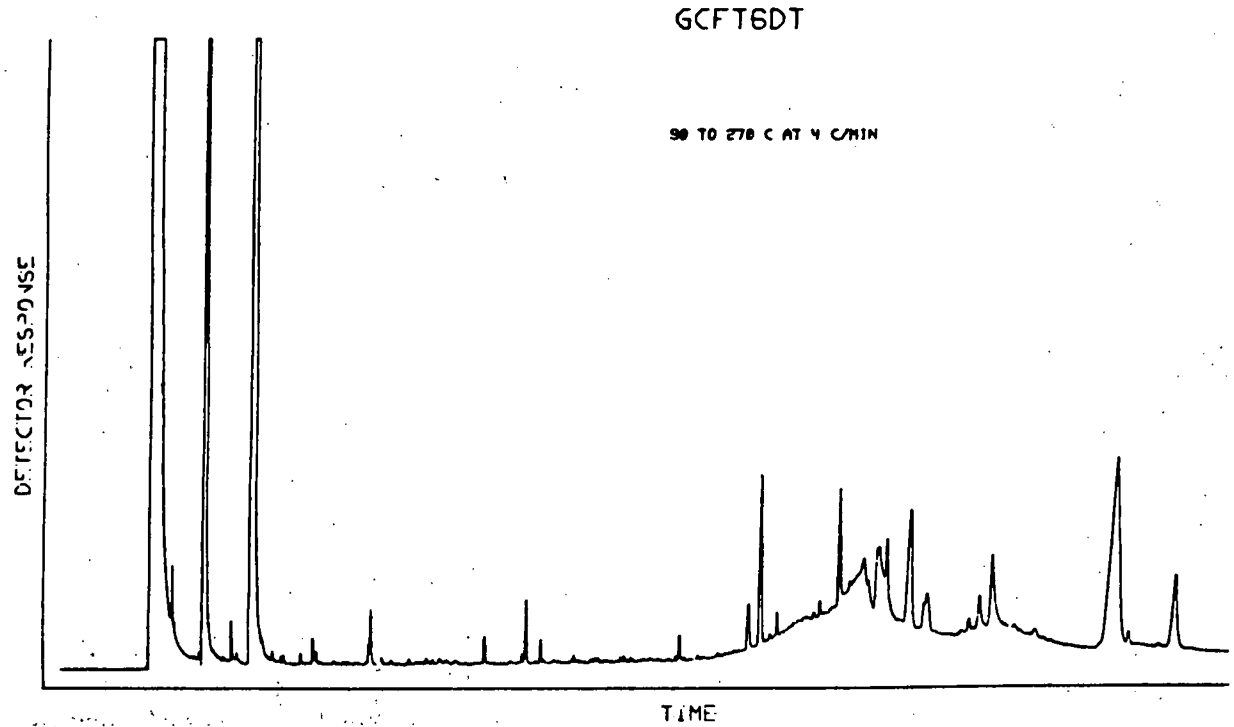


Figure 7.5.15 GC of the Dispersant Tank, top, 6th week.

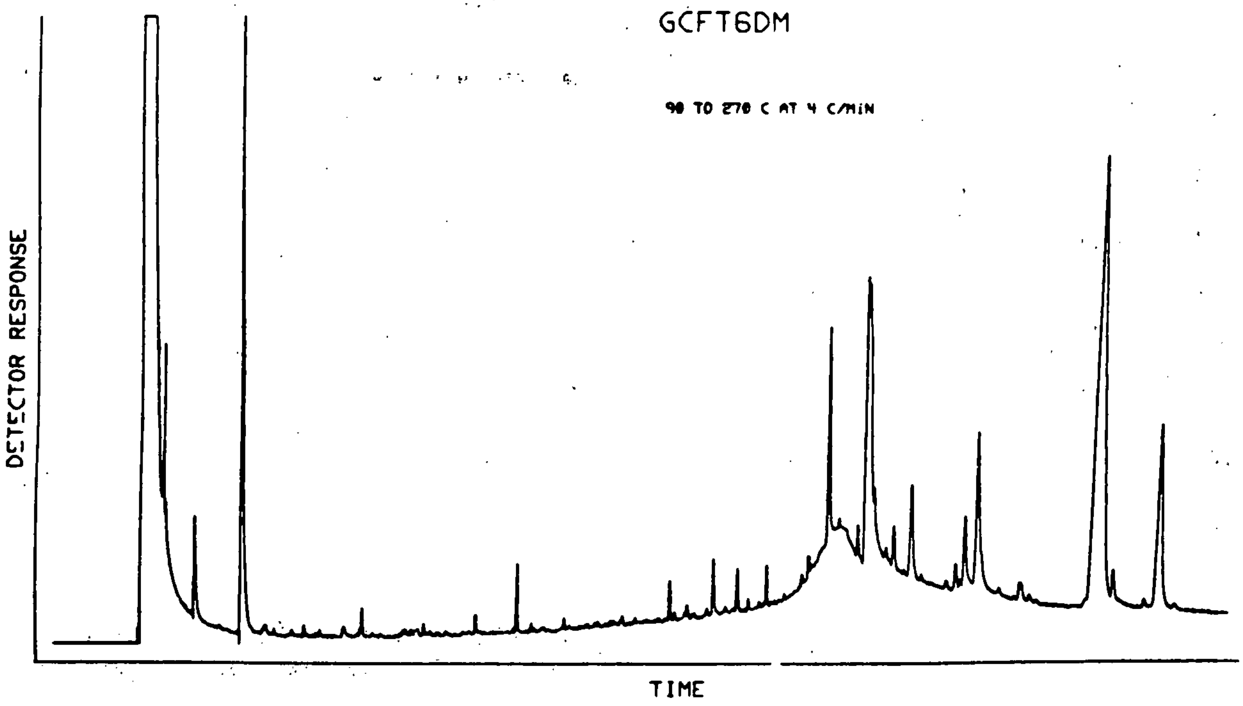


Figure 7.5.16 GC of the Dispersant Tank, middle, 6th week.

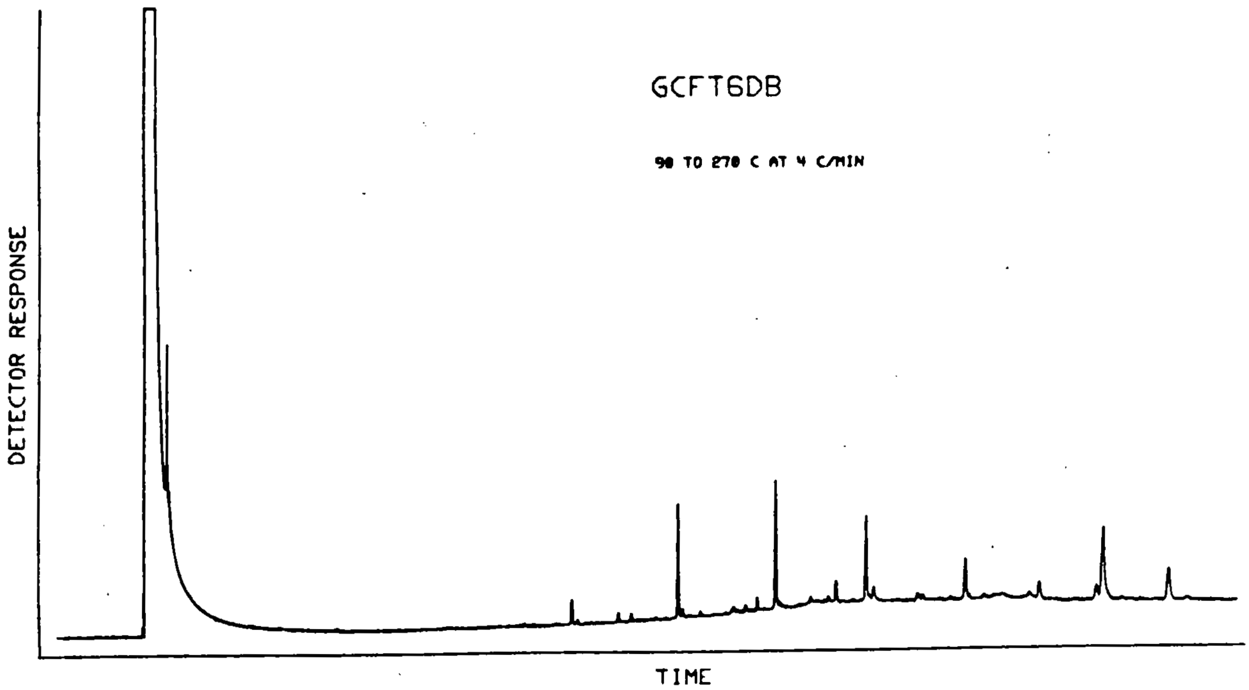


Figure 7.5.17 GC of the Dispersant Tank, bottom, 6th week.

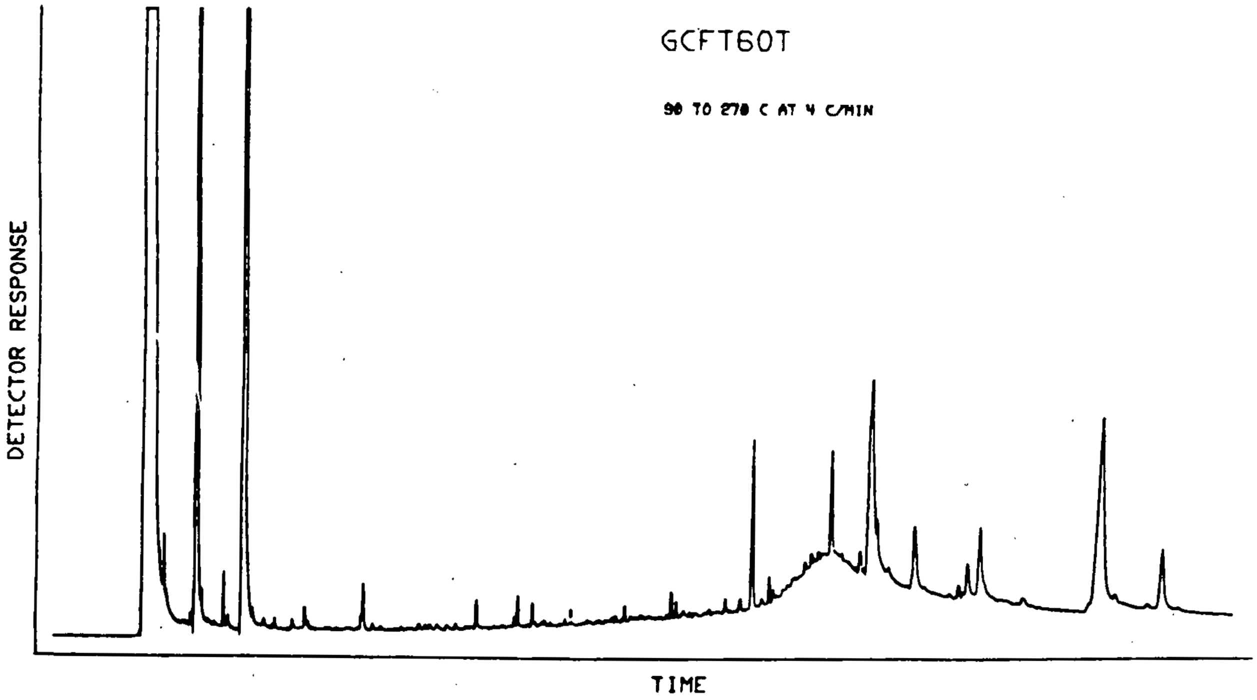


Figure 7.5.18 GC of the Oil Tank, top, 6th week.

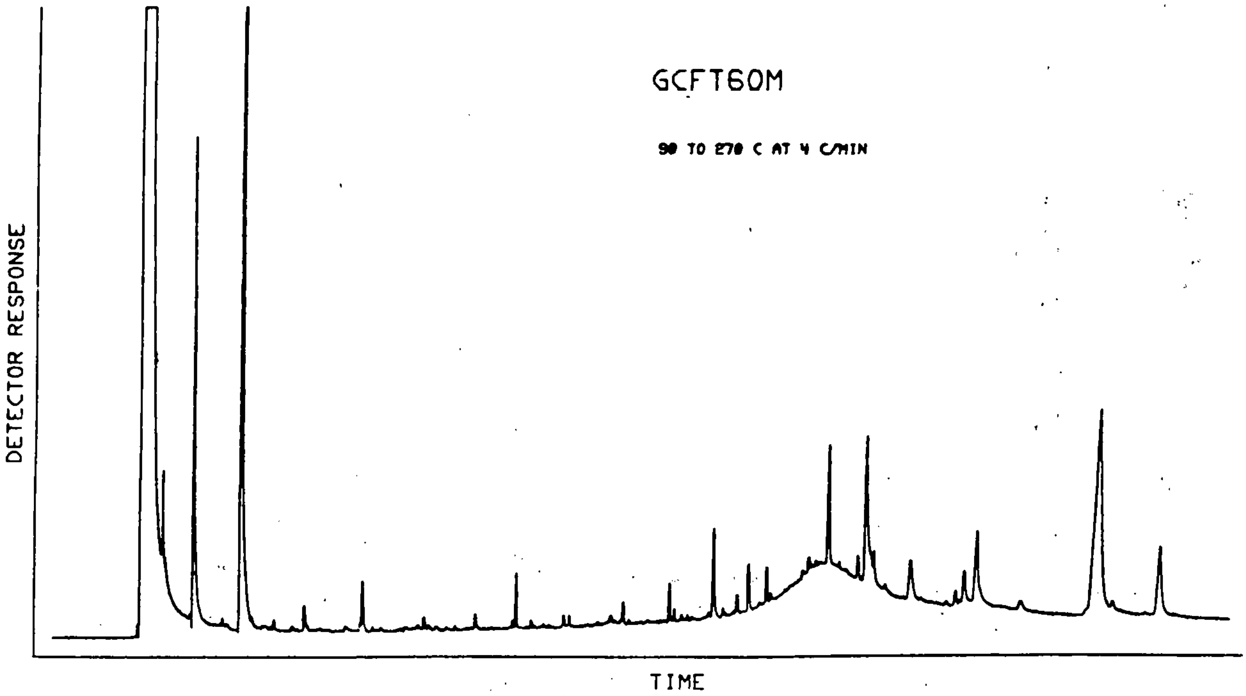


Figure 7.5.19 GC of the Oil Tank, middle, 6th week.

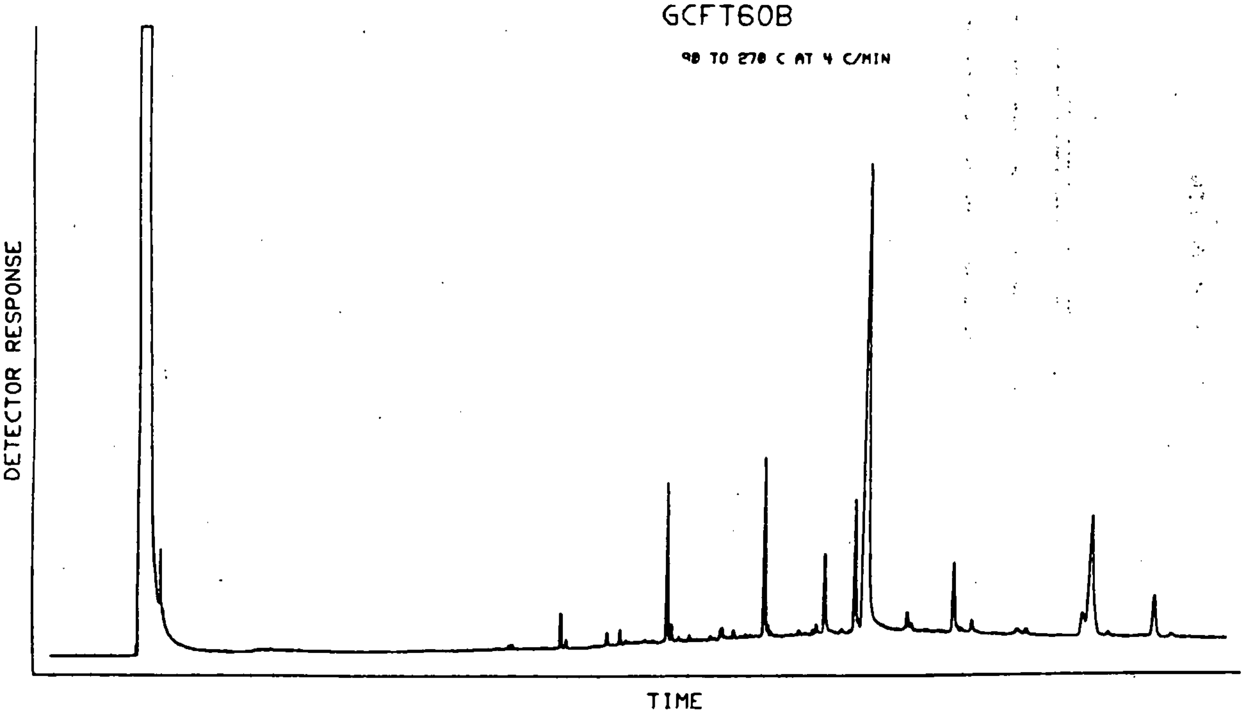


Figure 7.5.20 GC of the Oil Tank, bottom, 6th week.

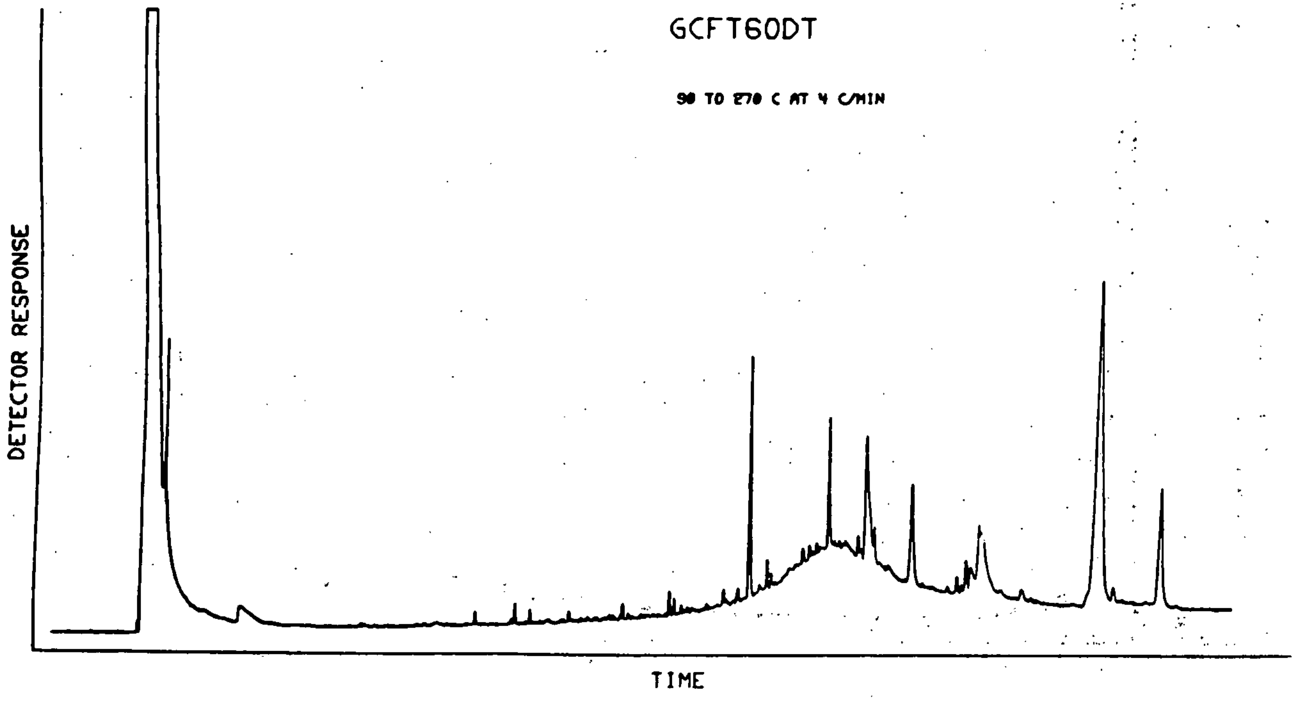


Figure 7.5.21 GC of the Oil/Dispersant Tank, top, 6th week.

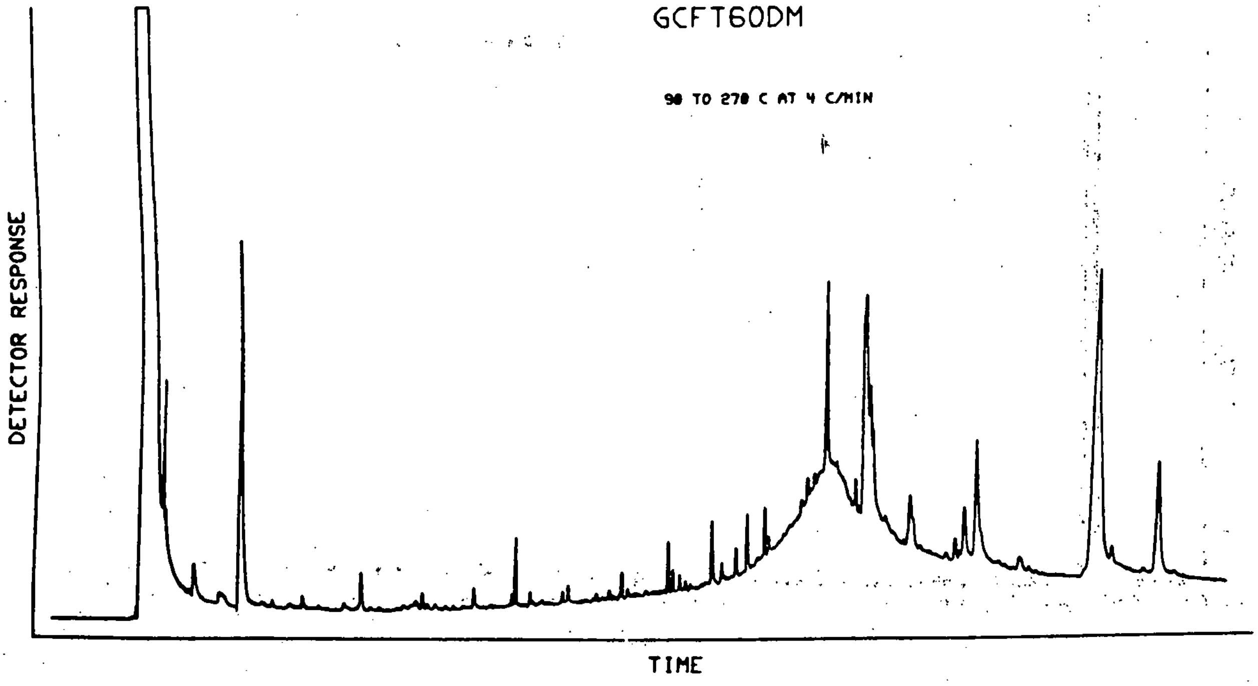


Figure 7.5.22 GC of the Oil/Dispersant Tank, middle, 6th week.

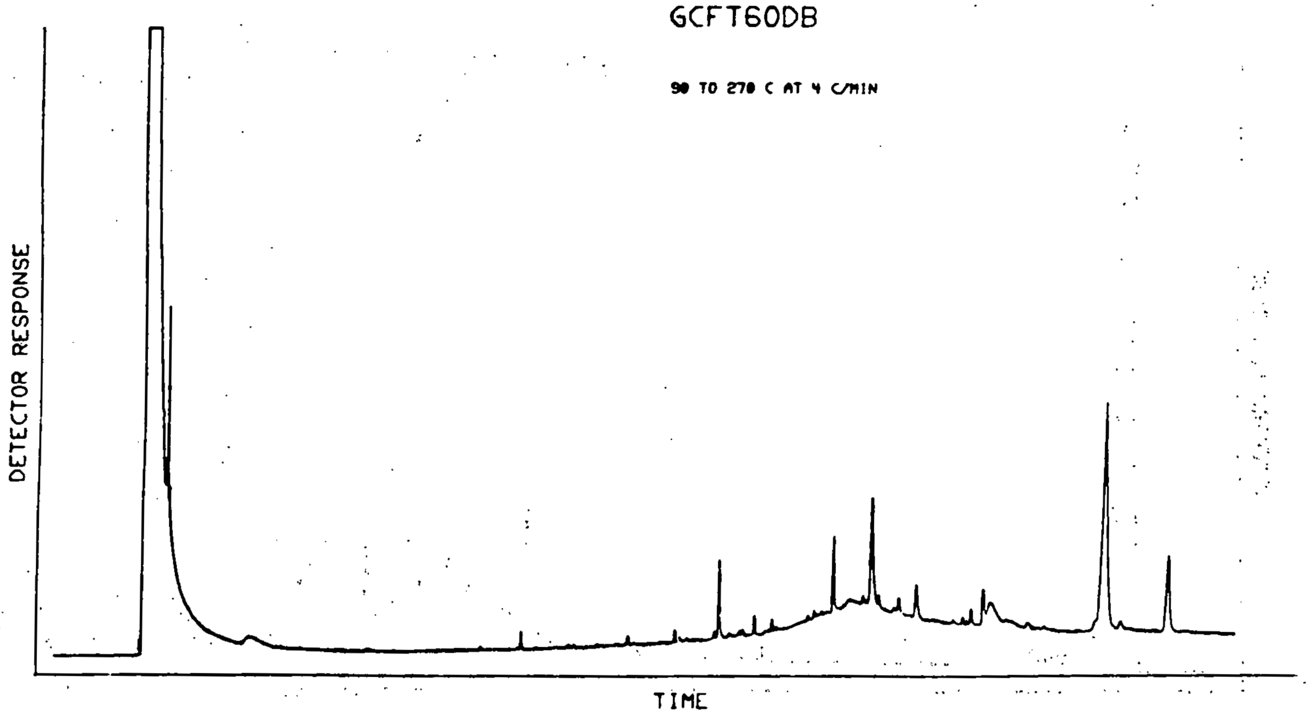


Figure 7.5.23 GC of the Oil/Dispersant Tank, bottom, 6th week.

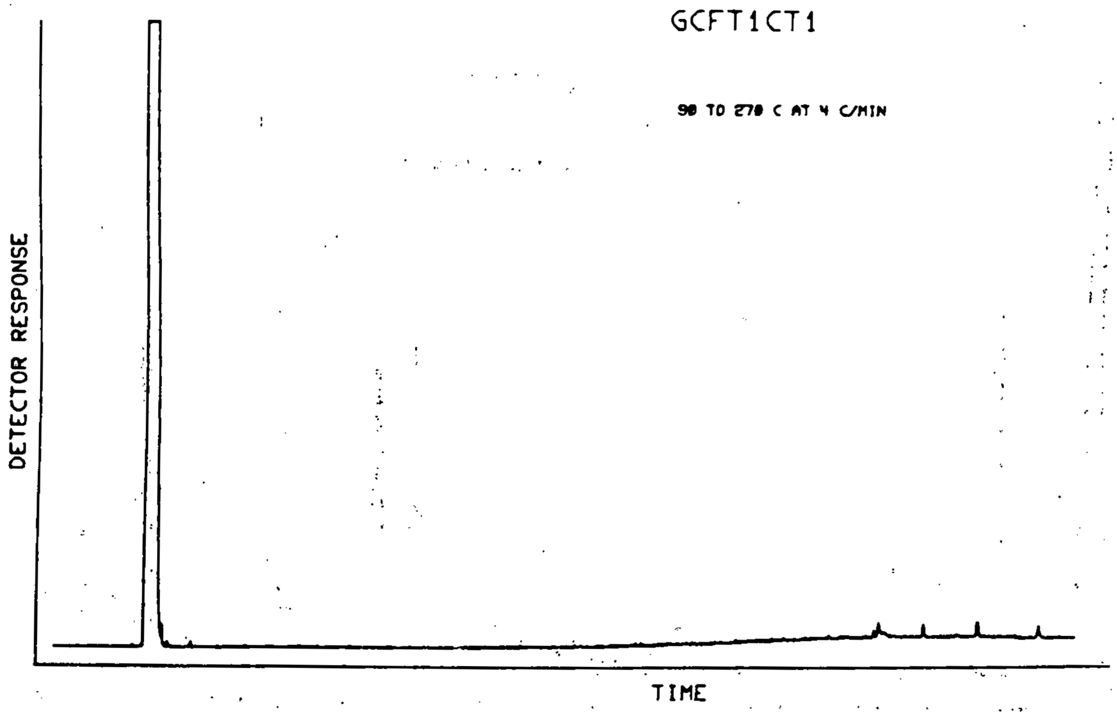


Figure 7.5.24 GC of the Control Tank, top, 1 hr, fraction 1.

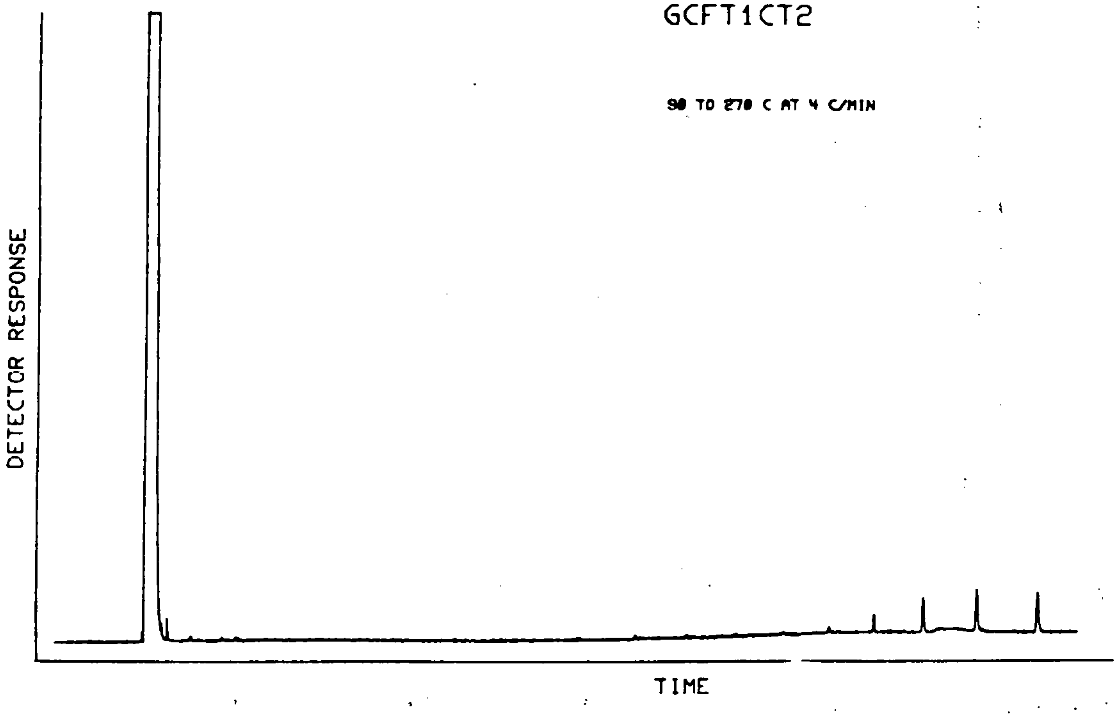


Figure 7.5.25 GC of the Control Tank, top, 1 hr, fraction 2.

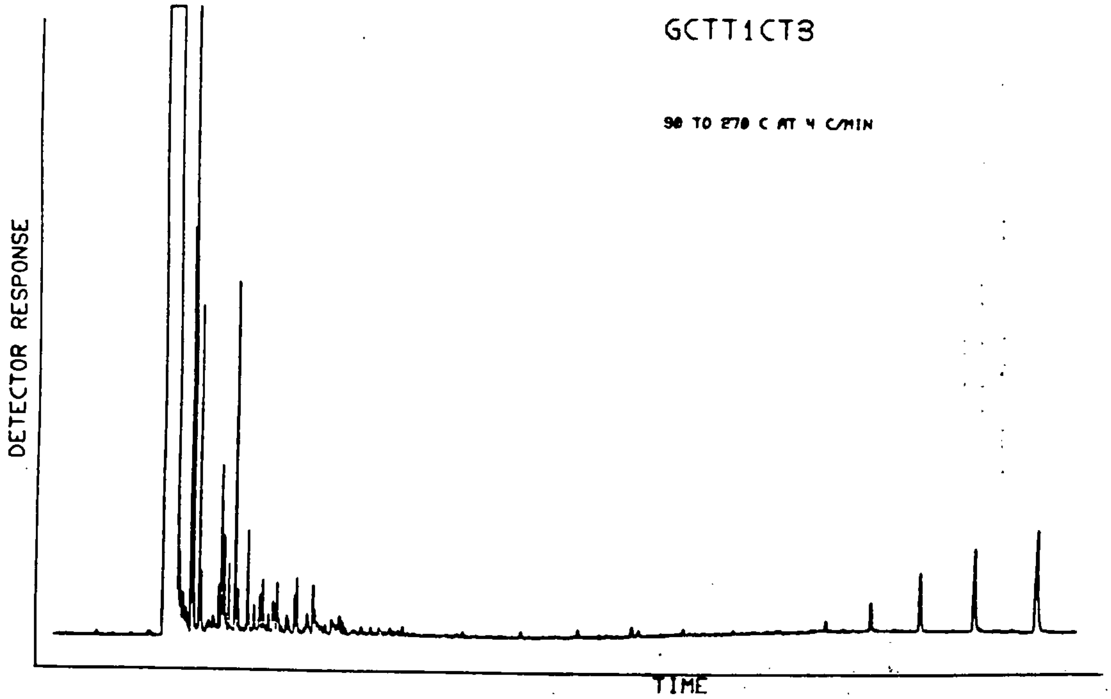


Figure 7.5.26 GC of the Control Tank, top, 1 hr, fraction 3.

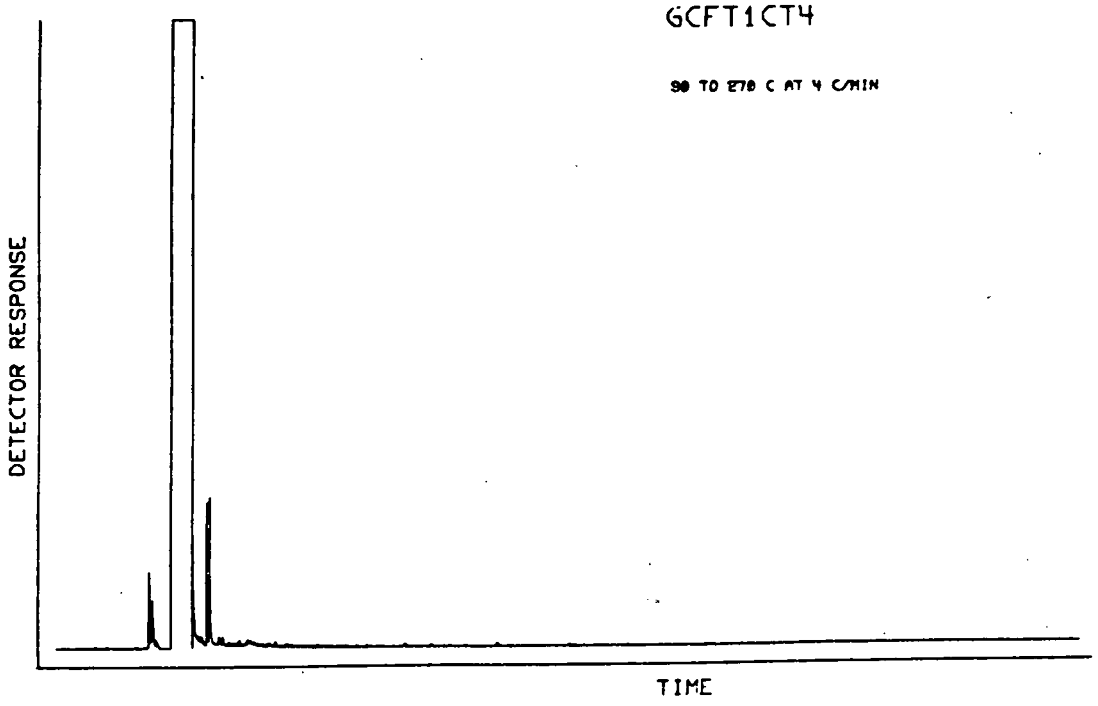


Figure 7.5.27 GC of the Control Tank, top, 1 hr, fraction 4.

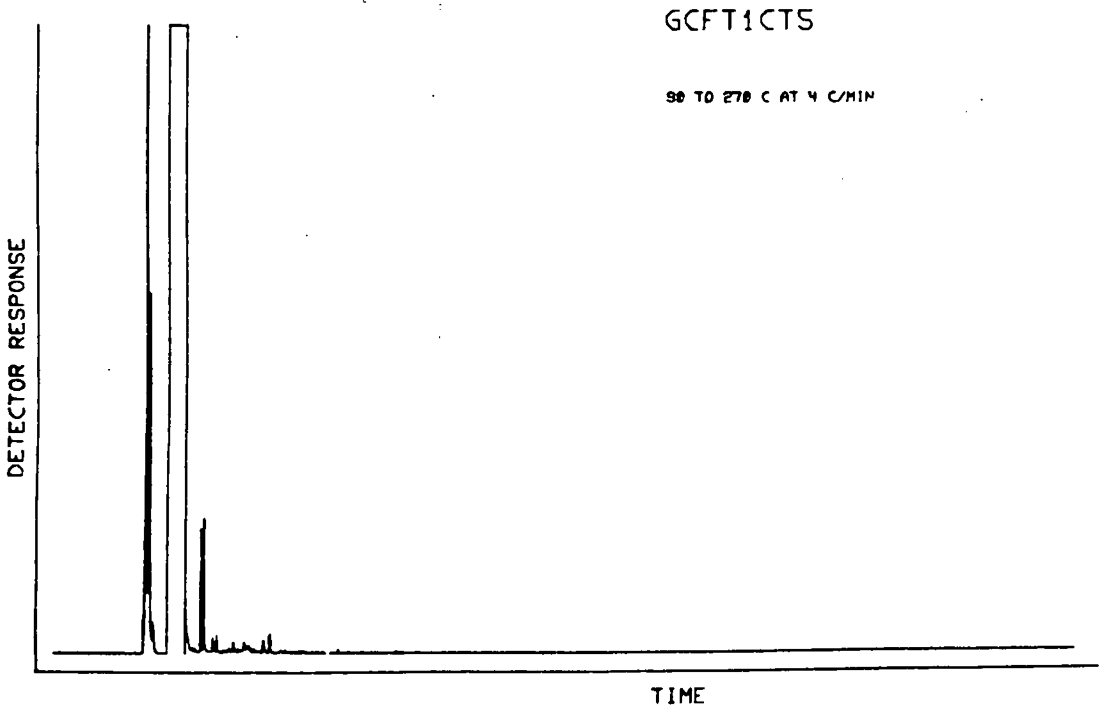


Figure 7.5.28 GC of the Control Tank, top, 1 hr, fraction 5.

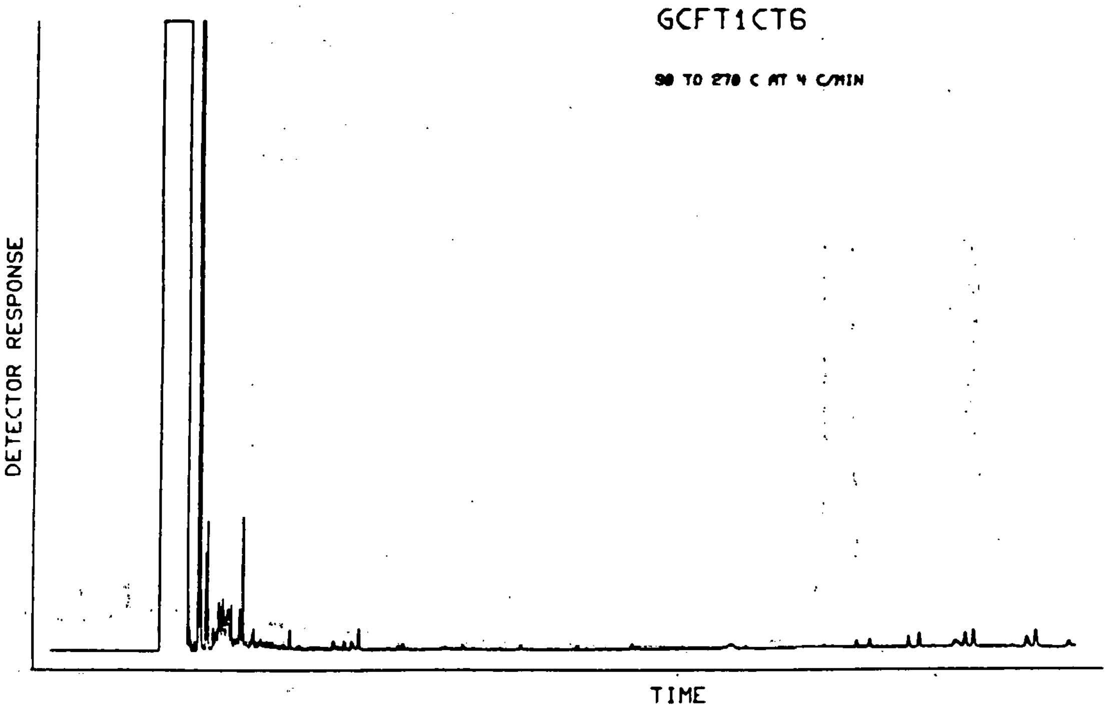


Figure 7.5.29 GC of the Control Tank, top, 1 hr, fraction 6.

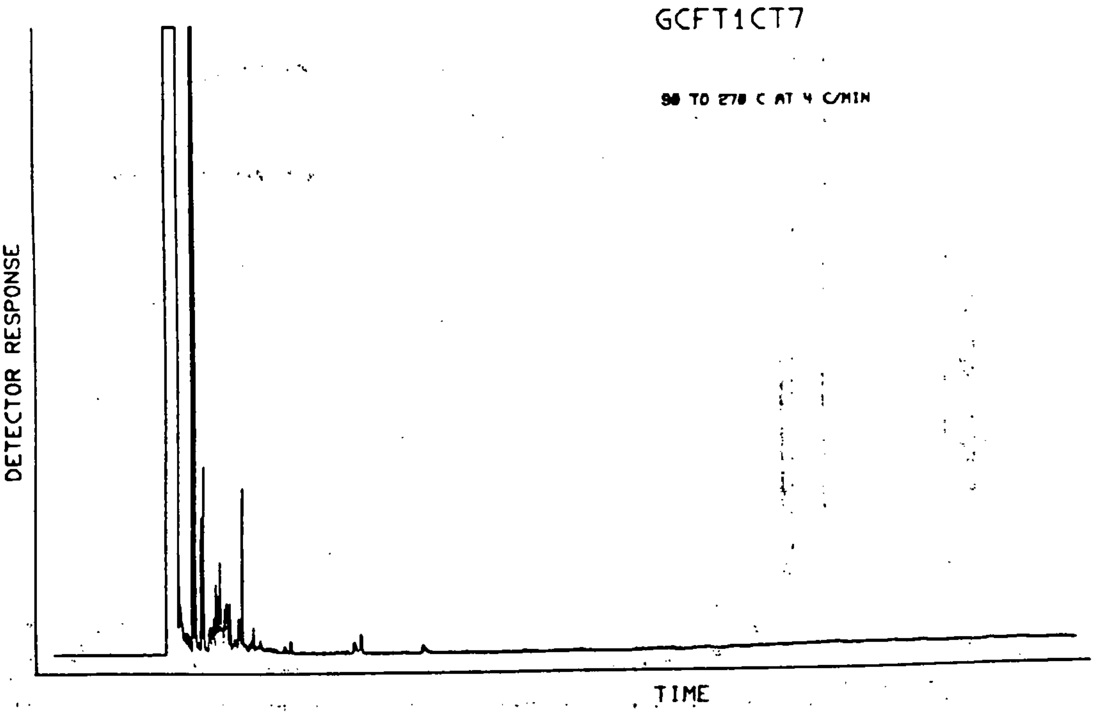


Figure 7.5.30 GC of the Control Tank, top, 1 hr, fraction 7.

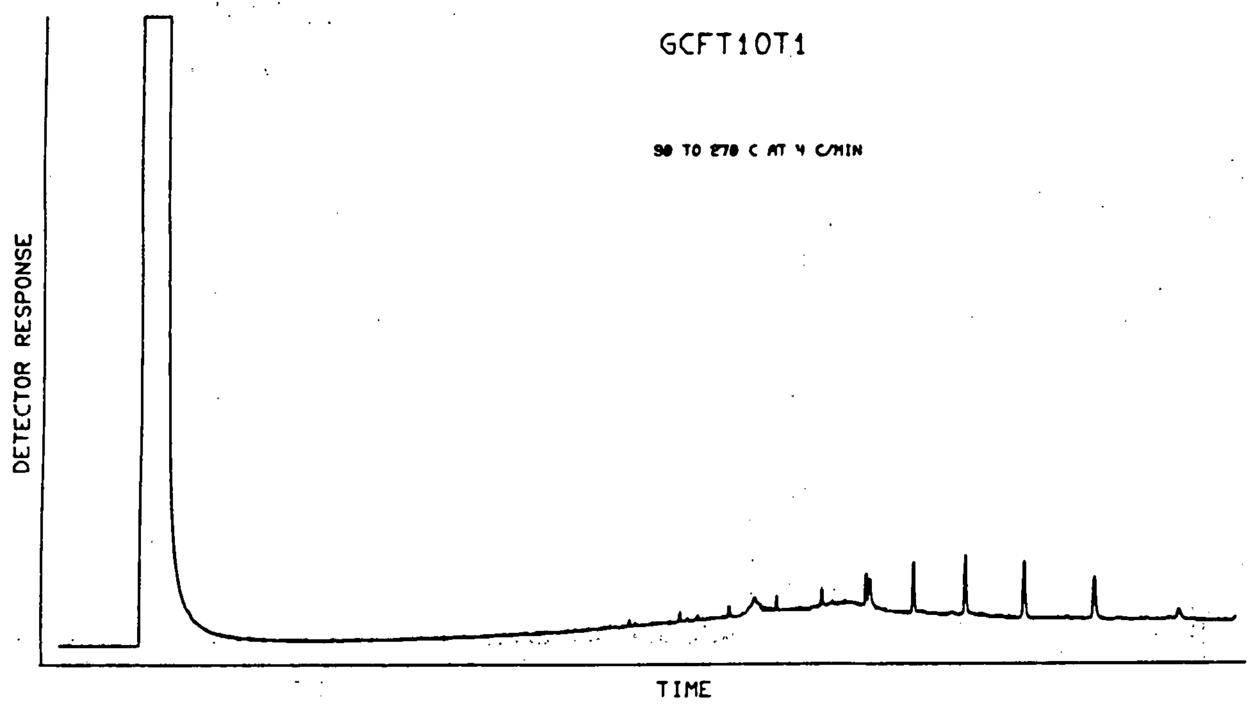


Figure 7.5.31 GC of the Oil Tank, top, 1 hr, fraction 1.

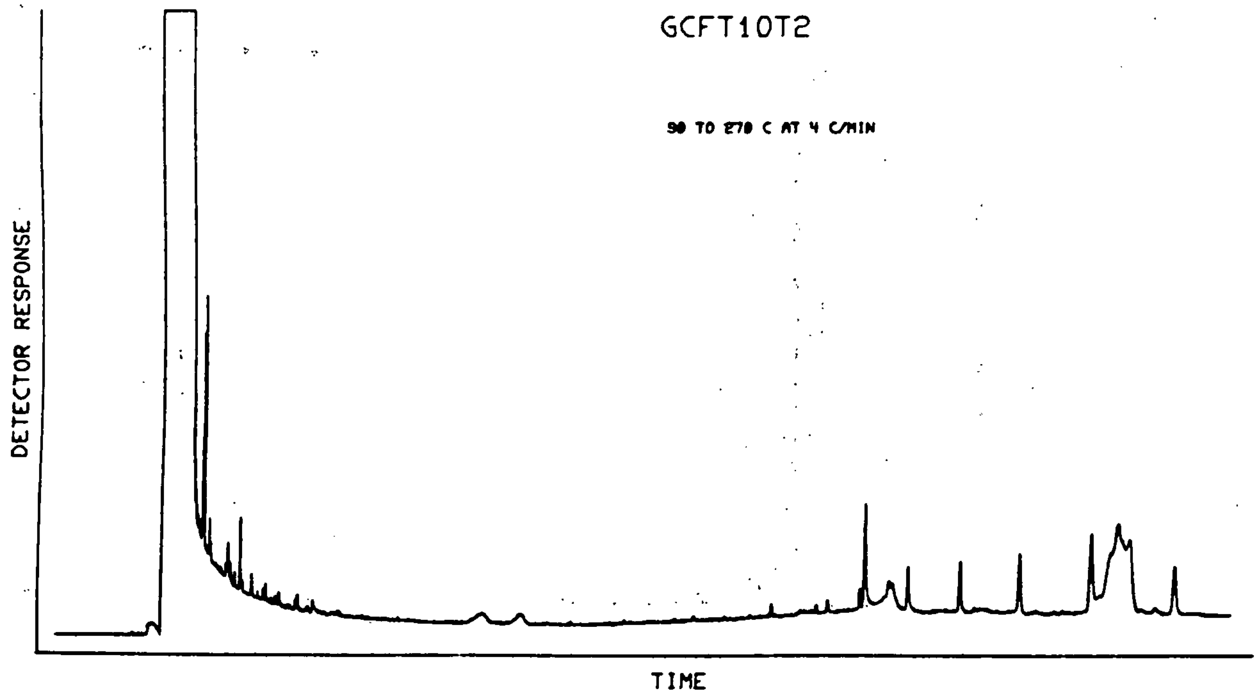


Figure 7.5.32 GC of the Oil Tank, top, 1 hr, fraction 2.

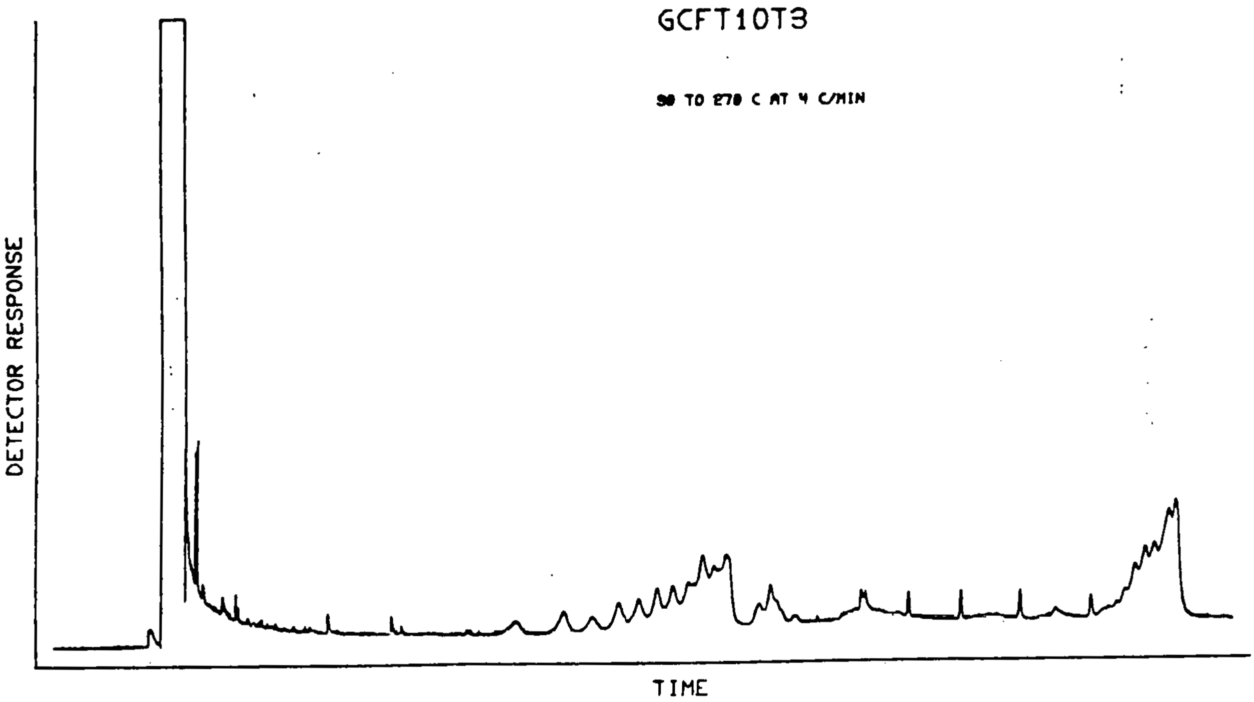


Figure 7.5.33 GC of the Oil Tank, top, 1 hr, fraction 3.

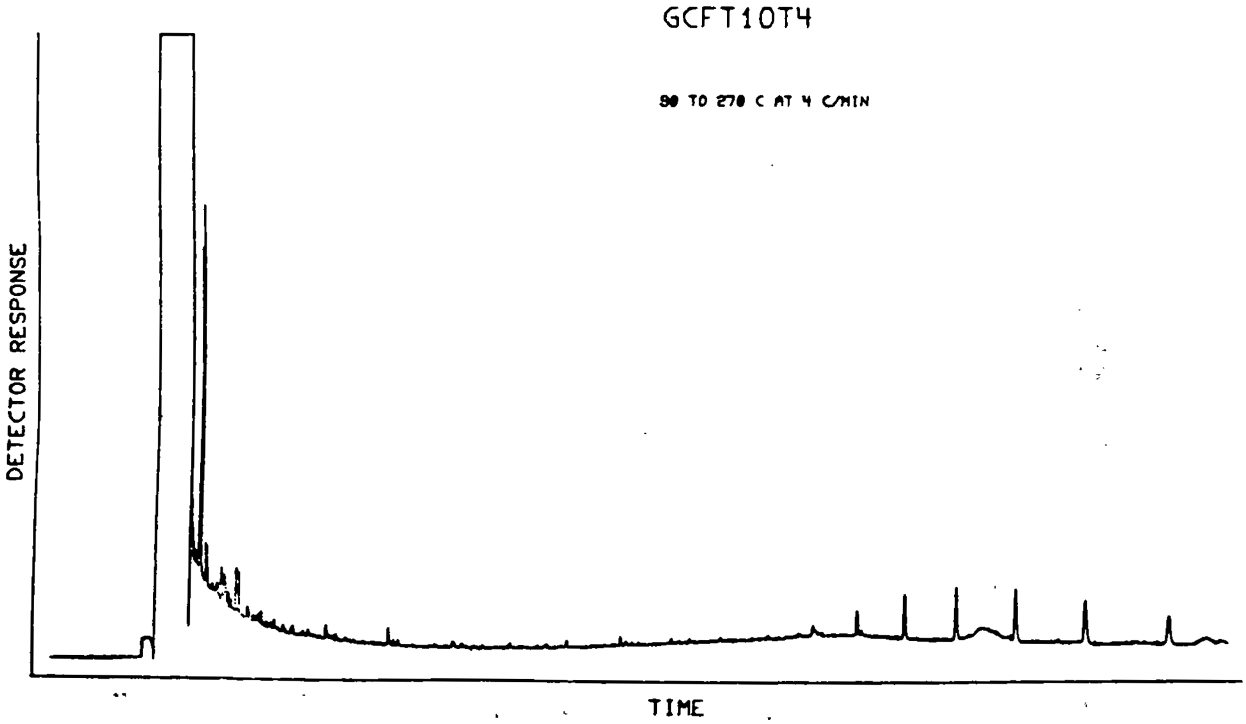


Figure 7.5.34 GC of the Oil Tank, top, 1 hr, fraction 4.

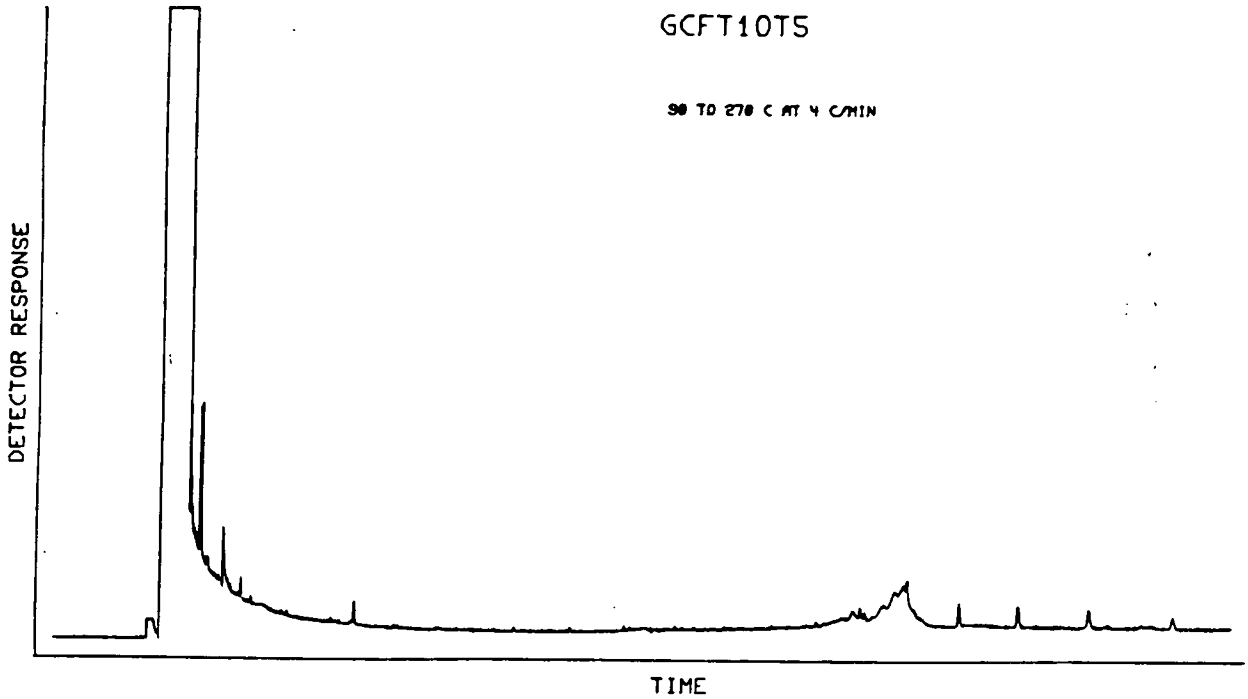


Figure 7.5.35 GC of the Oil Tank, top, 1 hr, fraction 5.

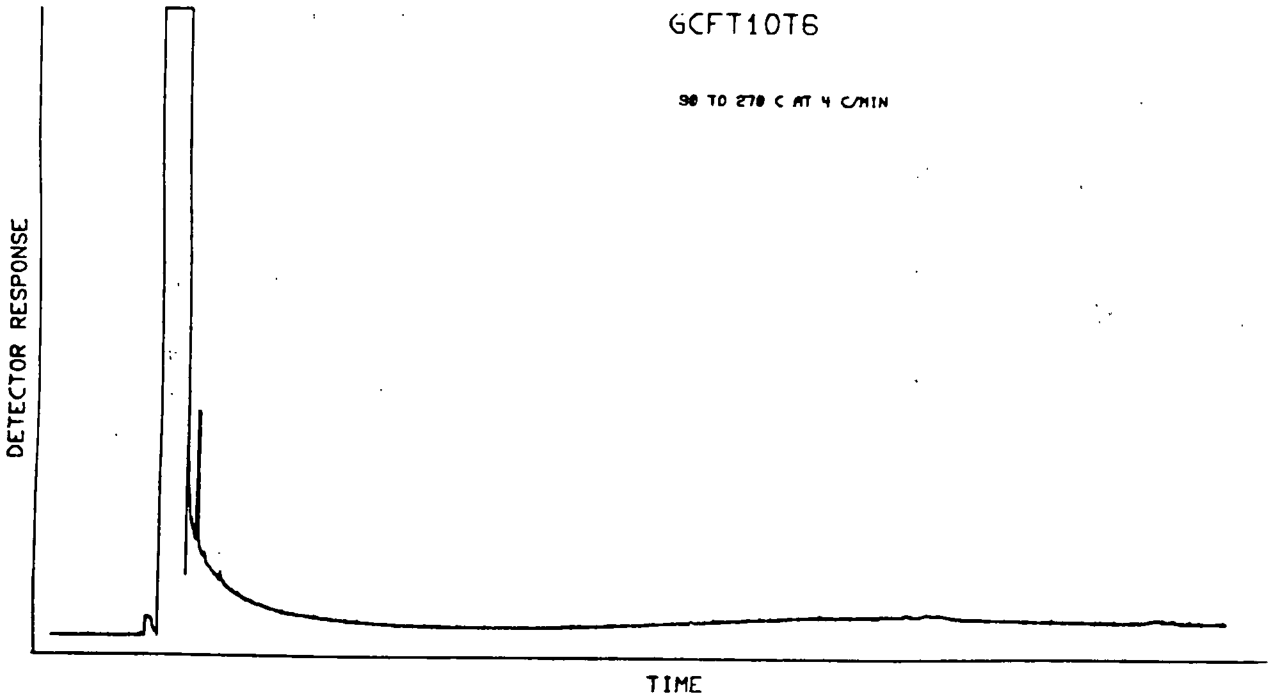


Figure 7.5.36 GC of the Oil Tank, top, 1 hr, fraction 6.

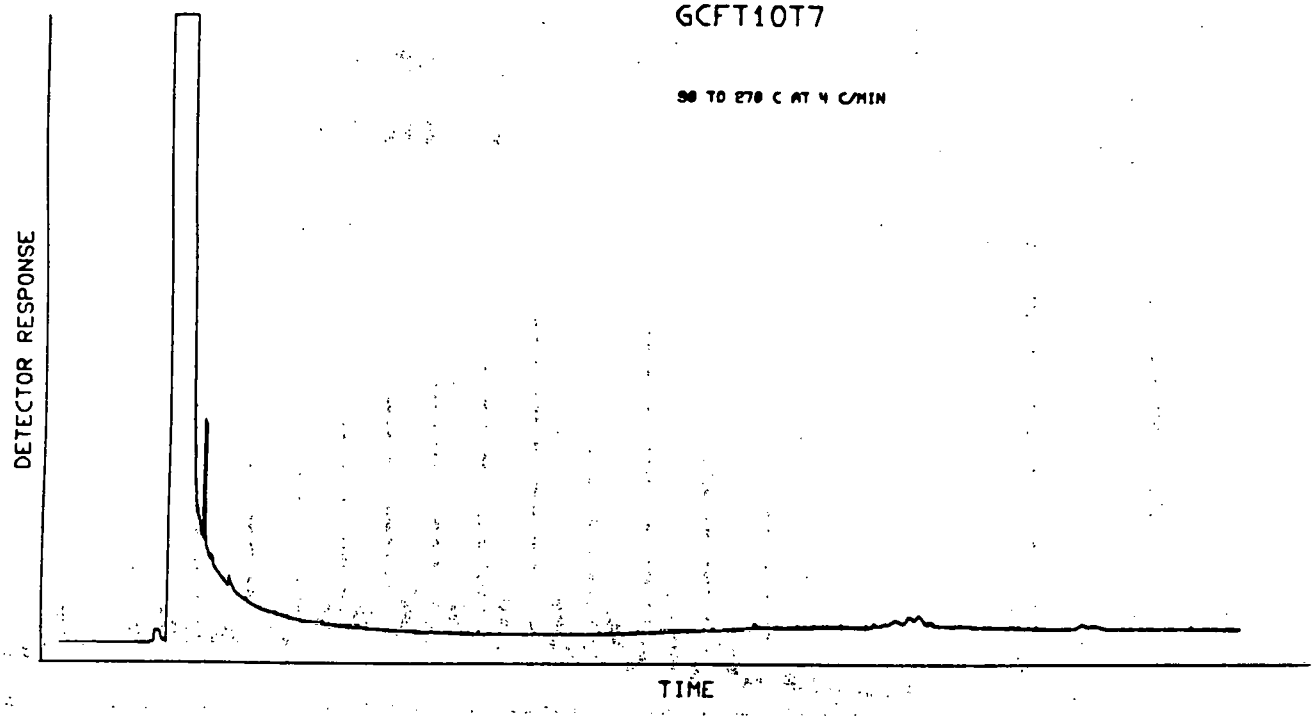


Figure 7.5.37 GC of the Oil Tank, top, 1 hr., fraction 7.

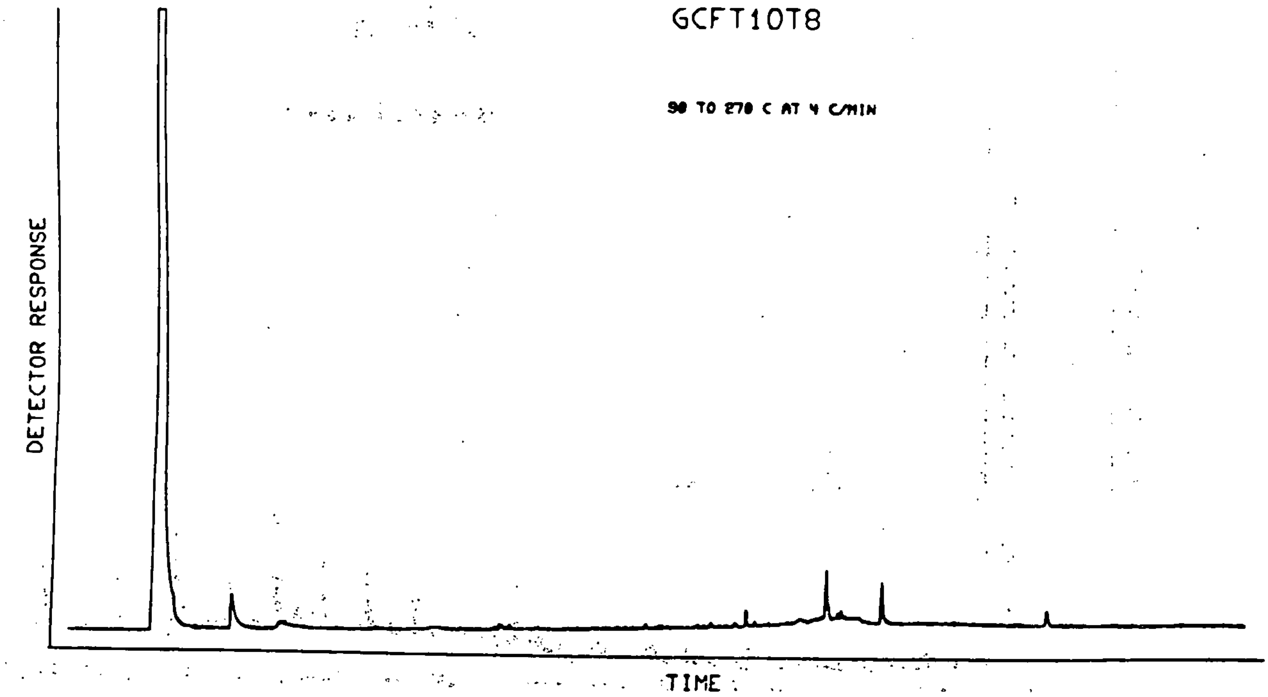


Figure 7.5.38 GC of the Oil Tank, top, 1 hr, fraction 8.

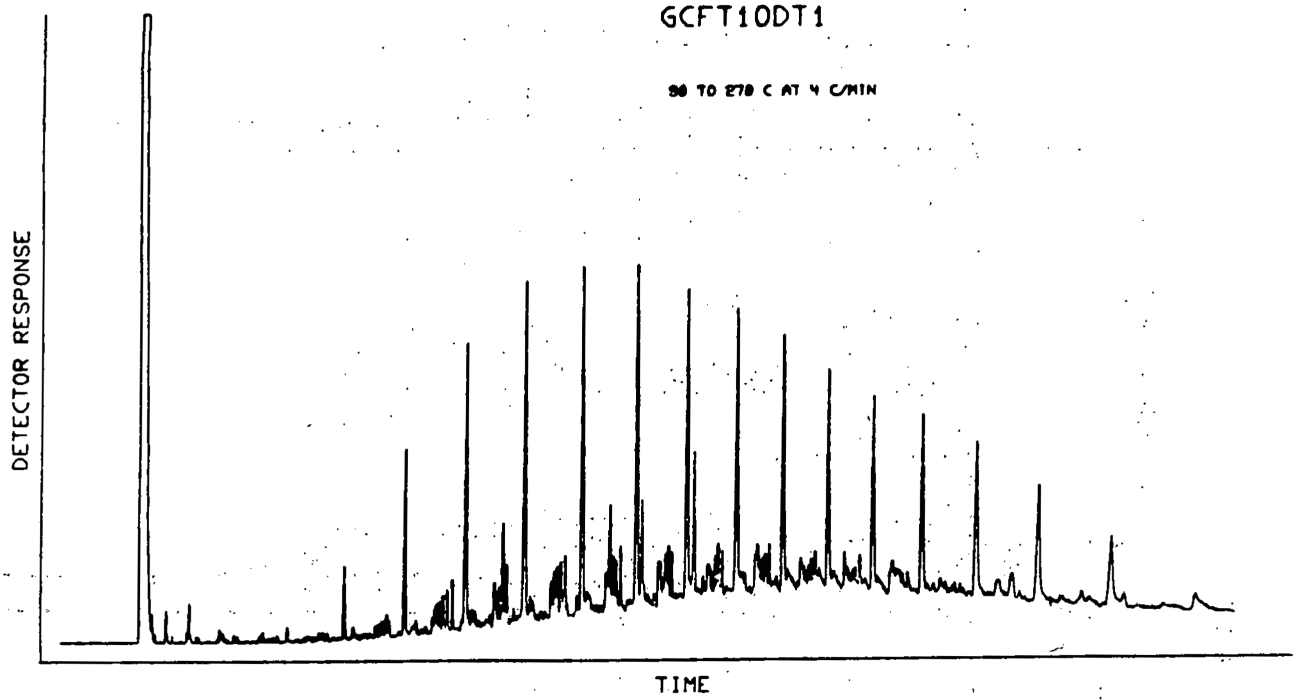


Figure 7.5.39 GC of the Oil/Dispersant Tank, 1 hr, fraction 1.

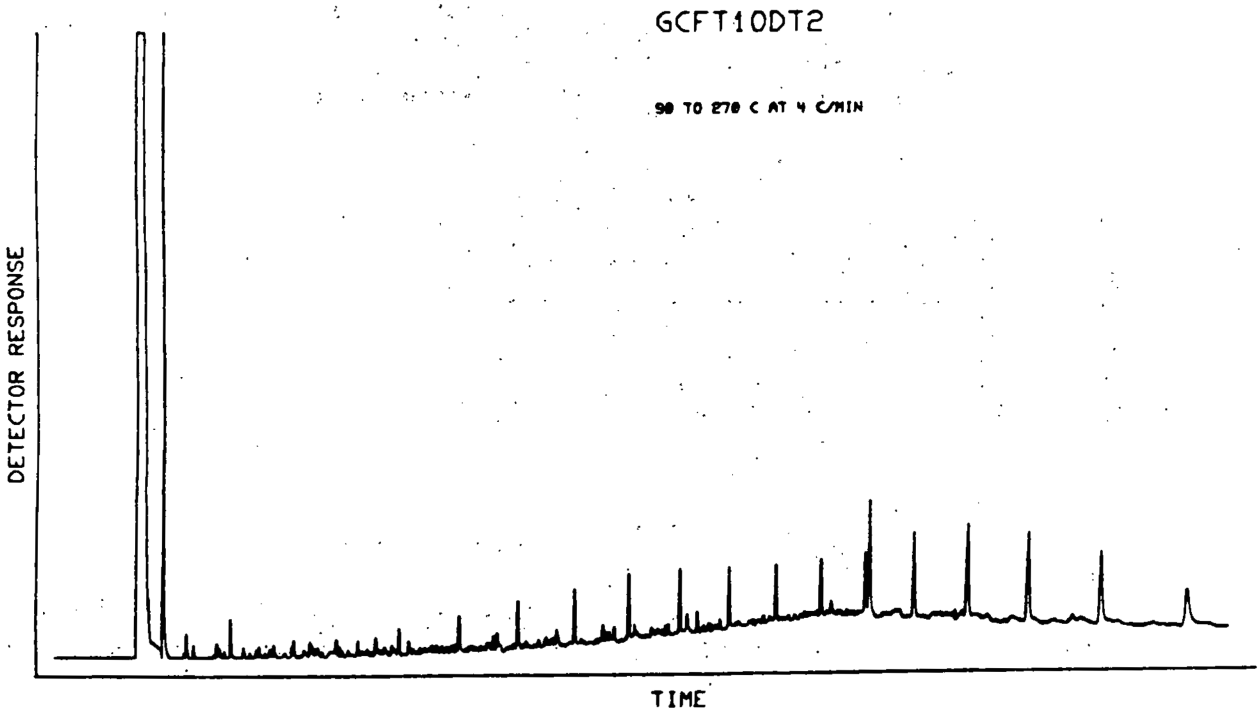


Figure 7.5.40 GC of the Oil/Dispersant Tank, 1 hr, fraction 2.

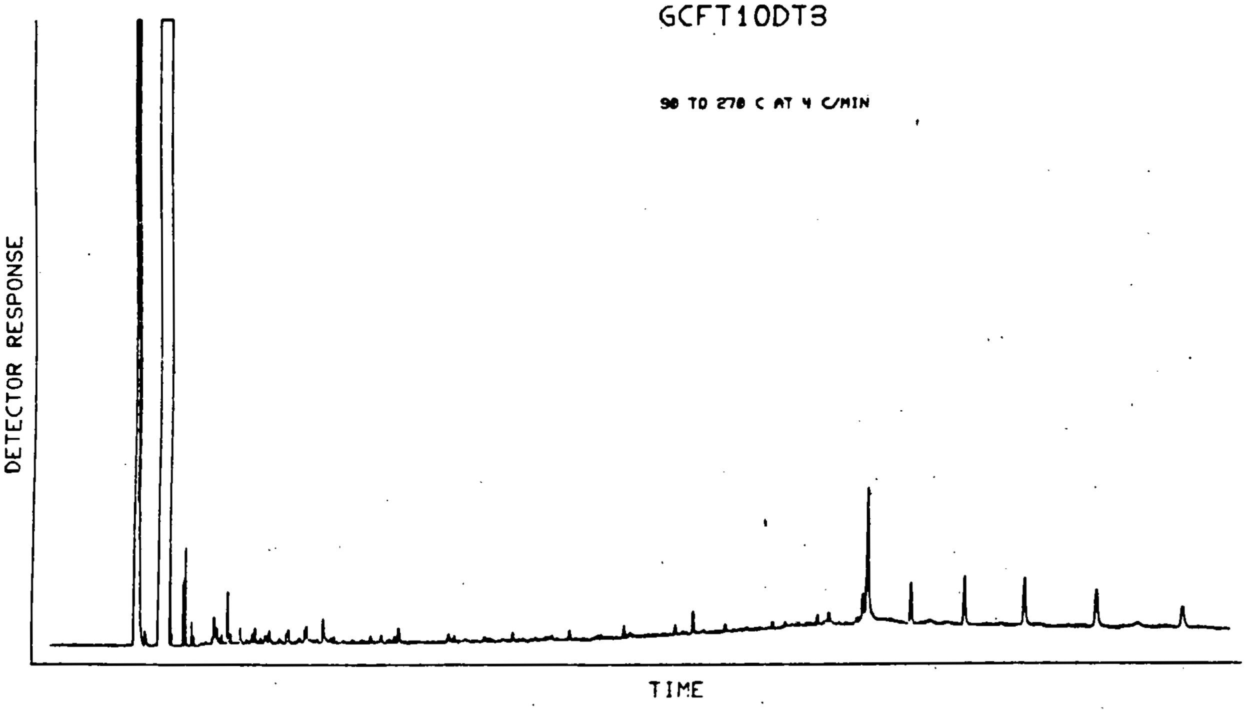


Figure 7.5.41 GC of the Oil/Dispersant Tank, 1 hr, fraction 3.

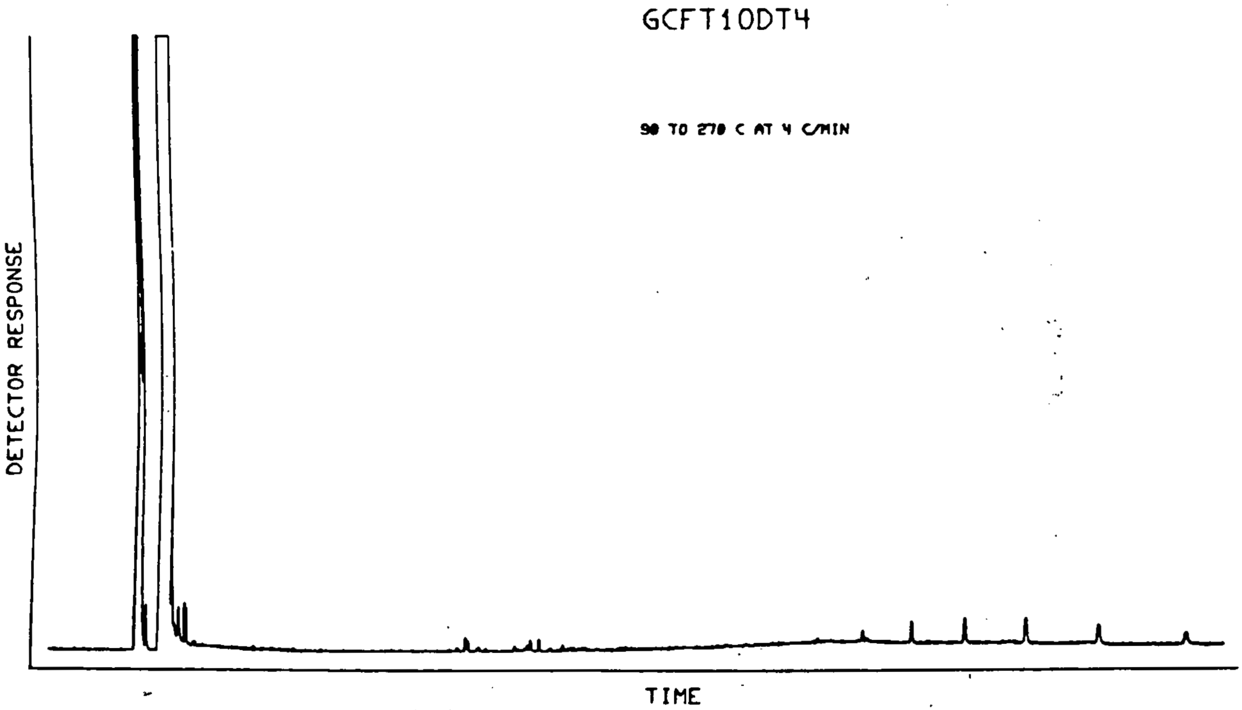


Figure 7.5.42 GC of the Oil/Dispersant Tank, 1 hr, fraction 4.

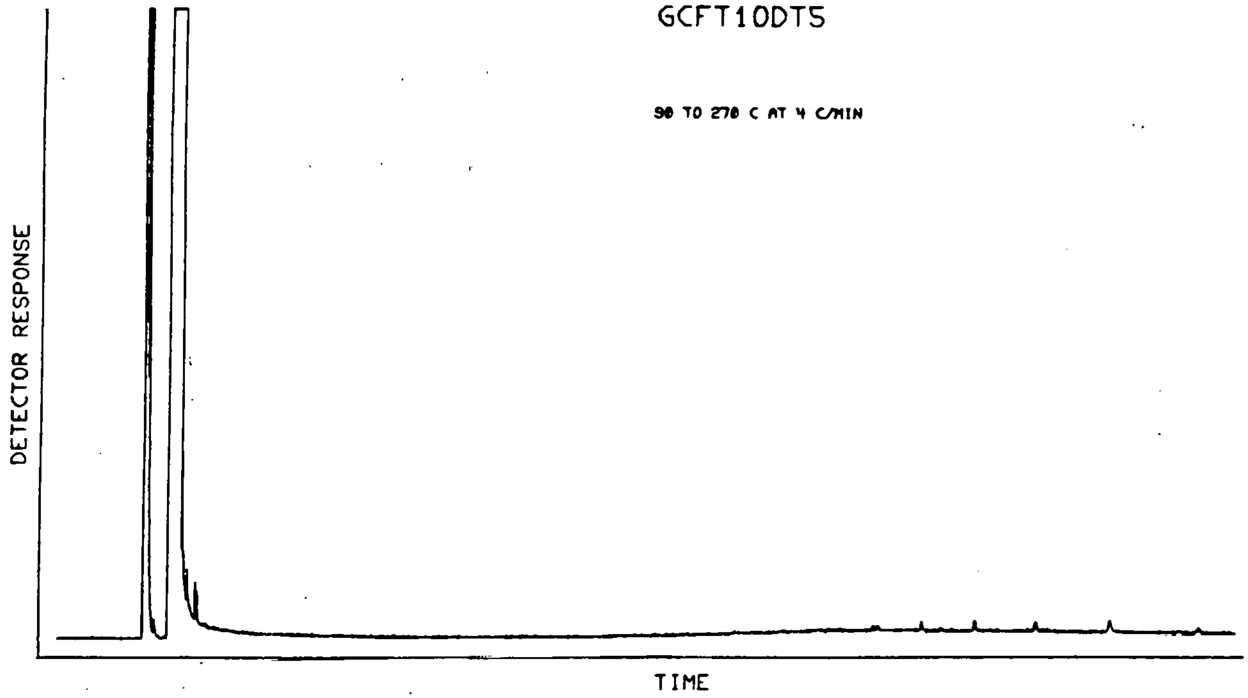


Figure 7.5.43 GC of the Oil/Dispersant Tank, 1 hr, fraction 5.

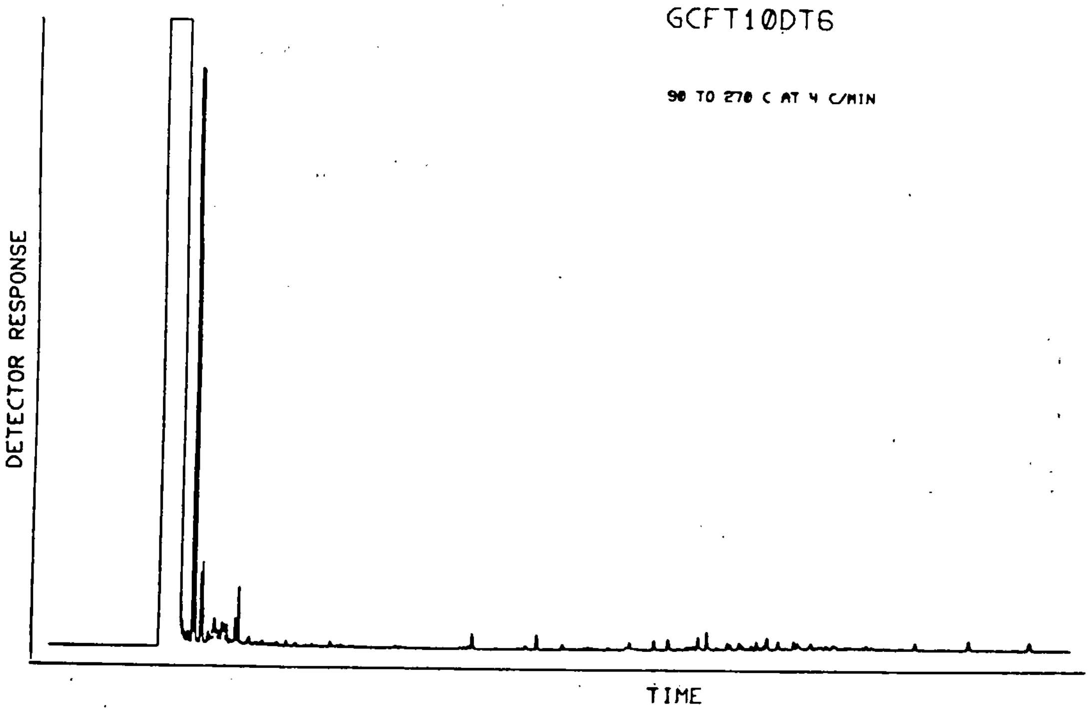


Figure 7.5.44 GC of the Oil/Dispersant Tank, 1 hr, fraction 6.

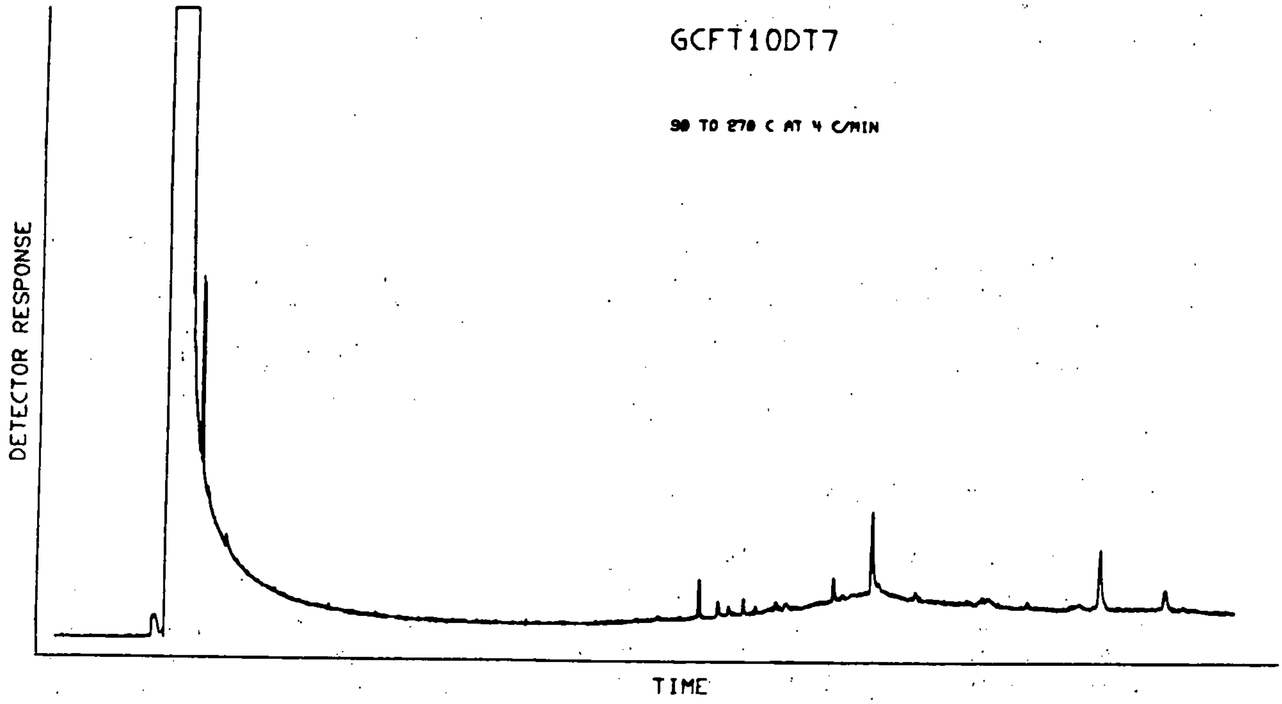


Figure 7.5.45 GC of the Oil/Dispersant Tank, 1 hr, fraction 7.

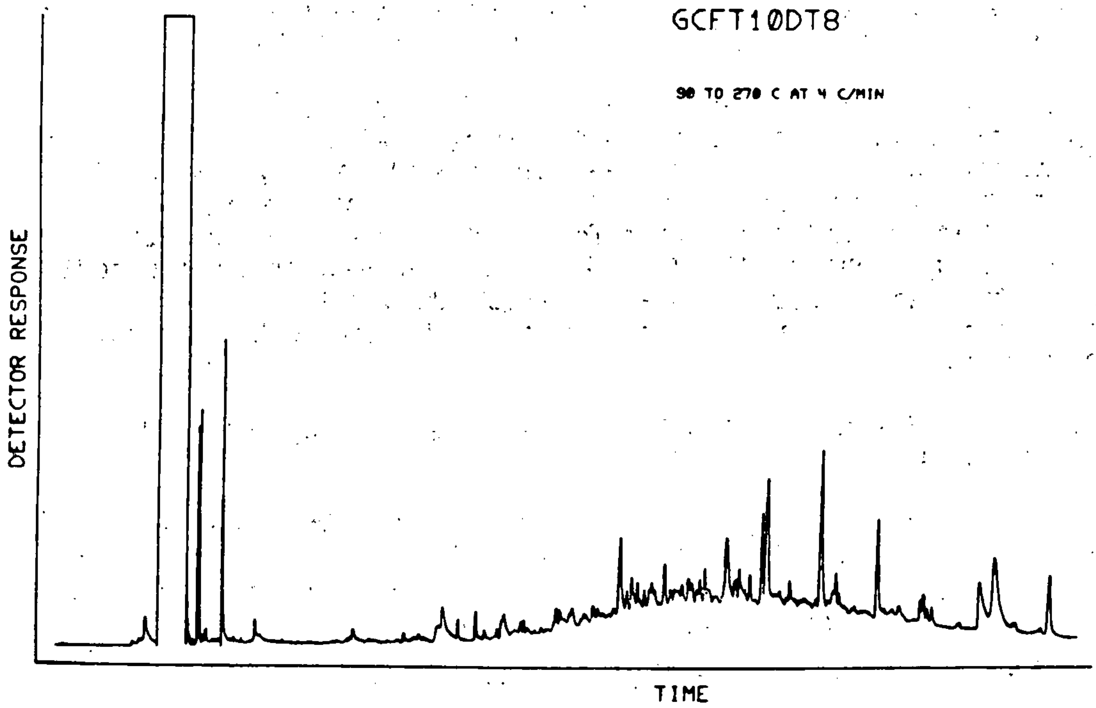


Figure 7.5.46 GC of the Oil/Dispersant Tank, 1 hr, fraction 8.

GC's of fractions 2 through 5 suggest increasing amounts of aromatics, whereas 6 through 8 go from the heavier aromatics to polars. It is interesting to compare the GC of the first fraction to that of the total material in Figure 7.5.10; a number of dissimilarities are observed. We also measured the GC of the surface slicks after five weeks of the experiment; these are shown in Figures 7.5.47 and 48. The GC of the first fraction is very similar to those of the surface slicks.

(C) Quantitative Analysis of Water Samples

Quantitative results for extractable organics in water samples are listed in Table 7.5.1. As mentioned previously, a 22% efficiency was used for the dispersant tank when the dispersant was present and a 65% efficiency when the dispersant was not detected. Very little dispersant was detected during week two; thus, the extraction efficiency is somewhere between 22 and 65%, and the values are lower than those in the table.

(D) Analysis of Sediment Samples

Sediment samples were collected from tanks 1, 3 and 4 on the first day and at the beginning of the fourth week. The quantitative results obtained by IR and GC are listed in Table 7.5.2. As in previous studies, the GC values are lower than the IR values; this is due to separation by thin layer chromatography between the IR and GC measurements. A very interesting fact is that the sediment values are lower in week four than in week one (except for tank 1 by GC). It should also be noted that the tank 4 (oil/dispersant) concentration was twice as high as the other two at the 1 hour sampling by the IR measurement. This is reasonable since most of the dispersant would be included in the IR measurement, but would be removed prior to the GC analysis by thin layer chromatography.

GC of the six sediment samples are shown in Figures 7.5.49-54. The pristane/phytane ratio in the control and the oil tank at one hour and in the GC of the control at the fourth week are greater than 1, whereas they are approximately one or less in the oil/dispersant at one hour and the fourth week and in the oil tank after four weeks. Thus, it appears that with the dispersant some of the petroleum hydrocarbons enter the sediments during the first hours. However, there does not appear to be a significant increase in petroleum hydrocarbons in the sediments during the three week period.

(E) Qualitative Analysis of Water and Slick Samples by Infrared Spectroscopy

Qualitative infrared spectra of all samples were measured from 1950 to 650 cm^{-1}. The IR spectra of the slick samples collected at the end of five weeks from the oil and dispersant tanks are identical, which is in agreement with the GC of the same two samples.

There are several noteworthy differences in the IR of the water samples. The infrared difference spectra of the sample from the top of the oil tank and from the top of the control tank at one hour is shown in Figure 7.5.55. Only one strong band appears at 1040 cm-1. Although exact identification of the compound is not possible from one band, it

Table 7.5.1. Concentrations (ppb) of Extractable Organics in Water Samples from Flow-Thru Tank Experiments at Experimental Station in Jeruselem

		Week 1 May 7	Week 2 May 14	Week 3 May 21	Week 4 May 29	Week 6 June 11	Week 7 June 18	Week 9 July 2
1) Control,	Top	89	332	515	106	103	354	206
	Mid	326	342	416	76	116	369	
	Bot	89	356	507	75	110	246	
2) Oil,	Top	230	355	415	197	1170	436	166
	Mid	44	539	406	N.D.	1639	346	
	Bot	46	303	402	77	301	213	
3) Oil/Disp,	Top	3611	252	637	60	2066	318	201
	Mid	941	257	897	56	1834	330	
	Bot	304	2043	624	87	2235	333	
4) Disp,	Top	9598*	1215*	319+	99+	11,499*	352+	216+
	Mid	20082*	3071*	306+	104+	5,723*	306+	
	Bot	3992*	949*	515+	79+	1,344*	351+	

* 22% extraction efficiency used

+ 65% extraction efficiency used

N.D. non-detectable

Table 7.5.2

Concentrations (μg/g dry weight) of Hydrocarbons in Sediment Samples

Tank	IR Values		GC Values	
	Week 1	Week 4	Week 1	Week 4
1. Control	36	17	6.8	10.3
2. Oil	29	15	6.9	4.4
3. Oil/dispersant	73	9	6.4	3.9

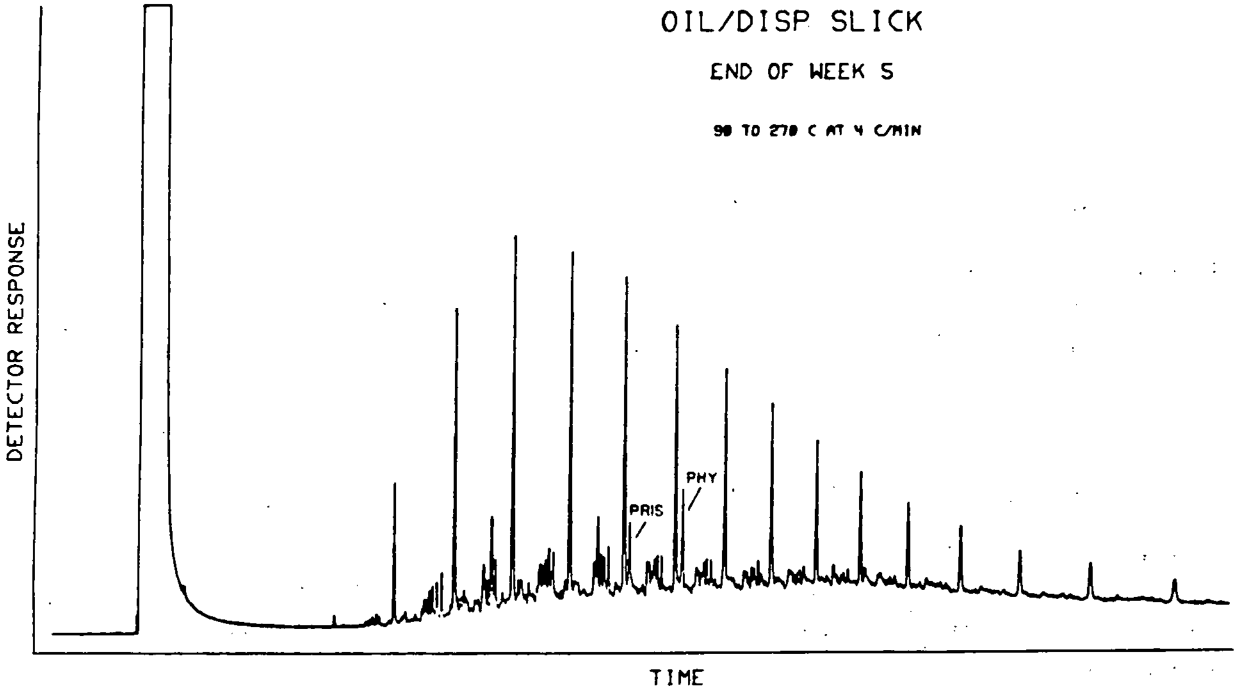


Figure 7.5.47 GC of the Slick in the Oil/Dispersant Tank, week 6.

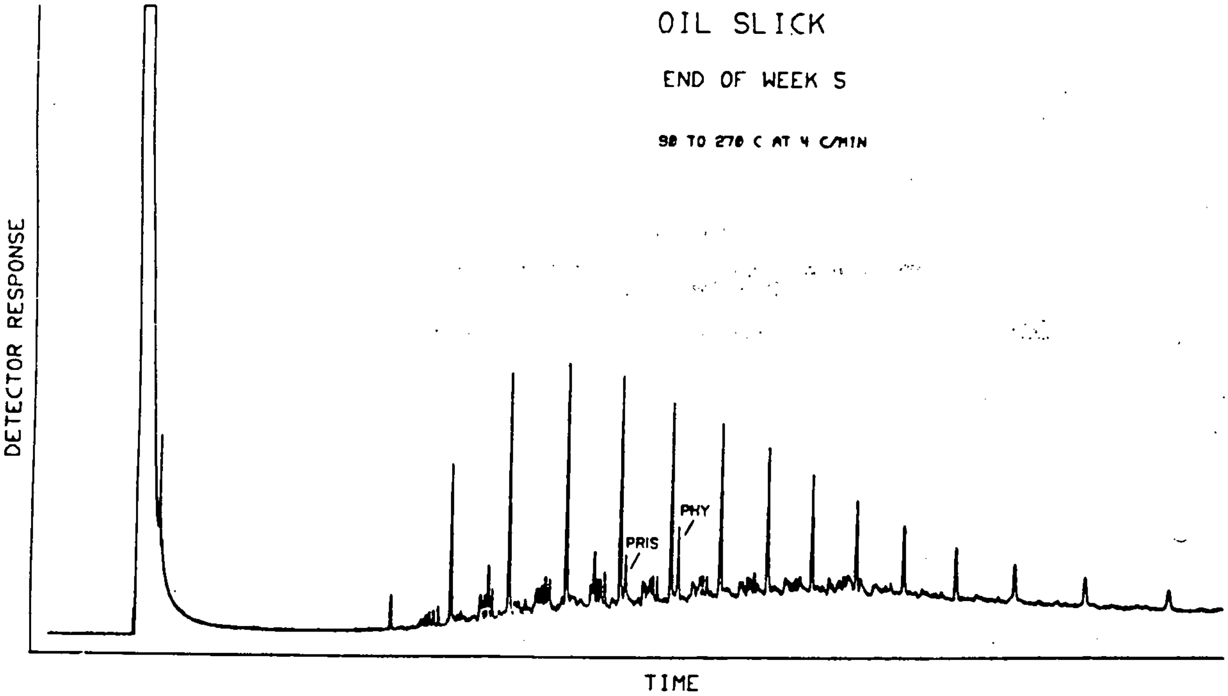


Figure 7.5.48 GC of the Slick in the Oil Tank, week 6.

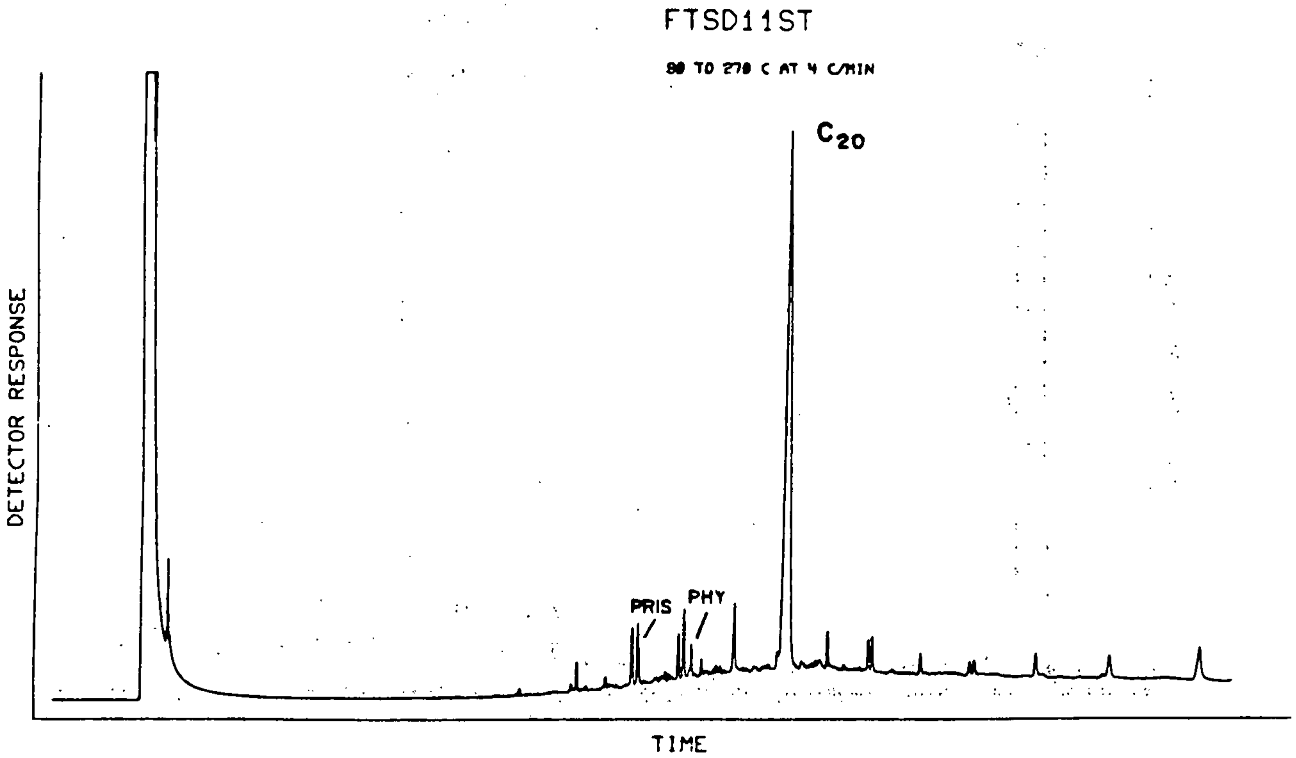


Figure 7.5.49 GC of the Sediment in Control Tank, 1 hr.

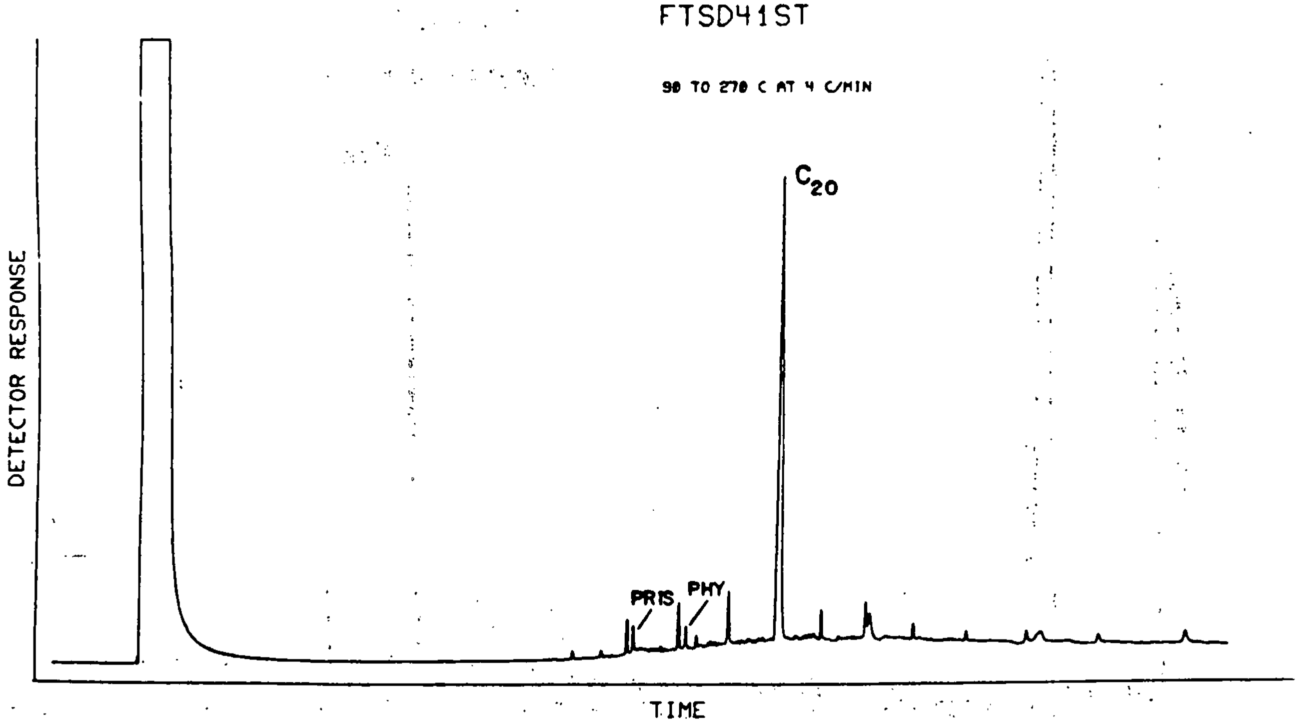


Figure 7.5.50 GC of the Sediment in Oil Tank, 1 hr.

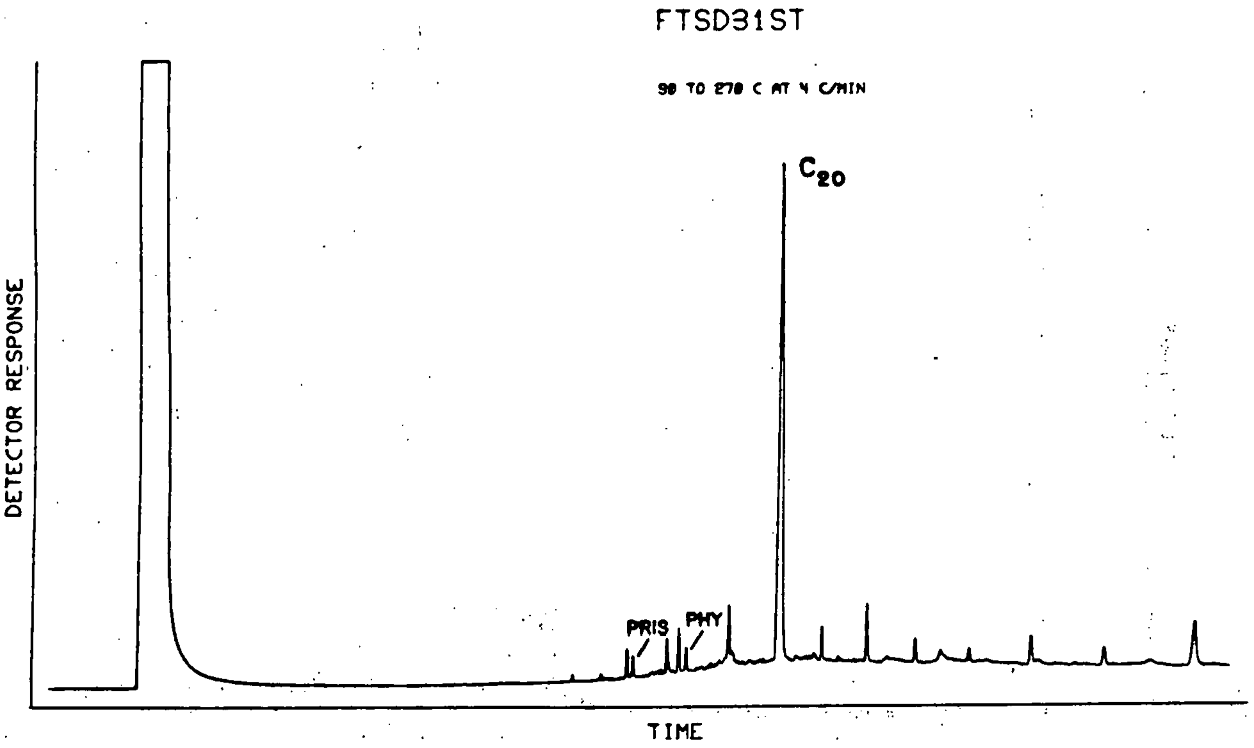


Figure 7.5.51 GC of the Sediment in Oil/Dispersant Tank, 1 hr.

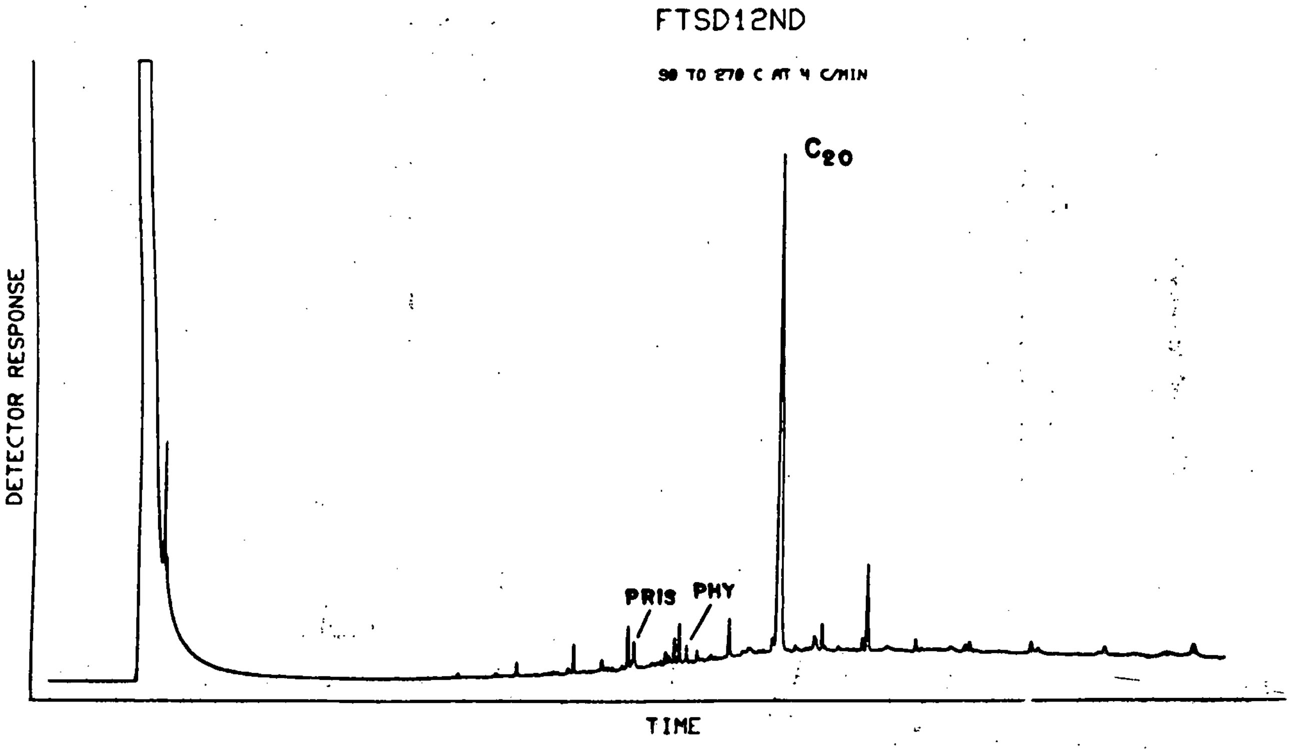


Figure 7.5.52 GC of the Sediment in Control Tank, 4th week.

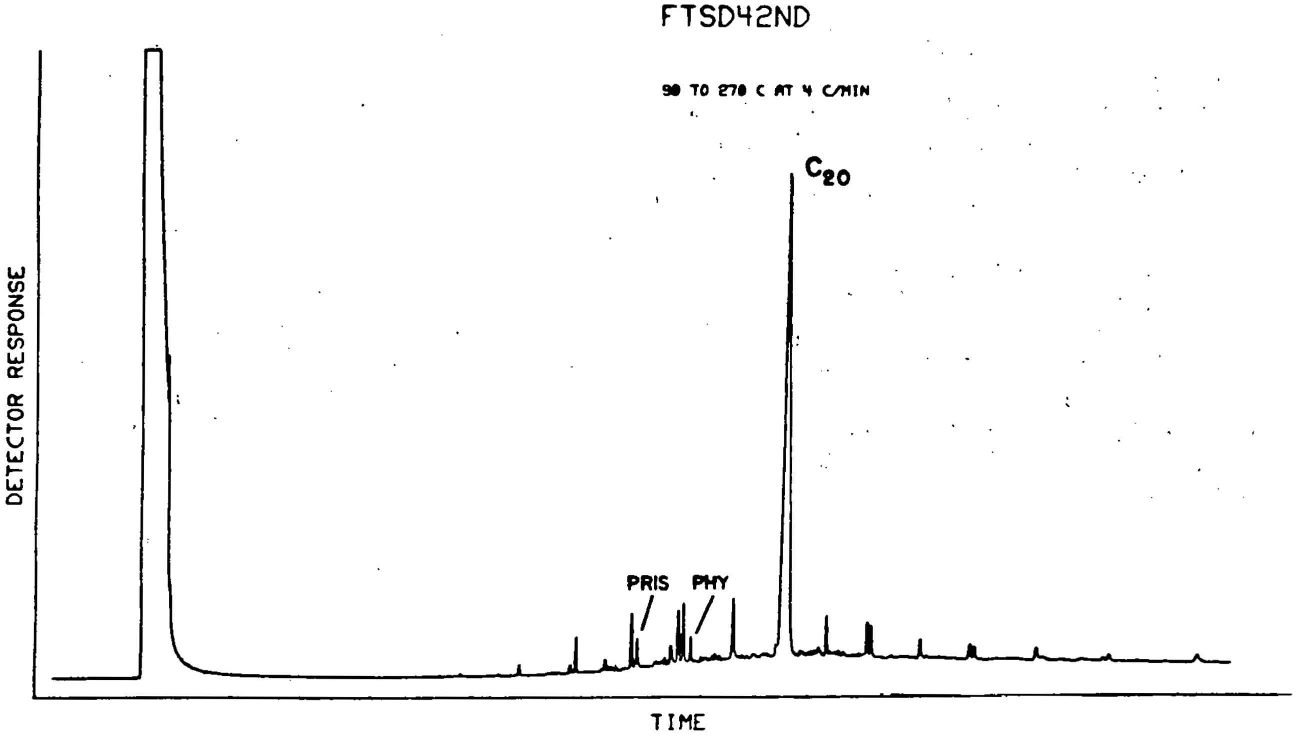


Figure 7.5.53 GC of the Sediment in Oil Tank, 4th week.

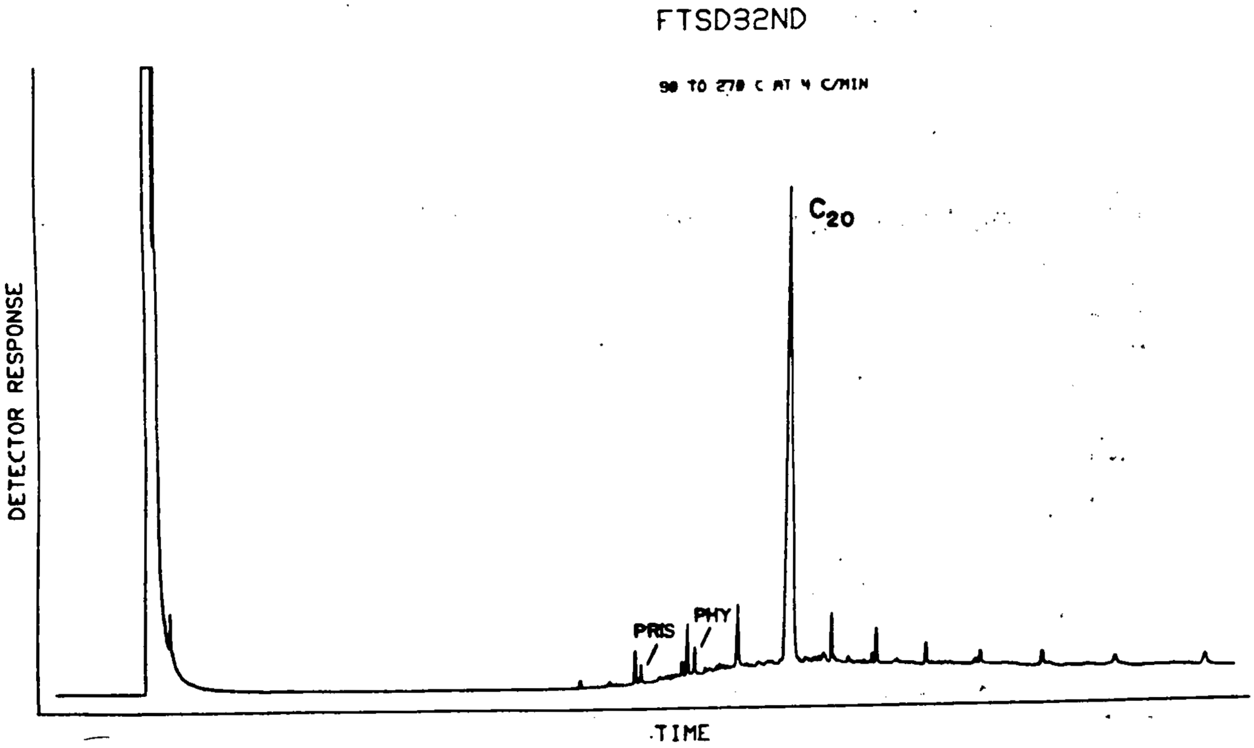
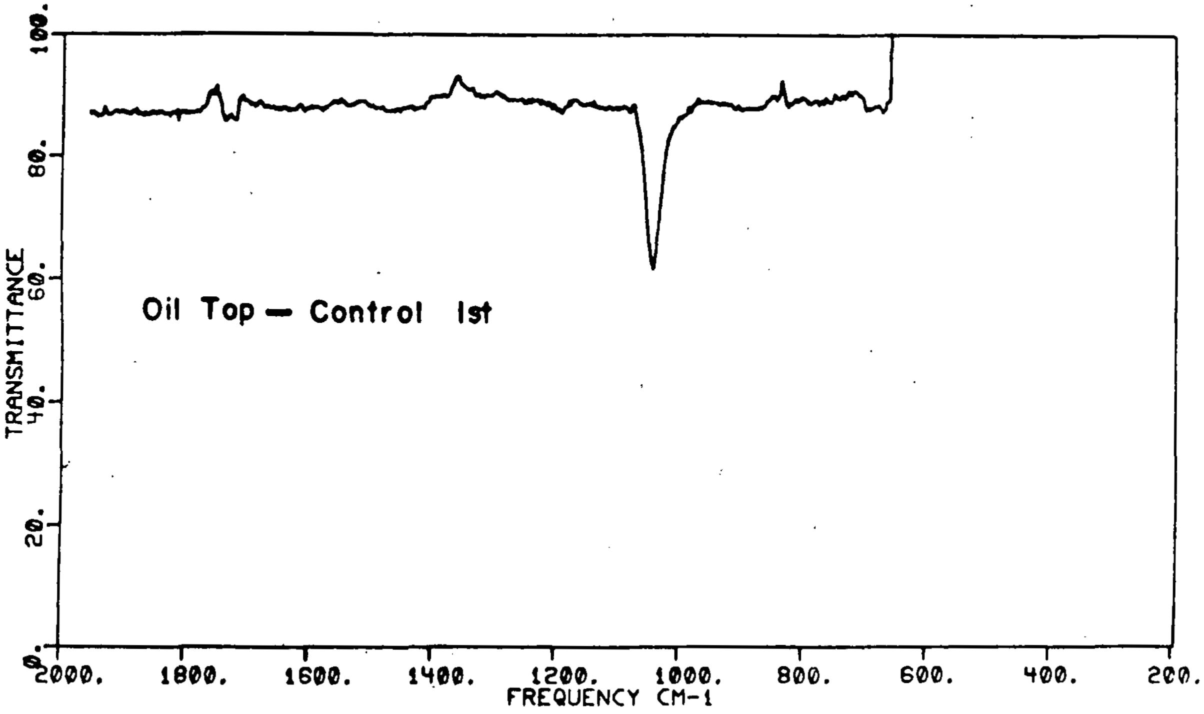


Figure 7.5.54 GC of the Sediment in Oil/Dispersant Tank, 4th week.

could well be a sulfoxide and the band due to the S=O group which absorbs strongly at this frequency. An organic sulfoxide could account for the tendency of this oil to form mousse and act as a self-dispersant. This band is also found in the difference spectrum obtained by subtracting the oil/dispersant middle from the oil/dispersant top at the first sampling as is shown in Figure 7.5.56.

Another interesting feature is found in the difference between the oil/dispersant and oil at the top after addition of dispersant in the sixth week as is shown in Figure 7.5.57. The peak at 770 appears only in the oil/dispersant spectrum; thus, it has a positive value (pointing down) in the difference spectrum. This peak was also observed in the top sample from the dispersant only tank. It may account for other differences observed between the tanks after the dispersant was applied a second time.

Figure 7.5.55 IR difference spectrum; top of oil tank minus top of control tank, 1 hr.



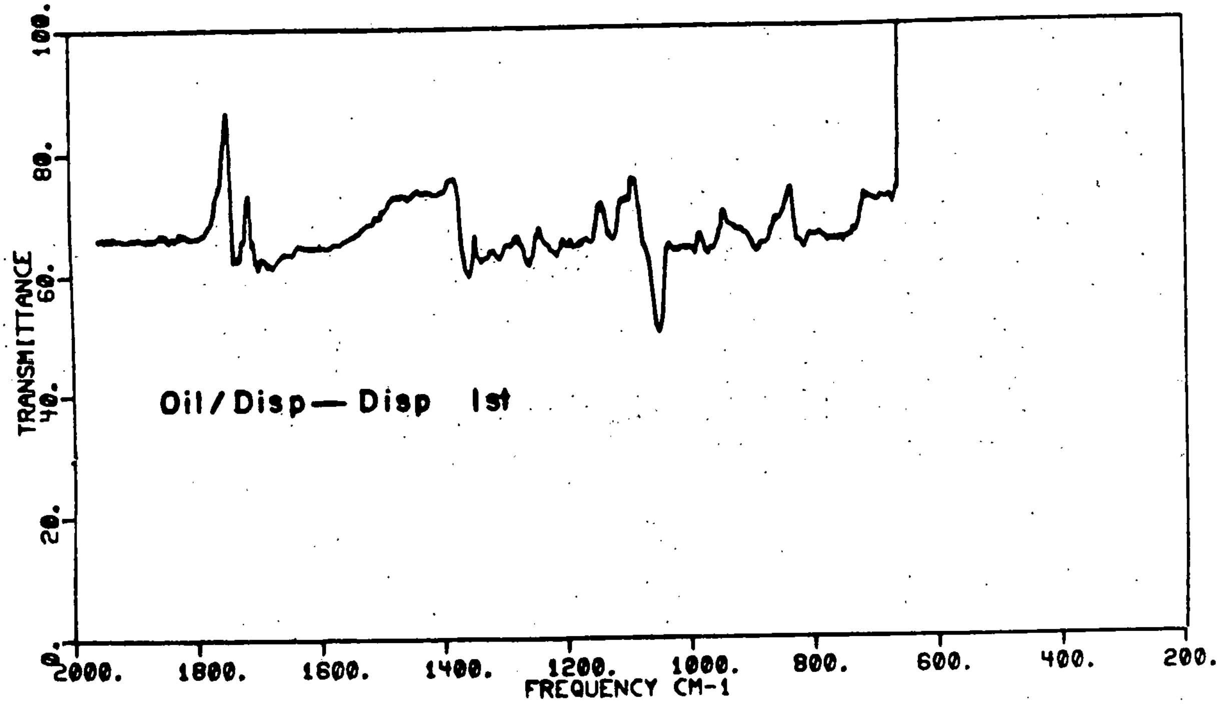


Figure 7.5.56 IR difference spectrum; oil/dispersant top minus oil/ dispersant middle, 1 hr.

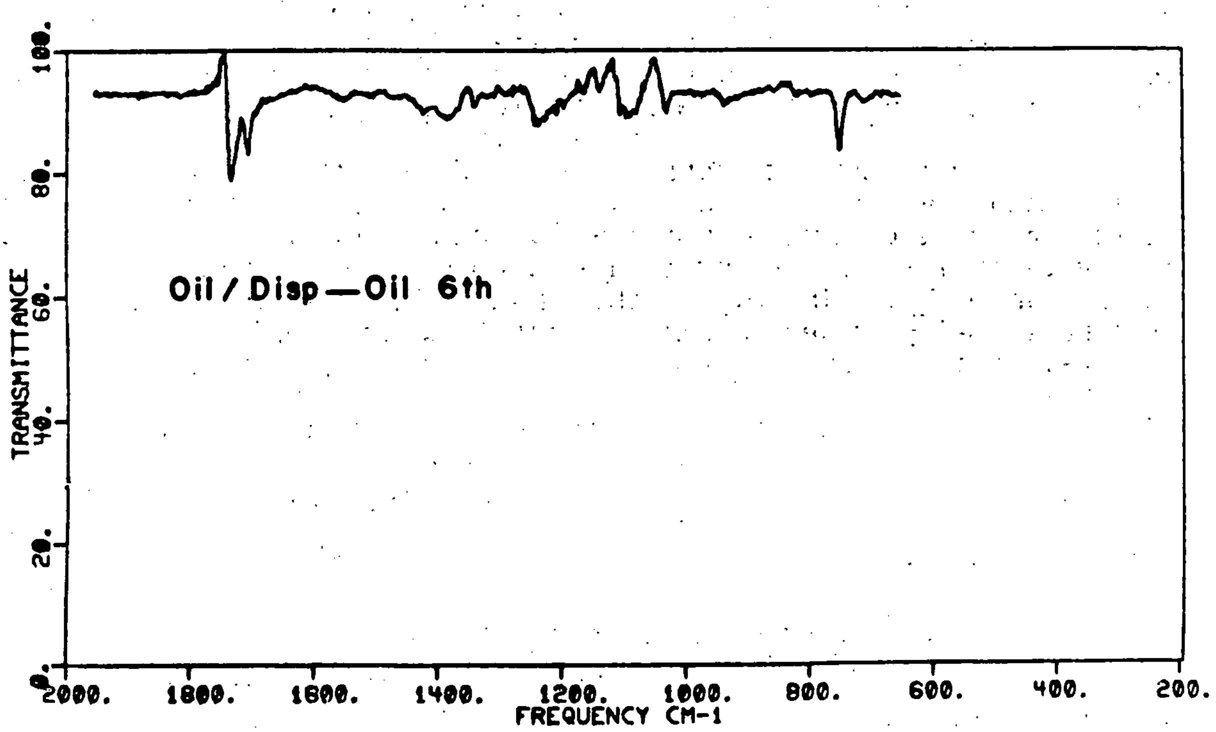


Figure 7.5.57 IR difference spectrum; oil/dispersant top minus oil top, 6th week.

7.6 Field Studies

7.6.1 Field Study of the Buzzard Bay Spill

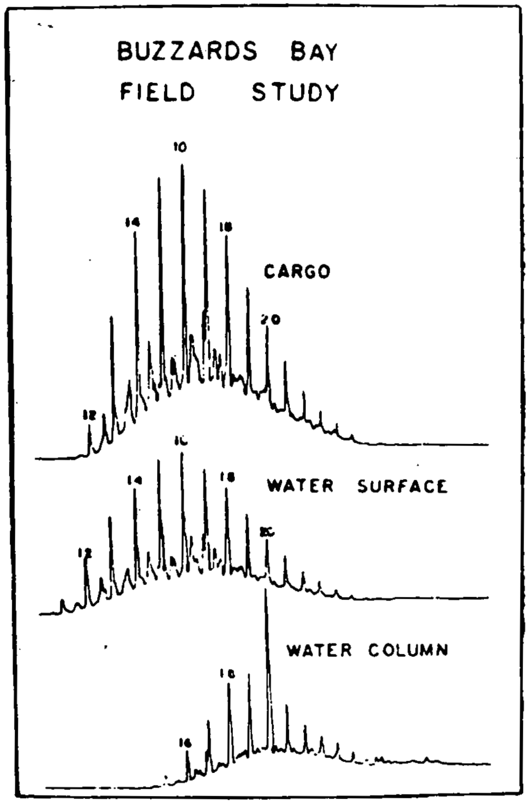
During the last week of January 1977, 100,000 gallons of a No. 2 fuel were spilled from a barge into the ice laden entrance to the Cape Cod Canal, i.e., in Buzzards Bay. The oil became trapped in and beneath the ice; thus this spill offered a unique opportunity to test our laboratory methodology on an actual spill. One week after the spill, we collected the following samples: oil in the ice, oil on the water; water samples at 3 m beneath the surface, and sediment samples with a grab sampler. Since the grab sampler had to be pulled through the surface water which possibly contained oil, we returned the following week and one member of the group collected sediment samples by diving beneath the ice. On this occasion an air sample was also collected on shore by pumping air through a charcoal cartridge for one hour.

All of the field samples were returned to the laboratory for analysis. We obtained a sample of the oil from the barge; the oil was analyzed and the results on the field samples were compared to those on the cargo oil and to the results of the laboratory experiments on the oil.

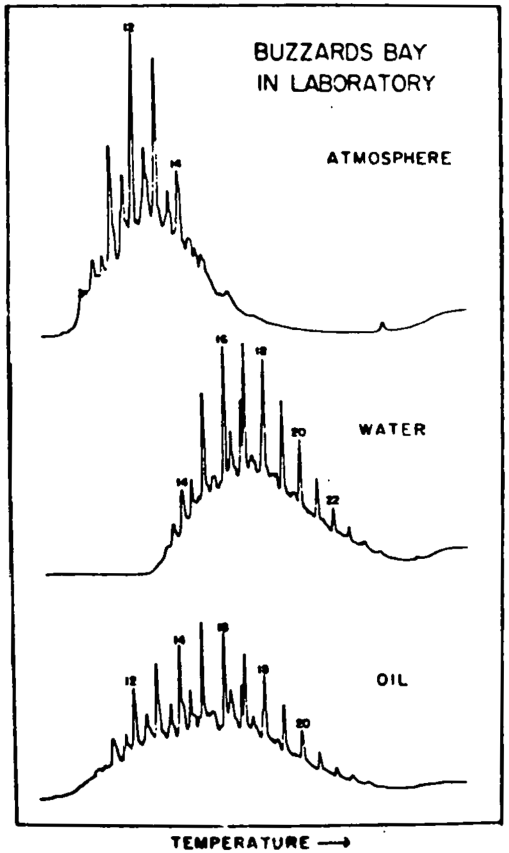
Oil was found in the water column and sediment samples. The infrared spectral fingerprints of the oil in the ice and on the water surface definitely matched the cargo oil. The spectral fingerprint of the oil in the water column was also very similar to that of the cargo; however, the fingerprint of the sediment hydrocarbons could not be directly related to that of the cargo. There are two possible explanations for this observation: the composition of the oil retained by the sediments could be considerably different from that of the cargo, or the hydrocarbons in the sediments could be from a different source. The latter explanation appears more reasonable, since the same barge spilled oil at this site in 1974. The amount of hydrocarbons in the sediments was relatively low. However, it should be mentioned that the sediment samples were very sandy and may not retain the oil as well as finer sediments.

Possibly the most interesting and useful results are on the air and water column samples. The gas chromatograms (GC) of the water column, water surface, and cargo samples are compared in Figure (7.6.1). The GC of the cargo and surface samples are virtually identical, e.g., note the doublet at n-C_{17}. The GC of the water column sample also has this doublet at n-C_{17}; however, only the higher boiling hydrocarbons can be observed in the GC of this sample. Fifty g of n-C_{20} were added to this sample as an internal standard: thus, the n-C_{20} peak is appropriately higher than those of the other n-paraffins. The latter GC should be compared to that of the laboratory water sample of the same oil which is shown in Figure 7.6.2. Both the field and the laboratory water samples show that only the hydrocarbons boiling at or higher than n-C_{14} enter the water column.

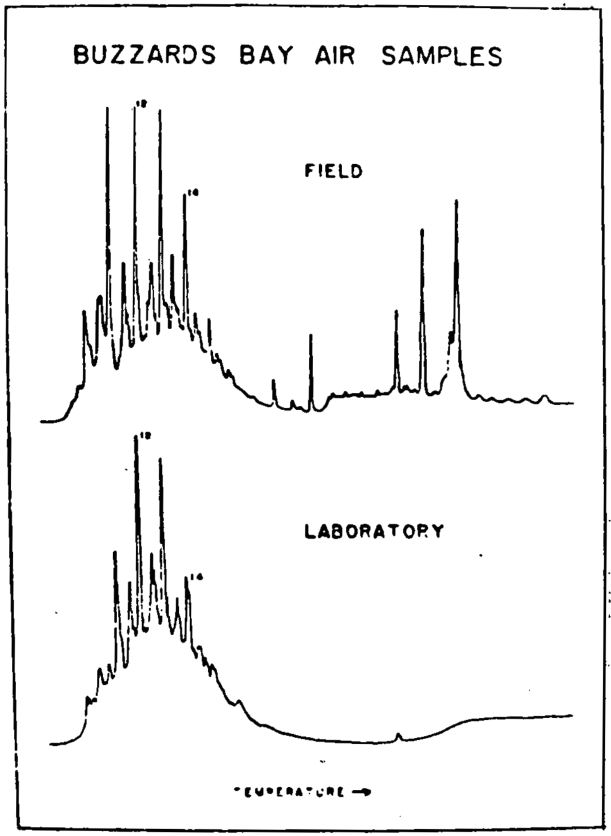
The air sample collected at Buzzards Bay offers even greater support to the laboratory results. The GC of the field and laboratory air samples are shown in Figure 7.6.3. Both show that the hydrocarbons entering the atmosphere are predominantly those boiling at or below n-C_{14}. There is a considerable similarity between the relative composition of



7.6.1 GC of the Buzzards Bay Oil, Cargo, Surface and Water Column.



7.6.2 GC from the Laboratory Experiment on the No. 2 Fuel Oil from the Buzzards Bay Spill



7.6.3 GC of Field and Laboratory Air Sample from the Buzzards Bay Oil.

the hydrocarbons in the two samples. The GC of the field sample does show some higher boiling chemicals. Possibly these are of biological origin and may be more polar than petroleum hydrocarbons which would account for their longer retention time on the GC column.

7.6.2 Field Study of the Argo Merchant Spill

Another spill of opportunity occurred during the early morning hours of December 15, 1976, when the Argo Merchant went aground in the Nantucket shoals. The tanker split and spilled its cargo of 7.7 million gallons of No. 6 oil into the sea. At about the same time, another tanker, the Grand Zenith, was lost at sea and was also carrying a No. 6 fuel.

Approximately 60 to 90 days after the grounding of the Argo Merchant, tarballs began to wash ashore on Jamestown (R.I.), Martha's Vineyard, Nantucket and Cape Cod (Mass.) (from Nauset Beach to Provincetown). This laboratory received and analyzed 22 of these tarballs ranging in weight from a few ounces to 15 lbs.

Table (7.6.1) lists the information on the tarballs which were analyzed. The samples, which contained aquatic debris and occluded water, needed to be pretreated and cleaned up prior to analysis. To do this, approximately 5 mls. of each sample were placed in a test tube and spun in a centrifuge for a few minutes, allowing the debris to separate to the bottom and the oil to rise to the top of the tube. The oil layer was then transferred to another test tube and 5 mls. of CCl_4 were added. The sample was then shaken well and centrifuged for five minutes. The top three-quarters of the sample was then transferred to another test tube, a drying agent, $MgSO_4$, was added and the sample was again centrifuged for five minutes at 35°C. This last series of steps was repeated until all water was removed from the sample. The CCl_4 was then removed by evaporation.

The samples were then placed in a demountable infrared cell with a 0.05 mm spacer and the spectra were measured on a Perkin-Elmer 521 Infrared Spectrometer. The digitized spectral data were stored in a computer data file and all data analyses were performed on an IBM 370/60 computer.

Kileen and Chien (1) proposed a method for obtaining the probability of matching spilled oil to one or more suspects from infrared spectra of the samples. Their method is an extension of the ratio method developed in our laboratory (Ahmadjian et al., 2).

In the ratio method, absorbances at 18 frequencies in the spectrum of one sample are ratioed with absorbances at the same frequencies in the spectrum of another sample. The log of each ratio, the average log-ratio, and the differences between each log-ratio and the average log-ratio are determined. Initially, we ratioed the absorbances in the spectrum of each suspect to those in the spectrum of the spill sample; the best match was assigned to the spectrum having the most ratios within 10% of the average. Later, the method was extended to give a single value for estimating the differences between spectra (2). This value is obtained from the sum of the squares of the differences between the

Information on Tar Balls

Tar Ball No.	*Site*	*~Date*	*Comment*
1	Jamestown, R.I.	2/9/77	a,~1 lb., composite
2	Jamestown, R.I.	2/9/77	a,~1 lb., outside
3	Jamestown, R.I.	2/9/77	a,~1 lb., inside
4	Jamestown, R.I.	2/9/77	b,~5 lb., inside
5	Jamestown, R.I.	2/9/77	c,~15 lb., inside
6	Martha's Vineyard	2/12/77	
7	Nantucket	2/15/77 to	
8	Nantucket	3/1/77	
9	Nantucket	3/1/77	
10	Nantucket	3/1/77	
11	Nauset Beach	3/1/77	
12	Nauset Beach		No. 11 weath. at GSO
13	Marconi Beach	3/1/77	
14	Marconi/Lecount	3/14/77	
15	Race Pt. Beach	2/10/77	Sewage
16	Race Pt. Light	3/1/77	
17	1000 yds. from Race Pt. Light	3/1/77	
18	Long Pt.	3/12/77	
19	Provincetown Wharf (a)	3/15/77	
20	Provincetown Wharf (b)	3/15/77	
21	Pilgrim Beach (a)	3/12/77	
22	Pilgrim Beach (b)	3/12/77	

Table 7.6.1
Information on Tar Balls

log-ratios and the average log-ratio, i.e.,

$$S^2 = \sum_{i=1}^{18} \left(\log \frac{A_i 1}{A_i 2} - \frac{1}{18} \sum_{i=1}^{18} \log \frac{A_i 1}{A_i 2} \right)^2$$

where A_i1 and A_i2 are the absorbances for the ith band in spectra 1 and 2, respectively. For a perfect match, the value of S^2 would be zero; thus, the magnitude of S^2 reflects the dissimilarity between oils.

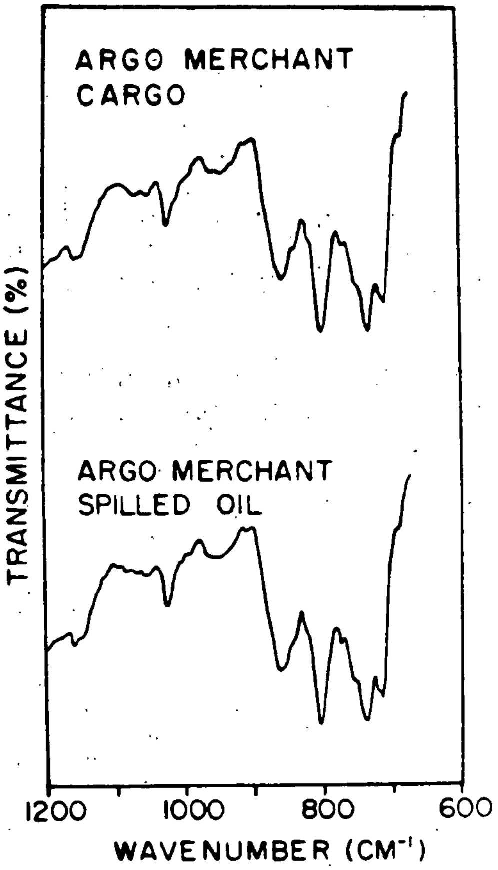
We (2) measured spectra of 198 neat and 647 weathered oils (including several weathered samples for each of 80 neat oils). S^2 values for all possible pairs of oils were calculated and placed in one of two categories: same oils (neat and weathered oils from the same origin) and different oils (neat and weathered oils from different origins). There were 5,534 pairs with the two oils originating from the same source, and 345,030 pairs with the two oils from different sources. The pairs in each category were then ordered according to increasing S^2 values, and two histograms for frequency of occurrence vs. S^2 in increments of 0.01 were plotted.

The histograms provided distributions for pairs of oils from the same sources and for pairs from different sources. Kileen and Chien (1) used these distributions to determine the probabilities of guilt for each suspect in a spill case and the probability that a sample from the "true spiller" was not included. Their method is based on Bayes Theorem and is described completely in their report (1).

In the present report, it is important to note that the distributions used to obtain the probabilities are based on all types of oils, i.e., they are comprised of light through heavy crudes, fuels and lubricating oils. This tends to give slightly higher probabilities especially at the low end of the 0 to 1 probability scale. For example, infrared fingerprints of two No. 6 fuels may be completely different and we would expect that the probability that they match would be close to 0.0; however, since they are both No. 6 fuels, their fingerprints will be more similar than the fingerprints of a No. 6 and No. 2 fuel. Thus, in many cases, the probability that two different No. 6 oils match will be higher than expected because they are the same type of oil.

Infrared spectra of the Argo Merchant cargo and of the spilled oil collected two days after the tanker broke apart are shown in Figure (7.6.4). (These samples were obtained from Dr. Jerome Milgram, MIT). When the digitized spectrum of the spilled oil was compared with that of the cargo, the following probabilities were obtained:

	Probability
Argo Merchant	0.986
Another Source	0.014



Infrared Spectra of the Argo Merchant Cargo and of the Spilled Oil Collected 2 Days After the Spill.

Infrared spectra of the 22 tar balls listed in Table (7.6.1) were measured and the digitized fingerprints stored in a computer data file. Many of the spectra had similar contours and some were almost identical as is shown in Figure (7.6.5). The spectrum of each tar ball was compared with that of each of the others and the probability that they came from the same source is given in Table (7.6.2). The results are categorized according to magnitude in Figure (7.6.6).

All samples from Jamestown, Martha's Vineyard and Nantucket have probabilities >0.85 of being identical except for sample 2 from Jamestown. This was a sample of the outside layer of a tar ball, and the differences reflect excessive weathering on the surface. In addition to samples 1-10 being from the same source, the probabilities that samples 12, 16, 17 and 19 came from this source are >0.5. Furthermore, tar balls 11 and 13 are virtually identical (P=0.99).

It should be mentioned that the differences between many of the tar balls could be due to weathering and that this effect is more pronounced on the surface of the tar balls. Many of the tar balls from Cape Cod were very small and these could have been subjected to extensive weathering.

The infrared spectral fingerprint of the Argo Merchant oil is compared to that of the Martha's Vineyard tar ball in Figure 7.6.7. The general contours of the spectra are entirely different. We treated each of the 22 tar balls as a spill sample and determined the probability that each came from the cargo. The results given in Table 7.6.3 show that only sample No. 11 (Nauset Beach) had a probability of matching >0.3; most were <0.2. The spectrum of the cargo and the tar balls (except for sample 15) were characteristic of No. 6 fuel oils. Thus, these finite probabilities reflect the fact that the samples are the same type of oil.

If the tar balls came from the Argo Merchant, they were "weathered" in the Atlantic for almost two months; thus, we weathered some of the cargo oil at the URI aquarium for one month and periodically analyzed the samples. In most cases, the spectra of the tar balls and weathered Argo Merchant tar balls became less similar. The probability of matching for the 3 and 10 day samples are also given in Table 7.6.3.

The tanker, Grand Zenith, disappeared somewhere off the New England coast on the way from Teeside, England to Fall River, Masachusetts during January 1977; thus, its cargo was also a possible source of the tar balls. The U.S. Coast Guard R & D Center supplied us with a sample of the oil loaded aboard the Grant Zenith. We measured infrared spectra of the neat oil and of samples collected periodically during one month of weathering at the URI aquarium. The infrared spectrum of the Grand Zenith oil is compared with the Argo Merchant cargo and the Martha's Vineyard tar ball in Figure 7.6.8.

The probabilities obtained when comparing the spectra of the neat and 7 weathered samples to the tar balls are given in Tables 7.6.4a and b. The probabilities run as high as 0.83 when the neat oil is compared to tar balls No. 3 and 4; however, the highest probability (90) was obtained from matching the 14 day weathered sample with tar ball No. 11 from Nauset Beach (see Figure 7.6.9 for spectra). Other tar balls found in

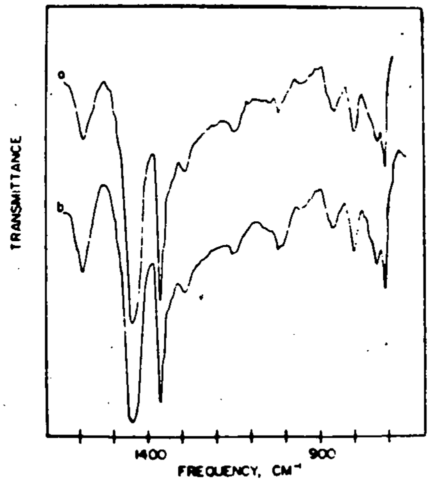


Figure 7.6.5 Infrared Spectra of Tar Balls: a. Jamestown and b. Martha's Vineyard.

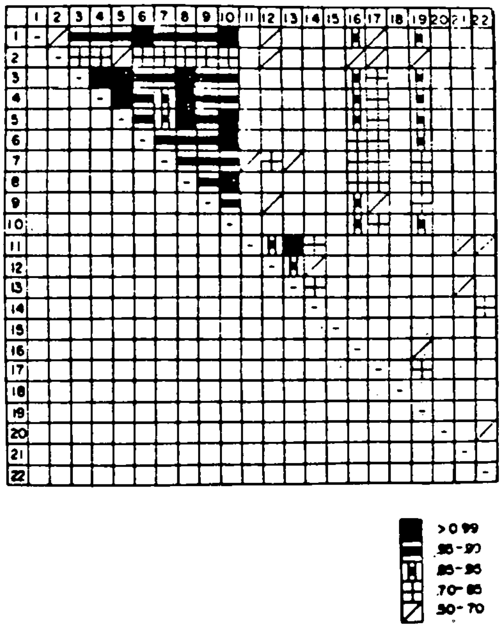


Figure 7.6.6 Probabilities of Tar Balls Matching.

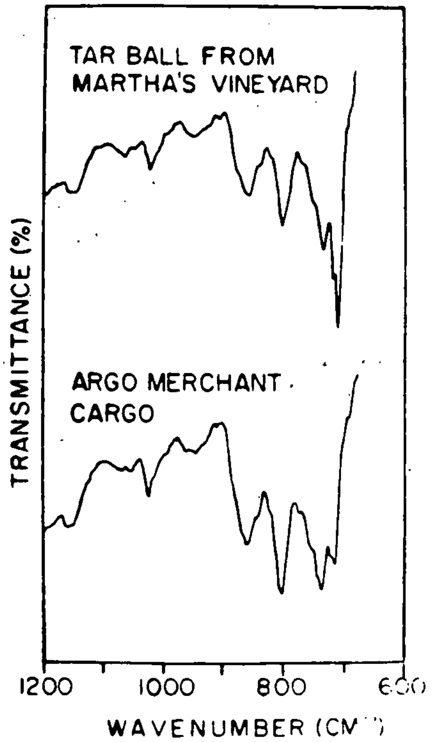


Figure 7.6.7 Infrared Spectra of Tar Balls from Martha's Vineyard and Argo Merchant Cargo.

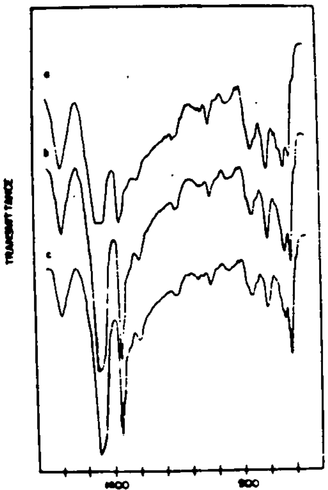


Figure 7.6.8 Infrared Spectra: a. Argo Merchant Cargo, b. Grand Zenith Oil and c. Martha's Vineyard Tar Ball.

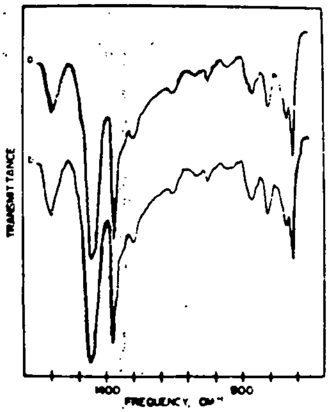


Figure 7.6.9 Infrared Spectra: a. Tar Ball from Nauset Beach and b. Grand Zenith Oil Weathered 14 Days.

Probabilities of Tar Balls Matching
(In % Units)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	–	66	96	96	97	99	95	97	97	99	46	55	43	20	0	86	66	16	89	16	22	18
2		–	76	70	67	79	77	77	71	71	45	56	41	33	0	56	51	16	59	18	19	20
3			–	96	100	97	96	99	97	98	38	45	36	18	0	90	77	20	91	17	19	18
4				–	100	98	93	100	97	99	33	41	31	18	0	87	83	17	90	16	18	17
5					–	97	93	99	98	100	35	42	34	16	0	90	80	20	91	14	18	18
6						–	98	98	97	99	47	60	44	22	0	84	76	17	89	18	22	18
7							–	95	98	95	55	72	53	26	0	74	73	16	82	18	28	19
8								–	96	99	38	48	35	19	0	84	84	19	84	16	17	18
9									–	97	45	50	42	21	0	91	63	16	73	17	23	18
10										–	40	48	38	19	0	91	76	18	86	16	20	18
11											–	94	99	81	0	33	23	21	33	34	55	50
12												–	94	57	0	31	37	18	44	32	39	36
13													–	80	0	31	23	19	33	32	54	48
14														–	0	18	18	21	18	44	36	71
15															–	0	0	0	0	0	0	0
16																–	25	16	58	15	20	19
17																	–	0	70	16	17	17
18																		–	22	19	19	43
19																			–	15	18	17
20																				–	23	55
21																					–	44
22																						–

TABLE 7.6.2 Probabilities of Tar Balls Matching

Probability of Tar Balls Originating From *Argo Merchant* Cargo
(In % Units)

Tar Ball	*Neat*	*Argo Merchant Cargo* *3 Days Weathered*	 *10 Days Weathered*
1	22	18	18
2	18	25	18
3	21	5	18
4	19	0	18
5	20	0	18
6	20	7	18
7	19	19	18
8	20	22	18
9	21	23	18
10	21	20	18
11	32	18	32
12	23	18	27
13	27	19	27
14	18	18	18
15	0	0	0
16	21	0	18
17	15	17	16
18	18	16	18
19	18	25	18
20	18	26	21
21	19	18	22
22	22	18	28

Table 7.6.3 Probability of Tar Balls Originating From Argo Merchant Cargo

Table A
Probability of Tar Balls Originating From *Grand Zenith* Cargo
(In % Units)

Tar Ball	*Grand Zenith Cargo Weathered (Days)* *0*	 *1*	 *2*	 *4*
1	74	77	75	51
2	45	45	52	55
3	83	87	86	66
4	83	87	88	69
5	82	86	86	63
6	73	75	76	57
7	60	65	70	52
8	76	81	81	58
9	69	73	73	44
10	79	83	83	55
11	36	35	38	31
12	38	38	42	41
13	32	33	35	30
14	18	18	18	18
15	0	0	0	0
16	75	78	77	40
17	33	37	40	44
18	14	16	16	20
19	71	75	74	81
20	16	16	16	15
21	18	18	20	19
22	18	18	18	18

Table B
Probability of Tar Balls Originating From *Grand Zenith* Cargo
(In % Units)

Tar Balls	*Grand Zenith Cargo Weathered (Days)* *7*	 *14*	 *21*	 *28*
1	73	55	26	27
2	58	47	33	34
3	77	50	22	24
4	75	49	20	21
5	76	47	20	21
6	77	58	29	29
7	70	63	35	34
8	72	47	23	23
9	74	61	29	30
10	78	54	25	26
11	55	90	86	87
12	51	73	64	58
13	47	84	81	63
14	23	41	87	77
15	0	0	0	0
16	85	58	23	26
17	32	24	18	18
18	17	19	18	21
19	59	37	18	20
20	18	22	37	30
21	27	46	61	63
22	22	40	58	64

Table 7.6.4 A. Probability of Tar Balls Originating from Grand Zenith Cargo Weathered 0-4 days
B. Probability of Tar Balls Originating from Grand Zenith Cargo Weathered 7-28 days

this area (Nos. 13 and 14) have probabilities of 0.85 of matching the weathered Grand Zenith oil.

According to the probabilities given in Table 7.6.4, the tar balls can generally be placed into three categories: i) those with high probabilities of matching the neat or short term weathered samples, ii) those with high probabilities of matching the long term weathered samples, and iii) those with low probability matches. Samples 1,3-10, 16 and 19 fall in category i, samples 11-14, 21 and 22 in category ii, and the rest in iii.

The study showed conclusively that the tar balls found along the New England coast after the Argo Merchant incident were not from the stricken tanker. Many of the tar balls had similar infrared spectra and there is a high probability that a number of these came from the same source. Finally, there is a reasonably high probability that some of the tar balls originated from the stricken tanker, Grand Zenith. It should be noted that the tar balls were compared with oil loaded onto the Grand Zenith, and not to the oil actually contained in the tanker. The composition of the oil in the tanker could have been slightly different due to residues in the tanker from previous shipments.

References.

1. T.J. Kileen and Y.T. Chien, Proceedings, Workshop on Pattern Recognition Applied to Oil Identification, Coronado, Ca. (Nov. 1976).

2. M. Ahmadjian, C.D. Baer, P.F. Lynch and C.W. Brown, Environ. Sci. & Technol., 10,777 (1976).

Titles and Authors

Computer Separation of Infrared Spectra for Analysis of Complex Organic Mixtures, P.F. Lynch* and M.M. Brady.

Predicting The Performance of Medium and Low Resolution Infrared Spectrometers and Analyzers, Chris W. Brown, Patricia F. Lynch and Mark A. Maris and Donald S. Lavery.

Quantitative Analysis of Gaseous Hydrocarbons By Infrared Spectroscopy, Chris W. Brown, Patricia F. Lynch and Mark A. Maris and Donald S. Lavery.

Computerized Infrared Spectroscopy as a Separation Technique-Analysis of Complex Organic Mixtures Extracted from Water, P.F. Lynch, and M.M. Brady.

Collection, Separation and Analysis of Organic Vapors by Computerized GC/IR, D. Goldfarb and C.W. Brown.

Chemical Analysis of Dispersed OIl in the Water Column, C.W. Brown,[1] P.F. Lynch,[1] and M. Ahmadjian.[1]

Collection of Gas Chromatographic Fractions on Activated Charcoal and Identification by Infrared Spectroscopy, Daniella Goldfarb and Chris W. Brown.

Computerized dispersive infrared spectroscopy gives results comparable to FTIR, as we perform "Festa of Magic," Dr. Chris W. Brown, Patricia F. Lynch and Mark Ahmadjian.

In the Wake of the Argo Merchant, Center for Ocean Management Studies.

8.0 Microbiology

Richard W. Traxler

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8.0 MICROBIOLOGY

8.1 Introduction:

The report of a special study group of the National Academy of Sciences on Petroleum in the Marine environment (1) indicated that the rates of microbial degradation of petroleum hydrocarbons vary with the complexity of the material, the nature of the microbial population and environmental conditions. The physical process of dispersion of a spilled oil will reduce the concentration of oil in the spill vicinity and greatly increases the surface area of the oil which renders the oil more susceptible to biological degradation (2).

The hydrocarbon degradation potential of ocean environments has not been adequately defined (3) but is known to be influenced by such factors as the number and types of hydrocarbon degrading microorganisms, the degree of oil dispersion, temperature and nutrient availability (4). Hydrocarbon degradation rates measured in the laboratory have been misleading as they were found to be considerably higher than in situ rates (5). It has been demonstrated (6) that degradation rates in cold waters are reduced compared to warmer water but not to the extent previously thought. Surfactants have been investigated as a mechanism to increase oil recovery (6),(7) and microorganisms have been shown to actively emulsify hydrocarbons (8), (9) and oils (10). Studies have shown that chemical dispersants stimulate bacterial growth on oil and the biodegradation of the oil (11).

This project was designed to investigate the effect of chemical dispersants on the ability of natural marine bacterial populations to biodegrade crude oil hydrocarbon components.

8.2 Materials and Methods:

8.2.1 Culture Media

The culture media used in the project were:

1. Nutrient Seawater Agar (NSA)

NaCl	21g.
Rila Salts	5g.
Polypeptone	5g.
Yeast Extract	3g.
Glucose	1g.
Succine Acid	.2g.
K_2HPO_4	.33g.
KH_2PO_4	.66g.
Agar-Agar	16g.
Distilled Water	1 L.

2. OZR Agar

Yeast Extract	1g.
Trypticase	1g.
$Fe PO_4 \ 2H_2O$	10mg.
Agar-Agar	16g.

Aged Seawater *pH 7.8	1 L.

3. Hydrocarbon Basal Medium (HBM)

Aged Seawater	990ml.
Supplement B*	10ml.
Washed Agar-Agar**	20g.

*Supplement B

NH_4 Cl	7.5g.
FE PO_4 $2H_2O$	4.75g.
Distilled Water	250ml.

*Narragansett Bay water (GSO site), cheesecloth filtered to remove particular matter and aged one month in the dark in glass carboys.

**Flaked agar was soaked and rinsed three times a day with tap water for three days, and once a day for the next five days, followed by once a day rinses in distilled water for six days, then air dryed and ground to powder.

The sterile melted agar was placed in a sterile Waring Blender, the hydrocarbon added at desired concentration, blended at high speed for three minutes and poured into sterile plates.

8.2.2 Dissolved Oxygen, Azide modification for BOD.

1. Solutions

   a. Manganese Sulfate
      $MnSO_4$ H_2O, 91g. in 250 ml distilled water, filter and dilute to volume.

   b. Alkalin-iodide-azide reagent

NaOH or KOH	250g.
NaI or KI	67.5g.
NaN_3	5g.

Dissolve NaOH and NaI in distilled water, dilute to 500ml, then add NaN_3 dissolved in 20 ml distilled water.

   c. Sulfuric acid 36N
   d. Starch
   e. Sodium thiosulfate

NaS_2O_3 $5H_2O$ (0.1N), 24.82g. dissolved, boiled, cooled, then distilled water added to 1000ml, add 5ml of chloroform as a preservative.

2. Method

Remove 200 ml of water from the BOD bottle, add 2ml of $MnSO_4$ and 2 ml of alkaline-iodide-azide reagent. Shake and let stand for at least two minutes, add 2 ml of H_2SO_4 and shake until the ppt is dissolved. Titrate with sodium thiosulfate until pale straw color, add 2 ml of starch solution and titrate until the purple color disappears.

3. Modified BOD Method

For the standard BOD method a standard inoculum is prepared for addition to each bottle and the measurement of O_2 used provides an estimate of organic matter in the water. The modification was to use the natural seawater microbial population as inoculum and challenge this population with a known quantity of substrate. A control was used for each series which consisted of the seawater without added nutrient. This provides an estimate of oxygen depletion caused by the natural microbial population metabolizing the endogenous nutrients present in the seawater. This value was substracted from the test results. All samples were run in triplicate and the average value used as the data point.

The results are reported as rates of oxygen depletion for a given microbial population at any time during the course of the experiment. A series of at least 21 BOD bottles containing the same water and challenge substrate are set up for each water sample. Three bottles are selected at random for any measurement time during the rate determination and measured for dissolved oxygen content.

8.2.3 Radioactive Degradation Rate Determination

Substrates labeled with ^{14}C carbon are used as an auxiliary method to determine the rate at which materials are degraded by natural microbial populations. Several different approaches have been used to estimate turn-over of hydrocarbon components. The metabolic $^{14}CO_2$ produced from the metabolism of the ^{14}C substrate was trapped at hourly intervals to calculate rate of CO_2 production. Another approach was to measure rate of CO_2 release, and rate of production of water soluble intermediates and end products. ^{14}C-Hexadecane was used as a representation n-alkane, ^{14}C-Naphthalene as representative of low molecular weight aromatic compounds and ^{14}C-Benzopyrene as a representative of high molecular weight aromatic compounds. The ^{14}C-hydrocarbons were used either at constant value (luci) or added to samples in the approximate ratio in which they occurred in the oil under investigation.

The reaction vessels were 250 ml flasks fitted with a CO_2 free air sweep to carry metabolic CO_2 into the methanol-ethanolaniene traps, or the same type of flask fitted with a rubber cap. In the latter case, the reaction vessel was incubated for three hours, acidified with 0.1N HCL to release all bicarbonate as CO_2 which was then flushed from the reaction vessels into CO_2 traps.

The flasks were extracted with n-pentane at acid pH to recover all residual hydrocarbon and any lipids produced during the reaction. The pentane extracted seawater was counted to measure low molecular weight, water soluble products left after the extraction. The pentane extract was then partitioned with acidified methanol: ethanol (1:1) to remove lipids from the pentane extract. The pentane and alcohol were counted for ^{14}C activity.

The specific radioactivity of the substrate is known, therefore, it is possible to convert the radioactivity in the various products by calculation to ng. of substrate utilized. If the initial amount of hydrocarbon is known, the turnover time of the substrate can be calculated using equation 1.

Equation 1.

$$T/F = \text{Time}/\frac{\text{ng Hydrocarbon metabolized}}{\text{ng Hydrocarbon added}}$$

The degradation time of a complex mixture such as crude oil can be estimated using equation 2.

Equation 2.

$$D/F = \text{Time}/\frac{\text{ng component a + ngb + ---}}{\text{Total Petroleum present}}$$

8.2.4 Viable Plate Counts

The plates for "total heterotrophic" bacterial counts (THB) and Hydrocarbanoclastic Bacteria counts (HYB) were prepared and incubated at least 24 hours but not over 96 hours at the temperature at which the experiment would be performed. This allowed proper drying of the agar surface to reduce spreading of the bacterial colonies as they developed on the agar surface. All glassware and diluents were held six hours at experiment temperature to prevent temperature shock to the bacteria.

Plating was performed via the spread plate technique which consisted of spreading 0.1 ml of the proper dilution over the entire agar surface using a sterile glass rod bent into the shape of a hockey stick. Samples were serially diluted and three consecutive dilutions of each sample were chosen for spread plating. The normal dilutions used were 10^{-1}, 10^{-2} and 10^{-3} but higher dilution values were used in some cases to achieve countable plates (30-300 colonies). In most experiments, two dilutions were prepared from each sample and two plates were spread from each dilution which means we had four plates for counting at each data point. This method increases the statistical accuracy of the spread plate count method. The values reported are the numerical average of the four plates.

The plates were counted on a Quebec Colony Counter with transmitted light. Plates with opaque media were counted on the same instrument but using an oblique light source.

8.2.5 Most Probable Number Technique

This method was performed with OZR and HBM medium without agar. Five parallel series of dilutions were made for each sample, utilizing four decimal dilution series. One ml of each dilution was added aseptically to 10 ml of medium. Five control tubes of medium were used as a contamination check. All work was performed in a hood system to prevent air contamination of the medium.

The tubes were incubated at the temperature chosen for the experiment and scored as growth or no growth. Growth was positive if there was visible bacteria on the tube bottom, throughout the medium, or underlying the hydrocarbon (oil) phase.

The number of positive tubes in each dilution of the five parallel series was determined and the number of bacteria per ml of sample determined using the MPN tables of Postgate (1969).

8.2.6 Replica Plating Technique

This technique was described by Pierce, Cundell, and Traxler (1975). The bacterial colonies from the master plate (obtained during viable plate count experiments) were transferred to other substrate plates using a velvet replicator pad (Fig. 8.1). The replication sequence was master plate to non-substrate basal agar, to hydrocarbon substrate to OZR agar. Colonies growing on the non-substrate basal agar were not scored when growing on a hydrocarbon substrate as they were considered to be growing at the expense for agar-agar rather than the hydrocarbon. The final OZR plate was used to insure that inoculum was carried forward from each colony.

8.2.7 Laboratory Experiment System

This system consisted of 5.5 gallon aquaria containing a 5 cm sediment base and fresh seawater overlay. A large glass tube extended into the midpoint of the water samples so that a pipet could be inserted to remove water without contact with the surface oil. Sediment samples were obtained with a tube within a tube arrangement. A large glass tube was placed in the water prior to the addition of oil and/or dispersant. When ready to sample the sediment, this tube was pushed into the sediment zone and a second smaller sterile tube was passed through the first glass tube to remove the sediment sample.

8.3 Results and Discussion

Three general purpose media were compared for use in the enumeration of "total" marine heterotrophic bacteria and as a base for a selective medium for hydrocarbon utilizing bacteria. The comparison of the three media to support growth of marine heterotrophic bacteria is shown in (Figure 8.2). OZR medium was superior to the other two media and was chosen as the basic medium for this study. Media K and G are both formulated using Rila Salts mix to replace the aged seawater of the OZR medium. It is apparent from these data that Rila Salts do not adequately substitute for aged seawater and that media so formulated provide much poorer productivity of the heterotrophic marine bacteria.

A comparison was made of the viable plate count (VPC) and most probable number (MPN) methods for enumerating marine heterotrophic bacteria in OZR medium. Both methods (Figure 8.3) were capable of determining increases in the number of bacteria. The MPN method did yield slightly higher total numbers, but still within the range of statistical variation. It was found that much greater logistical demands occurred with the MPN method to achieve the same accuracy as the VPC method. Also, it

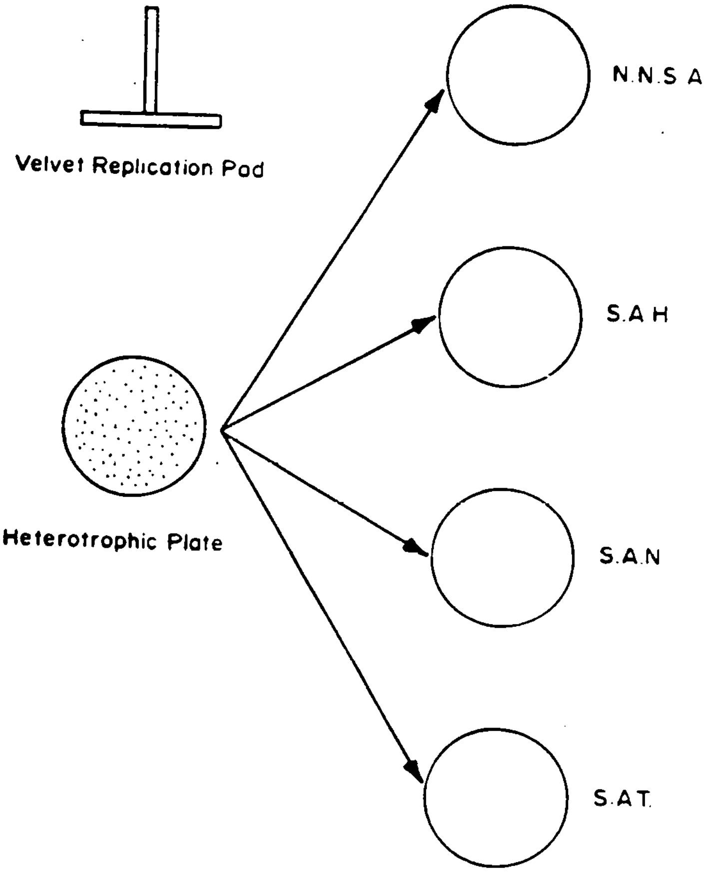


Fig. 8.1 Replicate Plating Technique

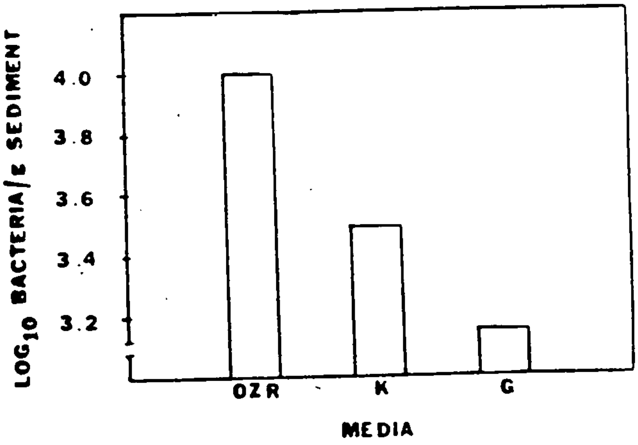


Fig. 8.2 Comparisons of Three Media for Ability to Support Growth of Marine Heterotrophic Bacteria

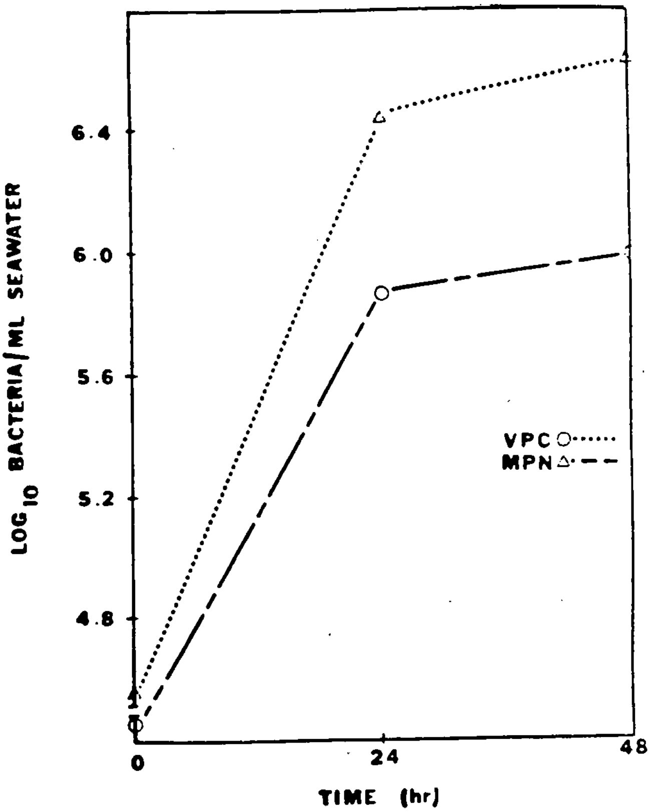


Fig. 8.3 Comparison of Most Probable Number (MPN) and Viable Plate Count (VPC) Methods for Enumerating Marine Heterotrophic Bacteria.

was desirable to have colonies on solid media for other aspects of the project. Therefore, the VPC method using OZR medium was chosen as the standard heterotrophic bacteria enumeration method.

The VPC was used with OZR and HBM media to estimate the relative percentage of hydrocarbon utilizing bacteria in the total heterotrophic population. This method was applied to seawater supplemented with Kuwait Crude oil dispersed with Corexit 9527. The relative percentage of oil degraders with the "total" heterotrophic population increased with time (Figure 8.4).

Biodegradation of a specific organic compound is most accurately measured by determining the rate of disappearance of the compound. When the study involves degradation of multiple substrates or a chemically complex material such as crude oil, the analytical chemistry required for the component loss approach is extremely complex and is drastically reduced in accuracy. The project objectives dictated a rapid, simple system which would provide a reasonable estimate of biodegradation potential. In an aerobic environment, all degradation reactions are associated with oxygen utilization, therefore we utilized a modified Biological Oxygen Demand (BOD) procedure which provided the rate and extent of oxygen depletion by the mixed sea water population on various substrates

Five tanks were filled with fresh untreated seawater at 14°C. Four tanks were loaded with one percent (weight/volume) of either n-hexadecane, naphthalene, Williamar crude or peptone. The fifth tank served as a control. The tanks were mechanically agitated to disperse the chemicals throughout the water column, then the water distributed into BOD bottles, which were incubated at 14°C. Oxygen levels were determined from duplicate bottles over the time course of the experiment.

The results are presented in Figure 8.5. The control value represents microbial utilization of the indigenous nutrients present in the seawater. These nutrients were exhausted after two days with a total oxygen depletion of 2 mg. The rates of oxygen depletion with the substrates were linear for an initial time period, then decreased in rate for a second time period. The depletion rates are summarized in Table 8.1. Peptone (used to express "total" biodegradation potential) showed the greatest depletion rate and completely utilized all available oxygen by day six. The oxygen depletion rates with Willimar crude oil and naphthalene were the same and it is noticed that the rates were higher than for hexadecane. The breakpoints in the oxygen depletion plots all occur at about 2 mg O_2 per liter and are believed to represent the point of oxygen limitation for the mixed population. In this experiment, mechanically dispersed substrate was introduced into the BOD bottle at extremely high substrate concentrations (10,000 mg/liter) which cannot be compared to <u>in situ</u> conditions but did serve to validate the modified BOD method.

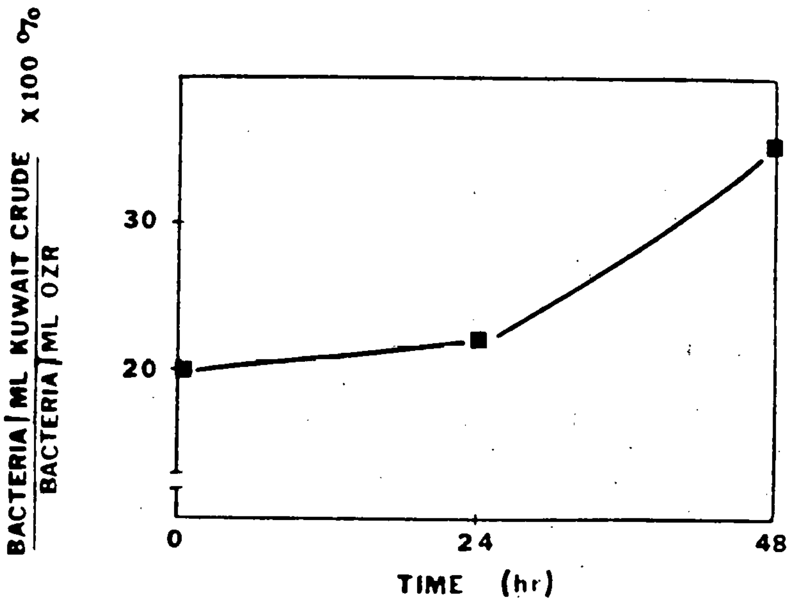


Fig. 8.4 Percentage of Marine Heterotrophic Bacteria Capable of Metabolizing Kuwait Crude Oil Agar Compared with OZR Medium.

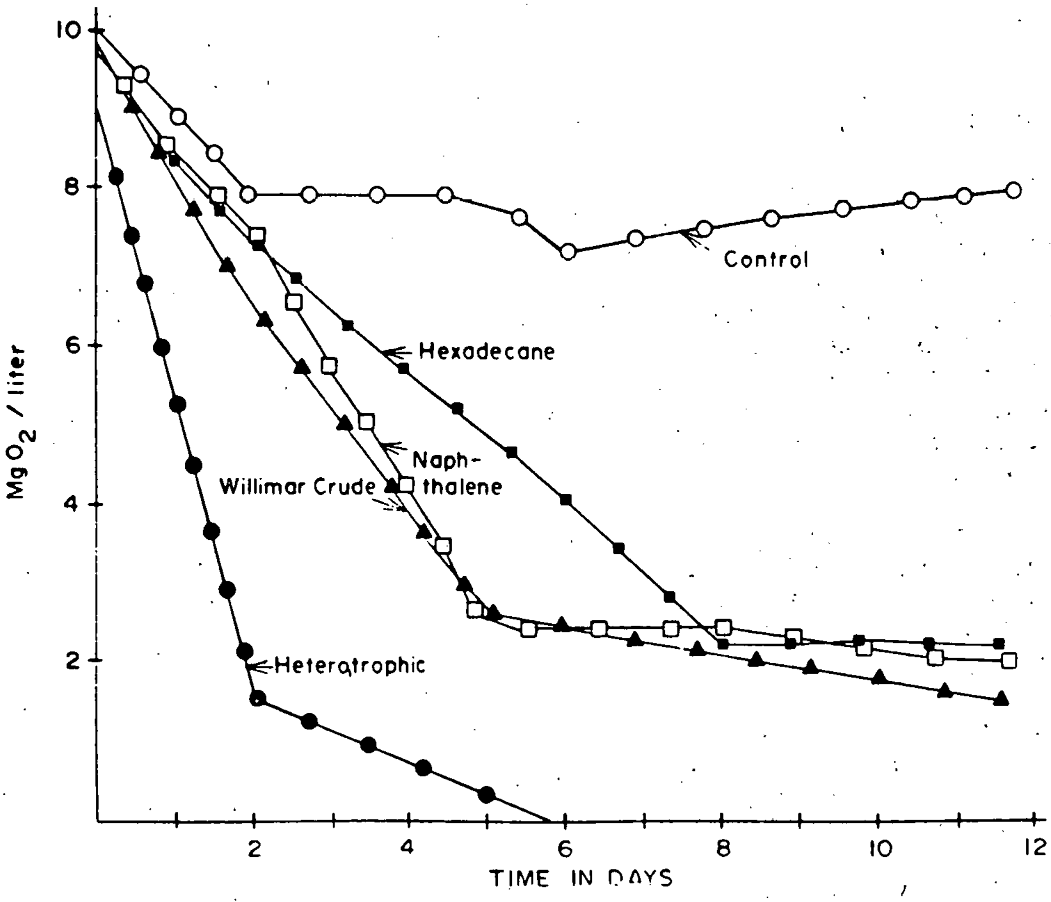


Fig. 8.5 Oxygen Depletion Rates of Various Substrates using a Modified BOD Method.

TABLE 8.1 RATE OF SUBSTRATE DEGRADATION, BY OXYGEN DEPLETION

Substrate	O_2mg/liter/day
Control (natural)	1.0
Peptone	3.5
Willimar Crude	1.25
Hexadecane	.94
Naphthalene	1.25

The experimental procedure was modified by eliminating mechanical mixing energy except for a gentle agitation of the tanks to simulate wave action. The tanks were filled with seawater and overlayed with API reference South Louisiana crude oil, the dispersant Corexit 9527, and a 10:1 mixture of crude oil and dispersant. Samples were removed from the center of the tanks after 24 hours for BOD measurements. Figure 8.6 shows the oxygen depletion for 24 hour samples from each of the four tanks. There was no oxygen utilization in the control tank, which indicated that the indigenous nutrient had been depleted during the 24 hour incubation prior to sampling the tanks. There was no depletion of oxygen in the South Louisiana crude tank, indicating either an absence of substrate in the water column or the inability of the resident bacterial population to utilize solubilized hydrocarbons. The absence of substrate was indicated from the results in the oil-dispersant tank.

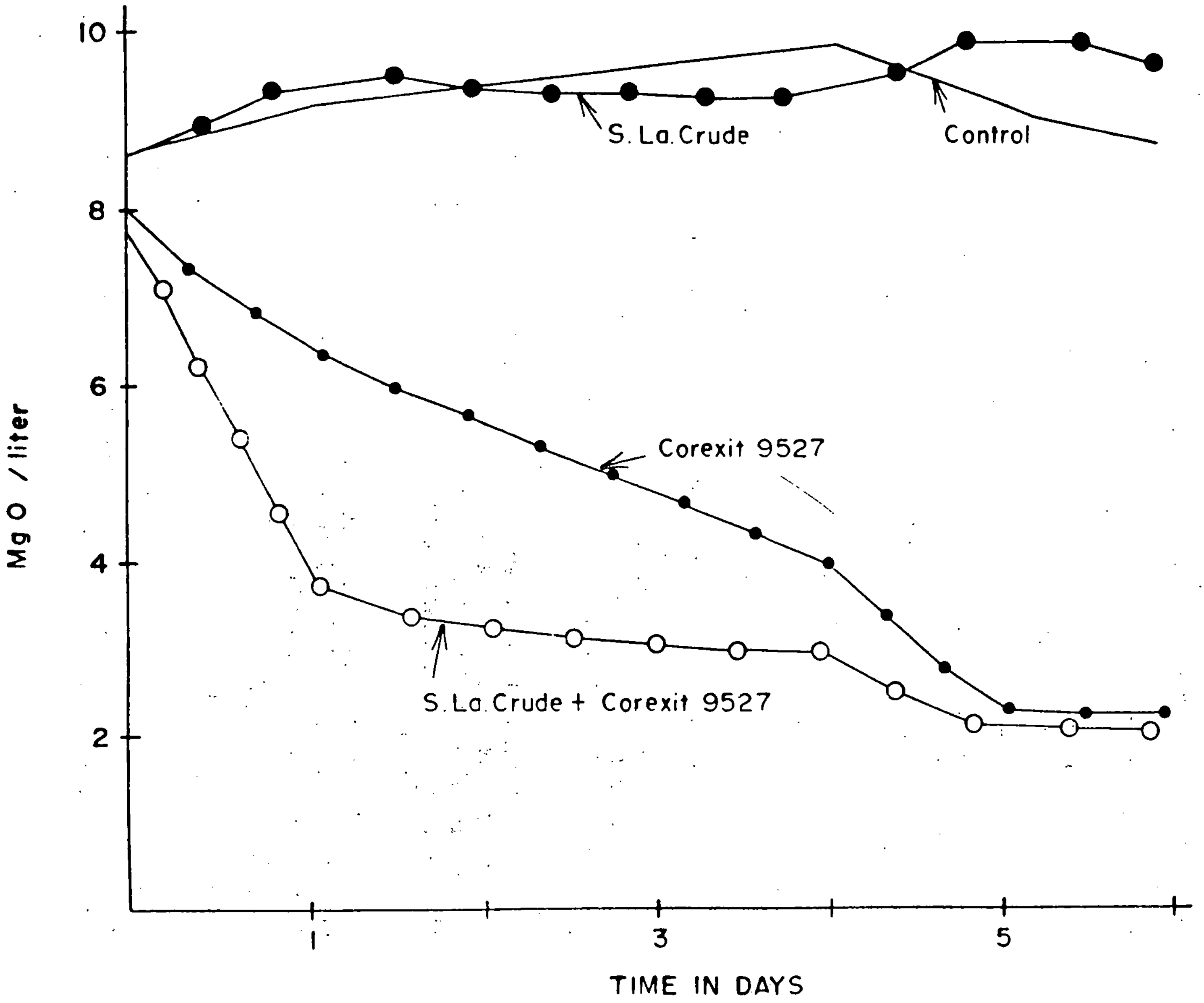
The biodegradable nature of Corexit 9527 was indicated by the oxygen depletion study, in which the oxygen was depleted at a rate of 1 mg O_2/liter/day. The oxygen depletion rate was much greater (4.25 mg/liter/day) with the mixture of crude oil and dispersant. This effect is apparent when considering no water column activity with just the crude oil and the much lower rate for the dispersant alone. The dispersant action would carry oil into the water column in small droplet form, in which it would be more readily available to the bacterial population.

It is interesting to note in these experiments as well as replications and other studies with the oxygen depletion method that the final oxygen level is always about 2 mg of O_2/liter. This would infer that microbial action on oil does not occur below this level of dissolved oxygen.

Conventional laboratory scale experiments have many advantages as they provide well controlled tests conditions and are easily replicated. However, there are certain inherent disadvantages to these small scale systems when operating in either the batch or continuous mode. Microbiologically, wall effects are magnified by the high wall to water ratio,the inability to achieve significant dilution effects or concentration gradients in small volumes of water. The ocean as an environment does not make possible controlled or easily replicated experiments. A compromise meso-scale test system was designed for use in this project with raw seawater.

Experiments were performed to determine the nature and variability of the meso-scale system. Two tanks were filled with seawater from

Fig. 8.6 Oxygen Depletion Rates of S. La Crude, Corexit 9527 and S. La. Crude & Corexit 9527.



Narragansett Bay and water samples removed from 1.5 meters below the surface on days, 0, 4 and 8 for use as inoculum for oxygen depletion studies. Three series were set up in duplicate to define the capacity of the resident population for utilization of endogenous nutrients (control), petroleum (Kuwait) and "total" heterotrophic potential (peptone). The experiment was repeated three times and a composite of the north and south tank data used to perform a polynomial regression for each substrate and the control. From the regression data, the R^2 value was determined and the best fit of the R^2 value to either a second or third degree polynomial. This was used to plot the x value, which is time in days against the estimated y value which is the mg of O_2/liter at each data point.

The statistical evaluation of the control values (Fig. 8.7) indicates a close correlation for the estimated depletion rates at each of the samples times. This is particularly true of the values for the 0 and 4 day samples. The general trend is for low initial depletion rates of 1.25 and 1.5 mg O_2/liter/day, followed by essentially level values, then increased oxygen content in the test values. The data indicates rapid exhaustion of the endogenous nutrients which are normally low in seawater.

The data for Kuwait crude oil (Fig. 8.8) shows a close correlation for all sampling times and a consistent oxygen depletion rate over the entire time course of the test. The initial rate is somewhat higher for the 0 day water than for the other two water samples.

A similar plot for "total" heterotrophic potential (Fig. 8.9) demonstrates the highest oxygen depletion rate of the three test series and an extremely close fit for all samples during the first day of the depletion rate measurement. The shifts in rate after one day reflect nutrient depletion and toxic products as seen in the conventional bacterial growth curve.

A comparison of the oxygen depletion rates with oil and peptone by 0 day water from the north and south tanks (Fig. 8.10) demonstrates the close fit of data from two different test tanks. The rates match those obtained from the composite data for all points on the three experiment statistical study.

The VPC method was also used to establish the reproducibility of the meso-scale system. This first validation was performed with only seawater (no oil or dispersant added) and compared to the VPC values of Narragansett Bay water. Samples were taken from 1.5 foot level and 9.5 foot level in both the north and south tanks. The results (Fig. 8.11) show excellent reproducibility between the two tanks and the bay water counts.

Salinity of the tanks was measured at surface, 1.5, 9.5 and 18 foot level (Fig. 8.12). A rain during the first 24 hours significantly reduced the salinity at the tank surface, but did not affect salinity at the other levels in the tank and had no effect on bacterial numbers (Fig. 8.11).

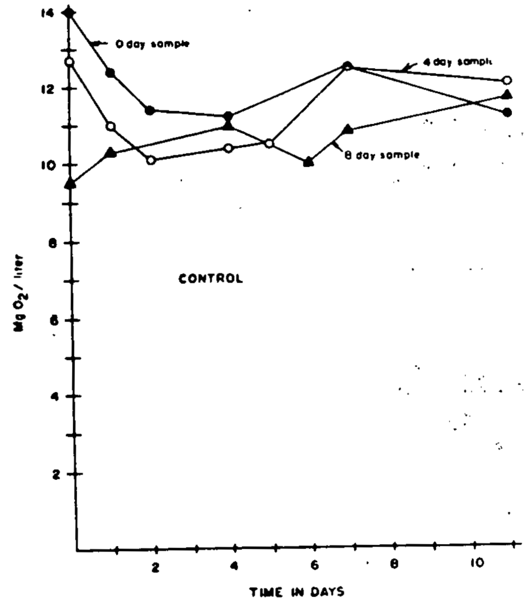


Fig. 8.7 Oxygen Depletion Rates of Zero, Four and Eight Day Control Task Samples.

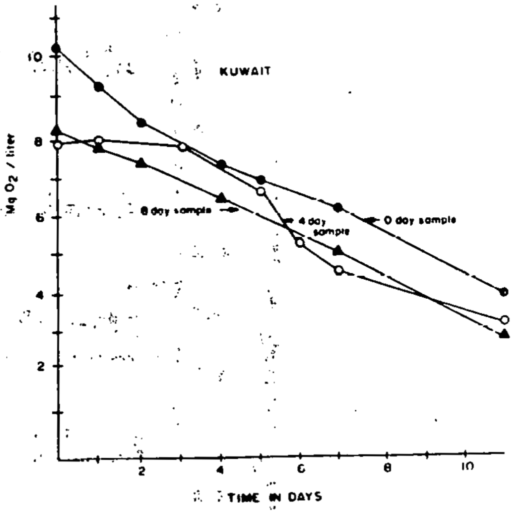


Fig. 8.8 Oxygen Depletion Rates of Zero, Four and Eight Day Kuwait Crude Oil Tank Samples.

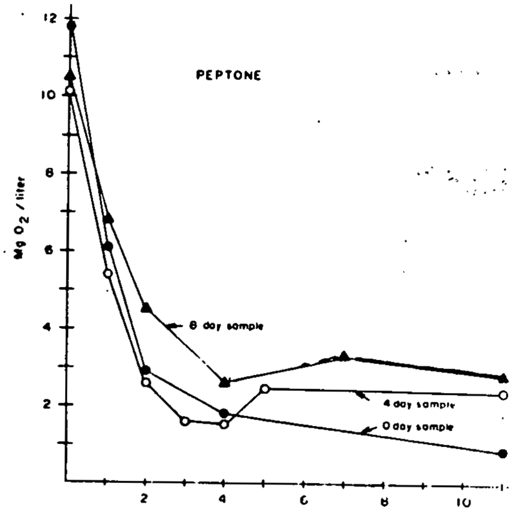


Fig. 8.9 Total Heterotrophic Potential of Zero, Four and Eight Day Samples.

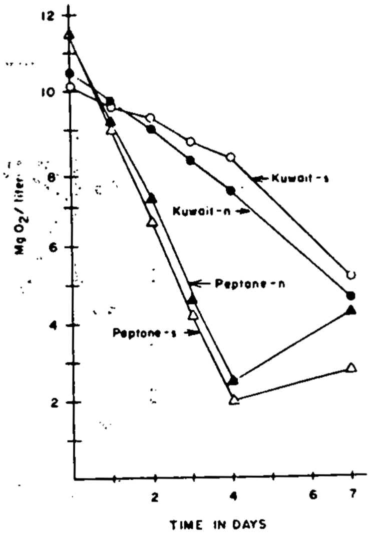


Fig. 8.10 Comparison of Oxygen Depletion Rates of Kuwait with Peptone.

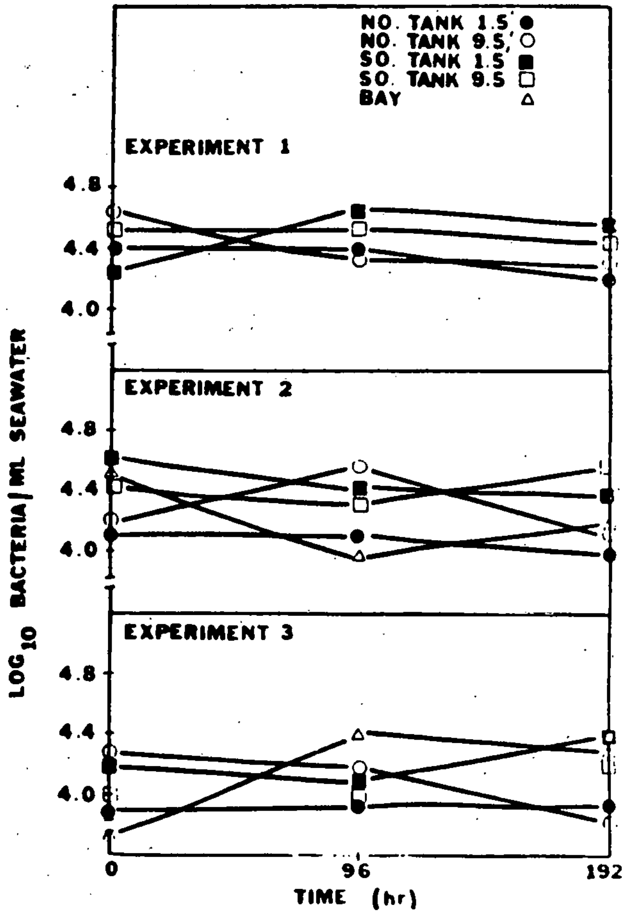


Fig. 8.11 Viable Plate Counts Validations of Test Tanks.

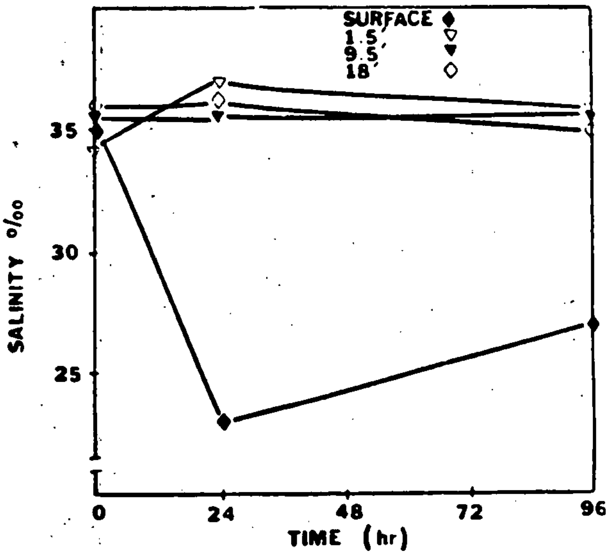


Fig. 8.12 Salinity Concentrations in the North Tank During Meso-Scale Experiment 1.

The reliability of viable plate count (VPC) and most probable number (MPN) data from the same test series is shown in Table 8.2 These values represent the numerical average of the same data points for three replicate experiments. There is a close correlation between the MPN and VPC values within a given tank as well as inter-tank values for the same sample times. The differences in values do not exceed one log and in most cases are much closer. As normally found in MPN and VPC, comparisons of bacterial numbers the MPN values are the higher of the two. These results were supported by carefully controlled laboratory experiments Figure 8.2.

TABLE 8.2 RELIABILITY OF VPC AND MPN DATA FROM MESO-SCALE TANKS

Determination	Sample day	North Tank	South Tank
MPN	0	$7.0 \times 10^{3*}$	1.1×10^5
VPC	0	1.5×10^4	1.7×10^4
MPN	4	1.6×10^4	1.1×10^4
VPC	4	1.4×10^4	2.3×10^4
MPN	8	2.2×10^4	1.3×10^4
VPC	8	8.6×10^3	1.9×10^4

*One test only.

The response of the total heterotrophic population to Kuwait crude oil and Kuwait dispersed with Corexit 9527 was tested in the meso-scale system. The north and south tanks each received 15 ppm of Kuwait and 3 ppm of Corexit 9527 was added to the south tank. The surface of both tanks received mixing (glass rod) for five minutes after chemical additions. Both tanks were sampled at 0, 24, 48 and 72 hours from the 1.5, 9.5 and 18 foot sample spigots. Dilutions from the samples were spread plated on to OZR medium and incubated at tank temperature (21°C) for six days.

The VPC data (Fig. 8.13) demonstrated more than one log increase during the first 24 hours in the dispersant treated tank (south tank), a level value between 24 and 48 hours, followed by a decrease in bacterial numbers at 72 hours. In the north tank, which received only Kuwait crude oil, there is an apparent trend for increased bacterial numbers during the 72 hour test period. The change in bacterial number in the north tank is minor compared to the south tank and may not represent bacterial growth but normal variation seen in VPC determinations. There was good correlation between bacterial numbers in the south tank and essentially the same values at all three test levels, suggesting a homogeneous mixture throughout the tank.

The enhanced growth in the dispersed oil tank could reflect metabolism of oil and/or dispersant. Mulkins-Phillips and Steward (11) in their experiments using gas chromatography to follow changes in components found that the dispersants were metabolized in preference to the C_{17} - C_{28} fraction of the Arabian crude oil used in their experiments. In contrast, Atlas and Bartha (12) using mineralization as a

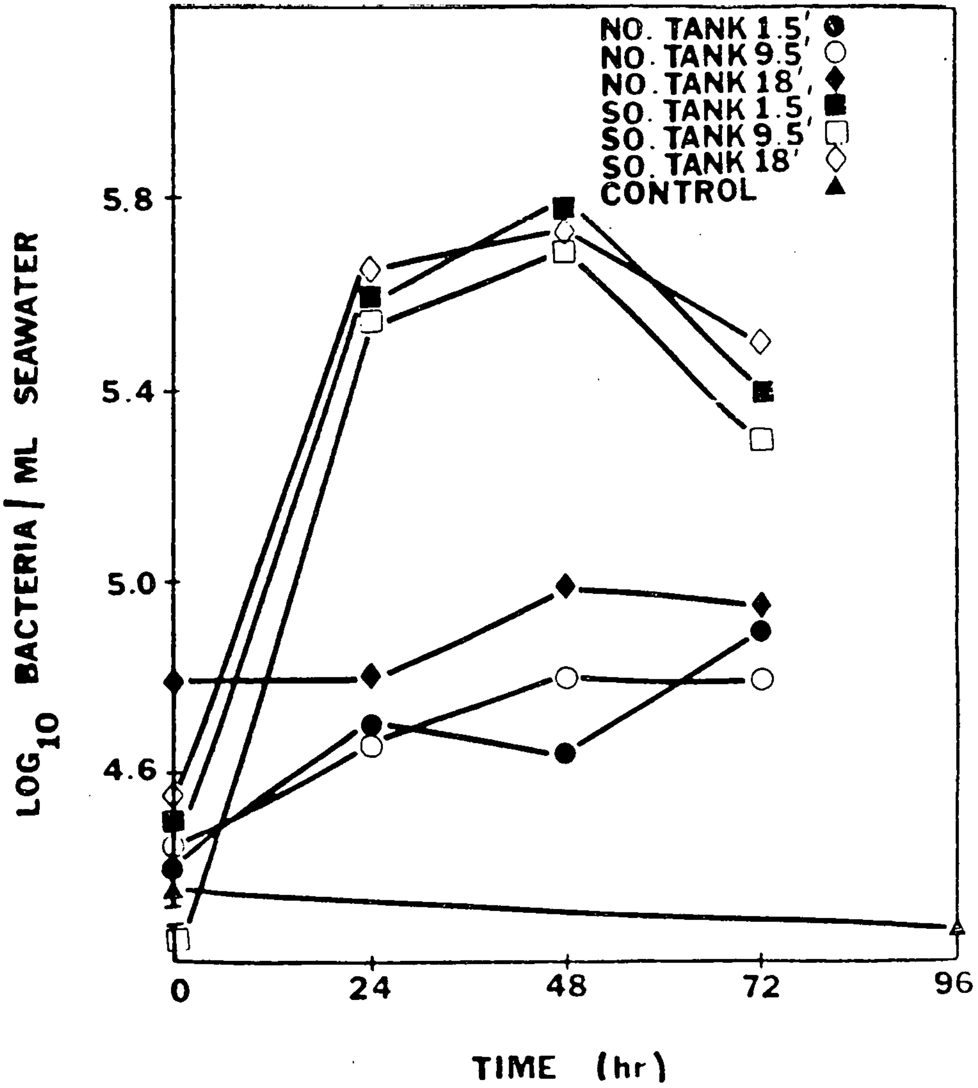


Fig. 8.13 VPC Data of Control, Kuwait Crude, and Kuwait Crude and Dispersant in the Meso-Scale Tanks.

measure of biodegradation, showed that dispersants increased the microbial utilization of Sweden crude oil.

The quantitative chemical analyses of the tanks for extractable organics (Exp. 2 Chemistry Section) demonstrated control values of 210 and 243 ppb in the seawater. The extractable organics in the oil tank are elevated only at the one hour samples taken at the top and mid zones of the tank. After one hour they return to or below background level. This would support the interpretation of no bacterial response in this tank. The quantity of extractable organics in the dispersant treated tank is significant at all levels and would provide sufficient substrate for increase in microbial numbers. The limiting factor, however, would be the quantity of nitrogen and phosphate available rather than carbon. The decrease in bacterial numbers between hours 48 and 72 (Fig. 8.13) are not related to carbon limitation which in all zones of the tank are well in excess of 500 ppb.

The qualitative GLC data from the chemical studies indicates loss of components boiling below n-C_{15} in the dispersant treated tank. The loss of these components may reflect biodegradation or evaporation or a combination of the two phenomenon and would support the observed increase in microbial numbers.

TABLE 8.3 OXYGEN DEPLETION RATES FROM MESO-SCALE EXPERIMENT 2
OIL AND OIL PLUS COREXIT 9527, mg L^{-1}

DAY	OIL			OIL AND COREXIT 9527		
	TOP	MID	BOT	TOP	MID	BOT
0	1.72	2.32	1.72	1.31	1.34	1.41
1	0.61	1.01	4.45	0.31	1.82	3.23
2	0.52	1.17	1.37	0.63	0.84	0.50
3	0.09	0	-	0.76	0.04	2.09

The oxygen depletion data from this experiment (Table 8.3) is highly confusing and apparently is of little value. The results were erratic except for day 0 results which were rather constant. A trend does exist in the dispersant treated tank which suggests increased activity with time at the lower region of the tank.

The third meso-scale experiment contained several modifications. The third tank was in place and used as a control tank containing only seawater. A cooling system was installed which maintained ambient bay temperature ± 2°C. An agitator was installed in the upper 2 feet of the water column and operated eight hours each day. Samples were taken from the 1.5, 9.5 and 18 foot levels at 24 and 48 hours. Samples were plated for both "total" heterotrophic bacteria (THB) and total number hydrocarbanoclastic bacteria (HYB) (Figures 8.14 and 8.15).

The THB counts (Figure 8.14) of bay water were constant over the two days of the experiment. The values in the 1.5 foot zone of the control

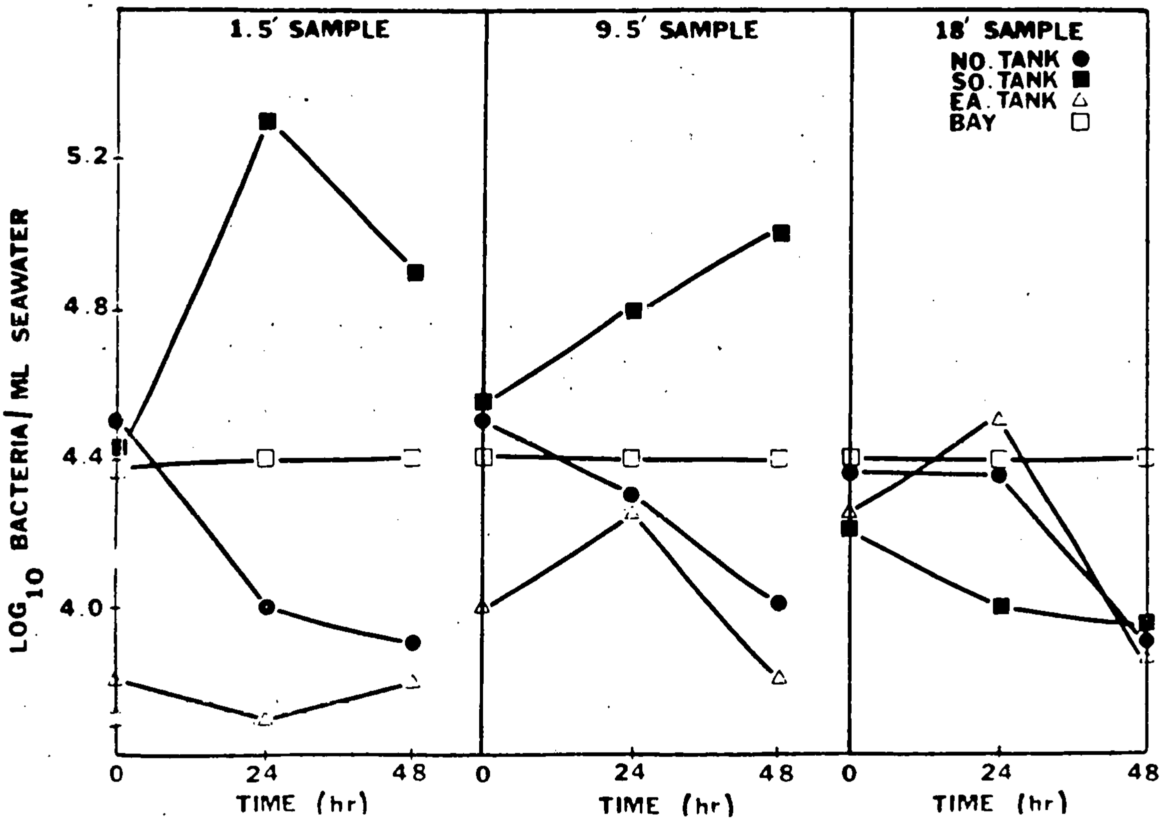


Fig. 8.14 Meso-Scale Experiment 3, Measured Heterotrophic Bacterial Growth.

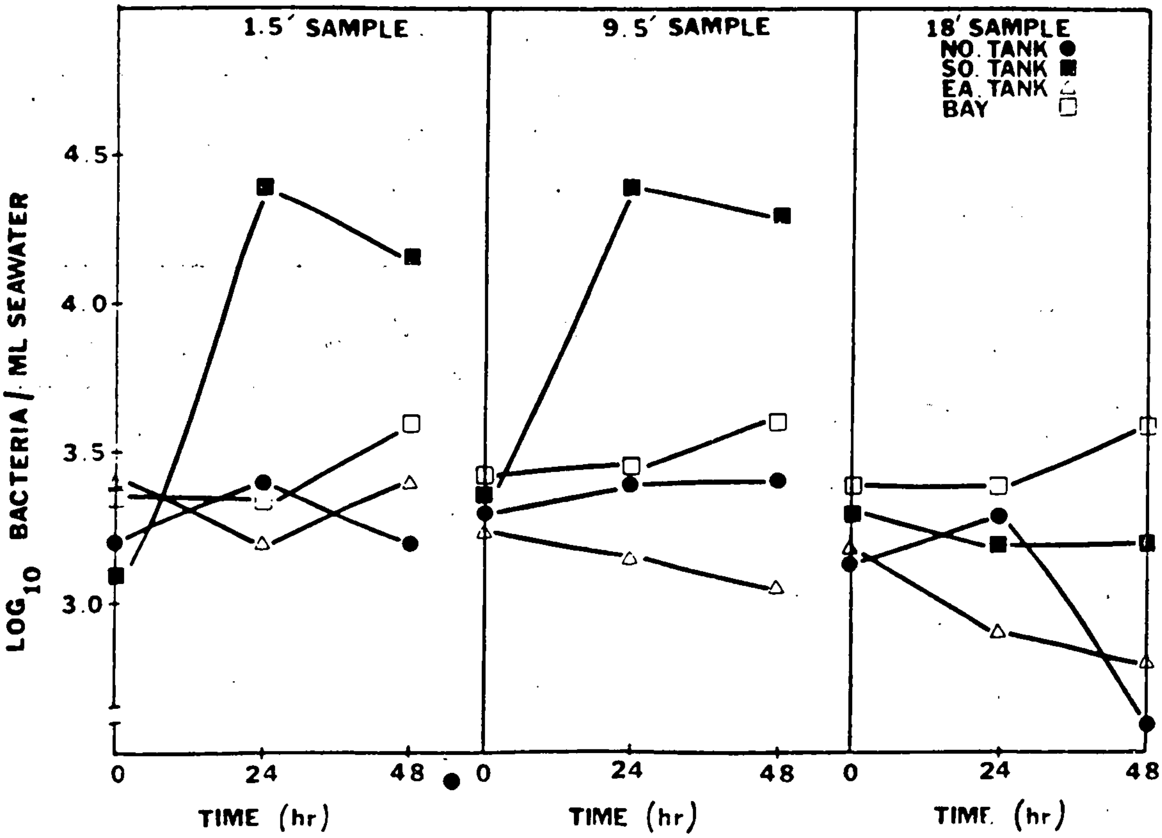


Fig. 8.15 Meso-Scale Experiment 3, Growth of Marine Hydrocarbon Degrading Bacteria.

tank were also constant but somewhat lower than the bay counts. There are apparent increases in THB of the oil plus dispersant tank which peaked at 24 hours at the top zone and 48 hours in the mid zone. However, the number of total heterotrophic bacteria in the bottom zone decayed over the course of 48 hours.

Although the actual number were somewhat less the trends for HYB were about the same as the THB counts. There was more stability in the top and mid zone counts which showed no significant change in HYB.

There appears to be a relationship between the number of hydrocarbon utilizing bacteria (HYB) and extractable organics in the water column. In the top and mid zones there are increased HYB present in the water column following the appearance of oil in a particular zone of the tank. For example, in the top zone hour 1 samples (chemistry data experiment 3) the oil concentration increased from about 450 ppb to nearly 2000 ppb between hours 1 and 24, and the HYB population also increased during this period. In the bottom zone the oil concentration never reached 900 ppb and there was no change in the HYB population. It might be inferred from this data that a critical oil concentration in the water is necessary for selection of hydrocarbon utilizing bacteria. Unfortunately, we cannot make the same comparison from the second experiment because we measured only THB.

Oxygen depletion measurements (Figures 8.16-8.23) essentially confirm the plate count and chemistry data. The initial biological activity was highest in the top zone of the oil-dispersant tank, somewhat decreased after 24 hours and had returned to baseline (control tank), rates by 48 hours. There is evidence of very little biological activity in the tank dosed with Kuwait crude oil. The bottom samples demonstrated no significant biological activity in the 0 and day 1 samples of either the oil or oil-dispersant tank. There is measurable activity in the oil-dispersant tank samples on days 2 and 3.

It was apparent from these two experiments that dispersed oil does induce slight increases in the total heterotrophic bacterial population (THB) and the hydrocarbanoclastic bacterial population (HYB). These effects were not as apparent as the results of the laboratory experiments of other investigators (11,12) in which the system was supplemented by the addition of nitrogen and phosphorus which are nutrient limiting in seawater.

Experiments were designed to determine the effects of oil and dispersant on bacterial population dynamics. These were small tank experiments under controlled laboratory conditions at $4^{\circ}C$ with sediment and seawater collected from Narragansett Bay. All tanks were gently shaken at 45 rpm and aerated to insure sufficient oxygen for maintenance of biological activity. The test series were: control seawater-sediment; Kuwait crude oil 15 ppm (v/v); Kuwait crude oil 15 ppm (v/v) plus 3 ppm (v/v) of Corexit 9527; and Corexit 9527 3 ppm (v/v). Samples were taken from the surface of the tanks (film area), mid water column and the sediments. Each sample was diluted and plated in duplicate onto OZR medium to express the heterotrophic bacterial population. Countable plates (30-300 colonies) were selected from each sample source to serve as

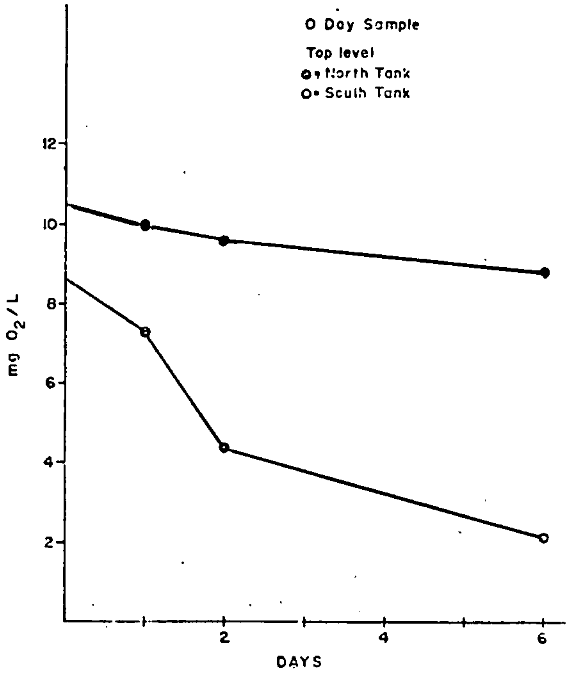


Fig. 8.16 Oxygen Depletion by Kuwait (North Tank) and Kuwait plus Corexit 9527 - Zero-Day Sample.

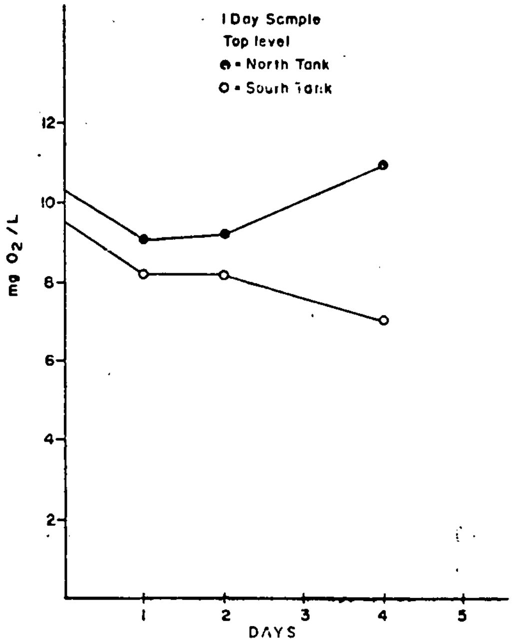


Fig. 8.17 Oxygen Depletion by Kuwait (North Tank) and Kuwait Plus Corexit 9527, One Day Sample. Top Level.

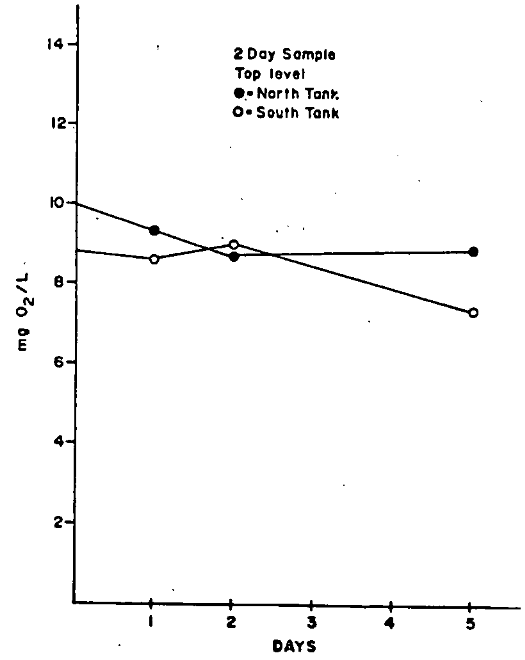


Fig. 8.18 Oxygen depletion by Kuwait (North Tank) and Kuwait Plus Corexit 9527 - Two Day Sample. Top Level.

and Kuwait Plus

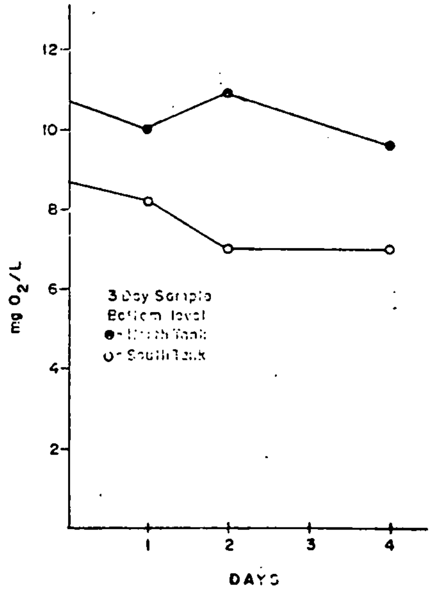


Fig. 8.19 Oxygen Depletion by Kuwait (North Tank Corexit 9527 - Three Day Sample. Bottom Level.

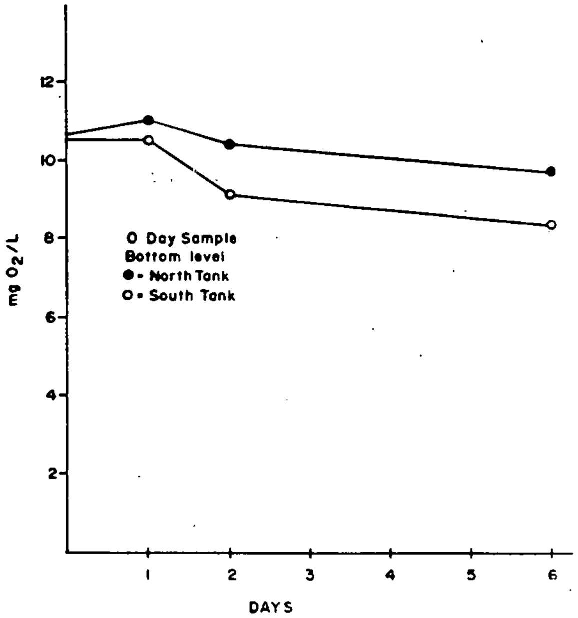


Fig. 8.20 Oxygen Depletion by Kuwait (North Tank) and Kuwait Plus Corexit 9527 - Zero Day Sample. Bottom Level.

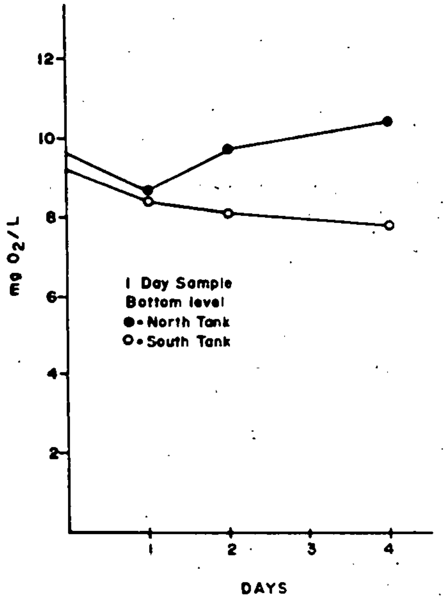


Fig. 8.21 Oxygen Depletion by Kuwait (North Tank) and Kuwait Plus Corexit - 9527 One Day Sample. Bottom Level

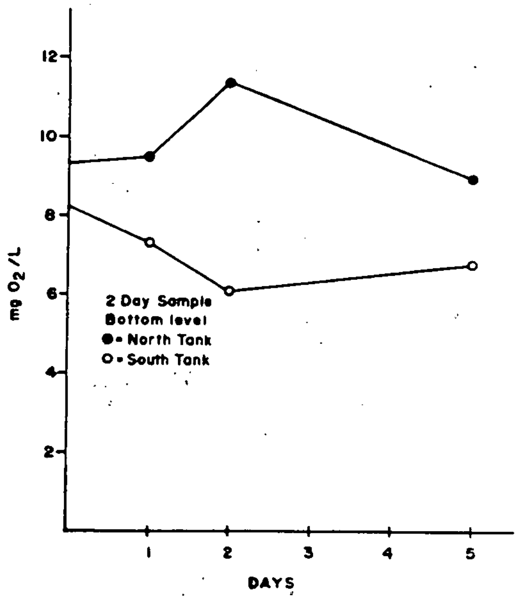


Fig. 8.22 Oxygen Depletion by Kuwait (North Tank) and Kuwait Plus Corexit - 9527 Two Day Sample. Bottom Level.

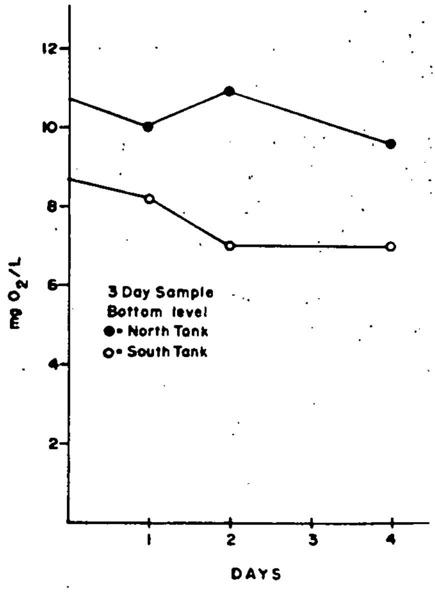


Fig. 8.23 Oxygen Depletion by Kuwait (North Tank and Kuwait Plus Corexit - 9527 Three Da Sample. Bottom Level.

master plates for replication. The master plates were replicated to n-hexadecane, napthalene, Kuwait and basal agars. All replicate and master plates were photographed in color for examination of colony types and verification of visual comparison made prior to photography.

The water column series included a Kuwait crude oil MPN series and duplicate sets of OZR plates incubated at 4°C and 13°C. The temperature differential test was performed to see if the system contained a mixture of psychrophilic and mesophilic bacteria which has been demonstrated to occur in Narragansett Bay (13,14).

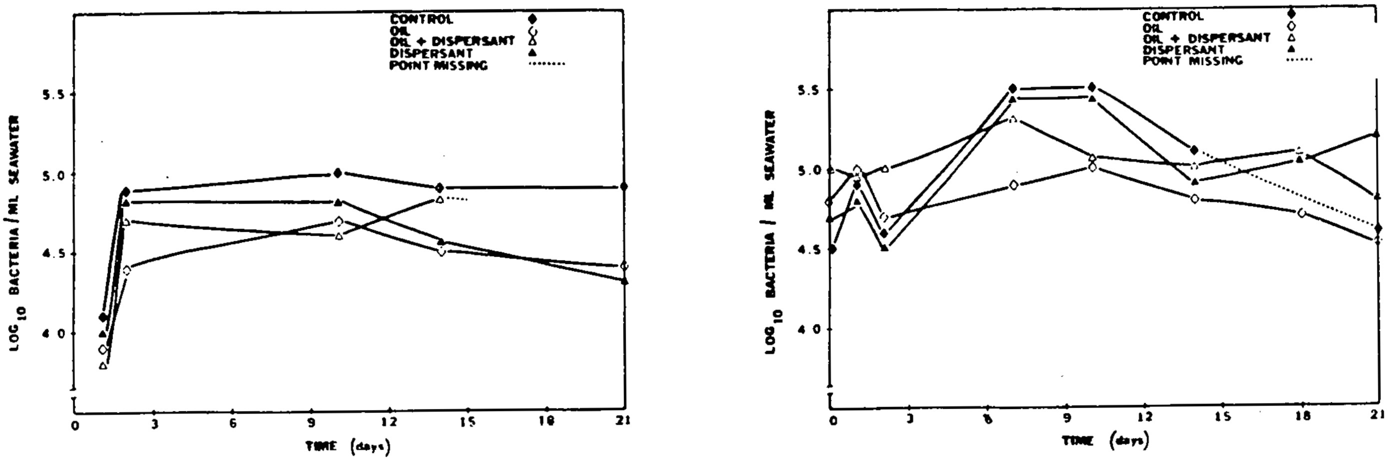
The VPC data for the surface films, sediment and water column at 13 and 4°C are shown in Figures 8.24 a-d. There was an increase in bacterial numbers of the surface film between day 1 and 2 in all four tanks. The least increase was in the oil tank which of course has an oil film at the air-water interface. The oil film was expected to destroy the function of the interface microlayer which typically shows considerable enrichment of bacteria and bacterial nutrients as compared to the water column. Indeed these increases in bacterial numbers could be interpreted as the forming of the microlayer rather than growth of bacteria. This hypothesis is supported by the organism increase in the control tank. The population size in all the surface samples does remain essentially constant through the 21 day experiment.

There are greater fluctuations in the sediment VPC data in all tanks. A general trend is apparent for an increase in the sediment bacterial population through day nine in the control, dispersant and oil-dispersant tanks. There is less of a trend for sediment enrichment in the oil tank. After day nine sediment numbers decline in the control and dispersant tanks but remain stable in the oil and oil-dispersant tanks.

The water column studies at 4 and 13°C are interesting in that they demonstrate evidence for two different populations, each with somewhat different dynamics. The initial 13°C population is larger than the 4°C population in the water column. There is a slight positive trend for the 13°C population through day 14 then a significant decline except in the control tank. On the other hand, the initial 4°C population is low in all tanks but rapidly increases by day three and then more slowly through day seven in all tanks. This is followed by a significant population decline, except in the control tank, through day 14.

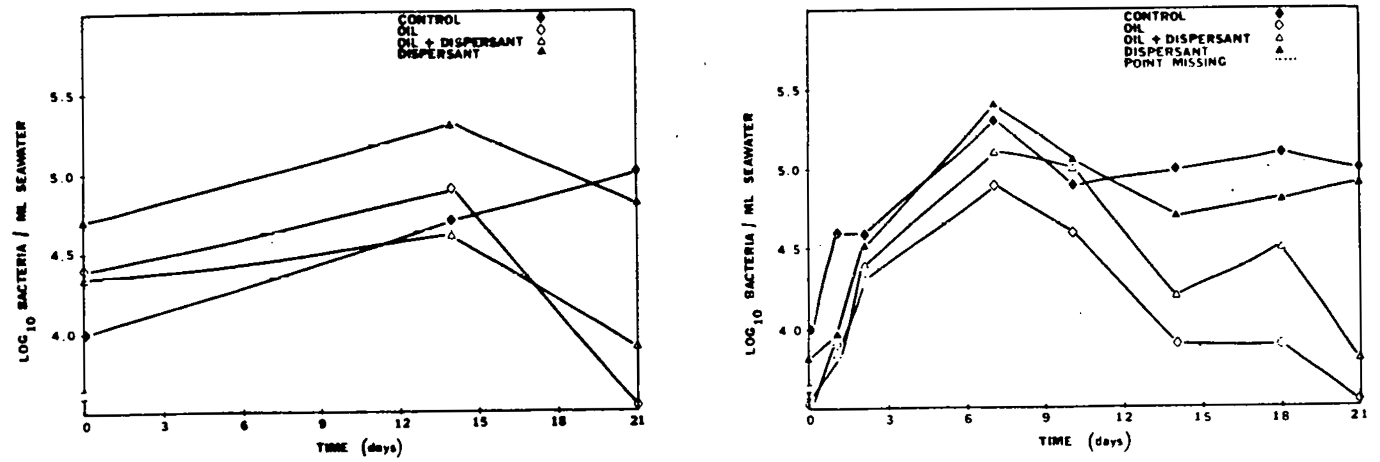
The numbers of HYB in the water column were determined by the VPC and MPN methods (Figure 8.25). As normally found in comparison of the two methods, the MPN values are higher than VPC values. This is partially explained by the fact that the two methods select for different heterotrophic populations (15).

In all the tanks using both the hydrocarbanoclastic MPN and VPC methods, there was a rapid increase in the number of HYB in all tanks until about day 7 after which the numbers declined to initial numbers found in the various tanks. The decline is less rapid by the MPN method but probably would have returned to baseline by days 18-20. We believe the decline is related to exhaustion of the N, P and Fe content of this closed system.



8.24 A Surface Samples

8.24 B Sediment Samples



8.24 C Water Column Samples at 13°C Incubation Temperature

8.24 D Water Column Samples at 4O°C Incubation Temperature

Fig. 8.24 Laboratory Experiment, Viable Plate Counts on OZR Medium from Surface *(A), sediment (B), and water column samples (C). Water column samples were incubated at 13°C and 4°C (D). Samples were taken from four aquaria with Narragansett Bay water plus: (1) control, (2) Kuwait crude oil 15 ppm (v/v), (3) Kuwait crude oil 15 ppm (v/v) plus 3 ppm (v/v) of dispersant Corexit 9527, and (4) Corexit 9527 3 ppm (v/v)*

It should be pointed out that this system received mechanical agitation which provides a rather uniform distribution of material throughout the water column as compared to the meso-scale tanks. Also the ambient temperature of the bay water and sediment used in this experiment was $1^{o}C$ so that the $4^{o}C$ incubations more nearly track bay conditions. It is significant that a sizeable population can be obtained at $13^{o}C$ incubation.

The diversity of the heterotrophic bacterial population was tabulated by counting the number of each type of colony on each of the OZR master plates from the surface film, water column and sediment samples. Colony morphology types and descriptions are given in Appendix I. The data indicate that the colony diversity decreased during the course of the experiment, with 2 or 3 colony types becoming predominant over the 21 day time frame of this experiment. The decrease in colony diversity occurred to a greater extent in the water column and surface film than in sediments.

In order to simplify the expression of colony diversity two methods were employed in analyzing the data from Appendix 2. In Fig. 8.26 colony diversity was expressed as the change in the number of colony types occurring on OZR master plates over time. The data depicts the decline in the number of colony types with time in the aquarium system. The other method of simplifying the expression of colony diversity was to quantify the degree of dominance within the total heterotrophic population of each OZR master plate.

Dominance was quantified by the equation $c = (n_i/N)^2$ where c the dominance factor is equal to the square of the ratio n_i the number of colonies of each colony type divided by N the number of colony types (100). The larger the value of c the greater is the predominance of bacterial species within the given population. The results are given in Fig. 8.27. The relationship between Fig. 8.26, the degree of dominance, and Fig. 8.24, the change in total heterotrophic bacterial numbers, suggests that the increase in bacterial numbers in all four aquaria was accomplished by a few bacterial species that predominated in the stressed environment of the aquaria system.

The degree of change in the heterotrophic bacterial population demonstrated a similar trend in all four aquaria. The data indicates that the aquaria system used was responsible for the changes in the bacterial populations and that the system used exerted a greater stress on the heterotrophic population than did the Kuwait crude oil and/or Corexit 9527. These findings are in concurrence with results published by Kaster and Van Auken (75). Kaster and Van Auken examined bacterial populations from the surface waters of the Gulf of Mexico over an eight week period. In their experiment South Louisiana Crude oil (0.5%) was added to one flask system and another flask served as a control. Over the eight week period there was an increase in bacterial numbers but a decrease in the bacterial diversity in both flasks. No significant difference in the heterotrophic bacterial population was detectable between the oiled flask and the control flask.

The replica plating data in Appendix 2 was incorporated with the data on the diversity of the heterotrophic bacterial population because the

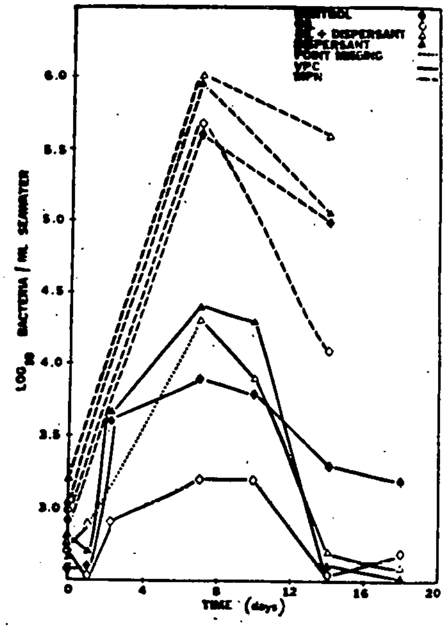


Fig. 8.25 Laboratory Experiment, Viable Plate Counts (VPC) and Most Probable Numbers (MPN) with Kuwait Crude Medium.

(MPN) with Kuwait Crude medium incubated at 4^oC were processed from water column samples. Four aquaria with Narragansett Bay water plus: (1) control, (2) Kuwait crude oil 15 ppm (v/v), (3) Corexit 9527, 3 ppm (v/v), and (4) Corexit 9527 3ppm (v/v). (MPN data points one day seven for the control and oil tanks were 5.6+, meaning the real value is greater than 5.6 but of an unknown amount.)

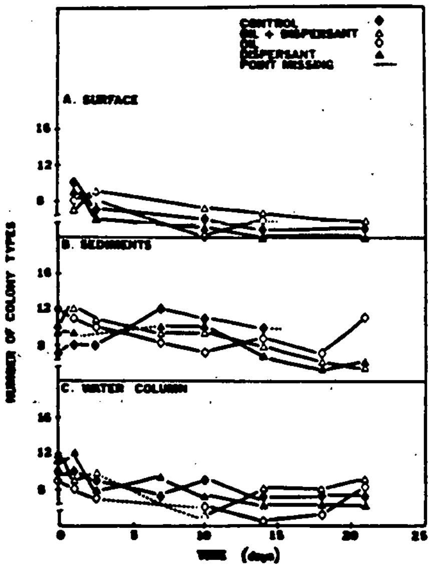


Fig. 8.26 Colony Diversity Expressed as Number of Colony Types over Time

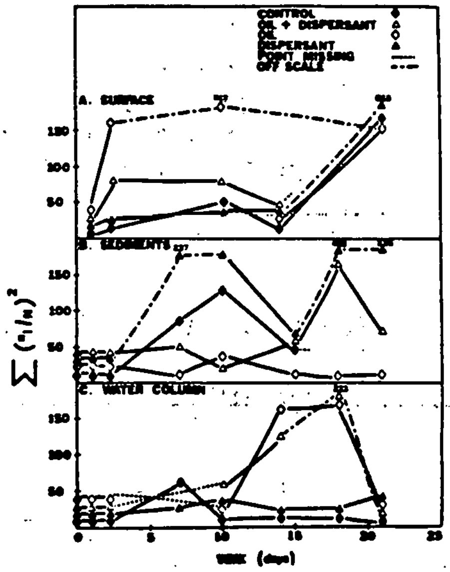


Fig. 8.27 Colonv Diversity Expressed as Quantification of Dominance

Fig. 8.26 and 8.27. Colony diversity of heterotrophic bacterial population on OZR master plates from surface, water column, and sediment samples. Narragansett Bay water plus: (1) control, (2) Kuwait crude oil 15 ppm (v/v), (3) Kuwait crude oil 15 ppm (v/v) + 3 ppm (v/v) of the dispersant Corexit 9527, and (4) Corexit 9527 3 ppm (v/v). The heterotrophic diversity is expressed as: (1) the total number of colony types on OZR master plates and (2) by the degree of dominance given by $C = \Sigma(n_i/N)^2$, where n_i equals the number of colonies of each colony type and N equals the total number of colony types.

oil degrading bacteria grew on both the OZR master plates and the hydrocarbon replica plates. The data suggests that no enrichment for hydrocarbon degraders occurred in the aquarium system as was originally anticipated. Table 8.4 exemplifies the data on the presence of hydrocarbon degraders during the time of the laboratory experiment. In Table 8.4 the number and type of hydrocarbon degraders are given from the Kuwait crude aquarium. The data exemplifies the low numbers and random nature of the presence of oil degraders in the aquarium system. The lack of enrichment may have been due in part to the stress of the aquarium system as mentioned previously and the cold temperature (4°C) of the seawater. The hydrocarbon metabolizing bacterial isolates usually metabolized only one of the hydrocarbon substrates with only a few being able to metabolize two or three substrates. The lack of predominance by any bacterial hydrocarbon utilizing species, as determined by colony diversity suggests that the different fractions of the Kuwait crude were simultaneously metabolized. Simultaneous metabolism is further substantiated by the even distribution of bacterial colonies growing on the different hydrocarbon substrates. Zobell (145) suggested that simultaneous metabolism of oil would occur under low substrate conditions. The aquarium system with 15 ppm (v/v) of Kuwait crude oil at 4°C would have very little oil in the water column due to the low solubility of Kuwait crude at this low temperature. The dispersant was probably inefficient in dispersing the oil in the aquarium system because of the low volumes applied, the difficulties of properly applying the small volume of dispersant, and because the oil often became stuck to the sides of the aquarium and the glassware making it unavailable for mixing with the seawater and dispersant.

Table 8.4 Hydrocarbon utilizers in heterotrophic bacterial population as determined by replica plating. Samples were taken from the Kuwait crude aquarium in the laboratory experiment. Colony types are given in Appendix 1.

	Hydrocarbon Utilizers						
Day	Kuwait Crude		Hexadecane		Naphthalene		Total
	Colony type	#	Colony type	#	Colony type	#	#
0	19	4	16	2			
			23	1	15	2	9
1	19	1					
	3	1		0		0	4
	1	2					
2	19	1					
	25	1		0		0	2
7		0	4	4		0	4
14	19	1		0		0	1
18		0		0		0	0
21	19	3					
	3	2	4	1	15	2	8

A long term experiment was designed to develop an approach for conversion to a flow-thru test system. The test system utilized four 55 gallon microcosms structured as diagrammed in Figure 8.28. Fresh seawater from the Jerusalem station, where the tests were performed, was introduced to the microcosms via a jet system which established a circular subsurface flow pattern in the top portion of the microcosms. The water was removed from the bottom zone so that flow was from the top reaction zone to the tank bottom where the test scallops were located. these systems all contained a sediment base obtained from the water adjacent to the Jerusalem test facility.

The Data Input-Output of this experiment is summarized in Table 8.5.

Table 8.5 Data Input-Output, Jerusalem Flow-Thru System,
5/7/79 - 7/2/79

Control TMB	Oil TMB	Dispersant TMB	Oil-Dispersant TMB

INPUT	Output
1. THB plate counts	no ml^{-1}
2. HYB plate counts	no ml^{-1}
3. Total Hydrocarbons	ppb
4. Hexadecane mineralization	ng hr^{-1}
5. Hexadecane Turnover Time	weeks
6. Naphthalene mineralization	ng hr^{-1}
7. Naphthalene Turnover Time	weeks
8. Hydrocarbon Degradation Time	hours
9. Temperature	^{o}C
10. Salinity	ppt
11. Phosphate	ug ml^{-1}
12. Ammonia	uM
13. GLC	Recorder plot
14. Scallop Mortality	No. dead
15. Scallop Behavior Responses	No. Swimming Claps

The data collected in the experiment is presented in computer entry format (Table 8.6). This data was analyzed by multiple regression and other techniques.

Multiple step-wise regression analysis of the data on this long term (5/7/79 - 6/25/80) experiment indicated no significant correlations between a number of the experimental parameters. A 0.5000 significance level was established for entry into the model.

There were no significant correlations between total hydrocarbon concentration and day of sampling or samples from top, middle or bottom portions of the flow-thru tanks. The tank temperatures increased from a low of 10.6^{o}C to a high of 18.7^{o}C over the course of the 50 day experiment but showed us correlation to total heterotrophic bacteria, total hydrocarbanoclastic bacteria, or hydrocarbon mineralization rates. A positive correlation was not found between total hydrocarbon concentration in the water column and either hexadecane or naphthalene mineralization rates. There was, however, a negative relationship when mean values (Table 8.7) were examined indicating inhibition of mineralization rates

Table 8.6. Data from Jerusalem Flow - Thru System, 5/7/79 - 7/2/79, Computer Format

Date	Tank Loc.[a]	THB[b] x 10^3				HYB x 10^2				Hexadec Mineralization ng/hr.				T/f C-16 weeks			
5/7/79 (1)	1	3.9	3.9	6.1	76	14	14	20	81	2.2	9.	16.7	1.9	1109	271	146	1262
5/7/79 (1)	2	66	66	17	16	67	67	33	48	3.	2.	1.3	1.4	813	1220	1927	1743
5/7/79 (1)	3	2.2	2.2	6.2	5.8	2.7	2.7	13	31	5.3	1	1.6	1.1	460	2440	1494	2287
5/14/79 (8)	1	1.4	1.4	4.2	7.7	2.3	2.3	9.4	9.0	10.6	10.1	4.3	13.9	230	241	196	176
5/14/79 (8)	2	6.4	6.4	3.4	5.6	5.5	5.5	3.1	1.7	5.6	27.3	30.3	4.8	433	89	81	505
5/14/79 (8)	3	2.1	2.1	4.5	2.7	1.4	1.4	4.9	2.2	28.5	.97	11.2	7.7	29	2525	219	318
5/21/79 (15)	1	3.6	3.6	5.1	7.5	3.5	3.5	1.9	8.2	4.3	9.3	3.5	5.6	568	263	697	436
5/21/79 (15)	2	8.3	8.3	7.2	2.4	9.7	9.7	2.0	13	4.7	6.3	9.3	5.2	516	385	263	160
5/21/79 (15)	3	4.6	4.6	5.9	5.4	5.5	5.5	4.0	3.8	5.8	3.7	4.4	6.6	418	666	555	371
5/29/79 (23)	1	.9	1.7	1.3	3.3	.63	6.7	1.2	5.3	2.3	12.7	21	27	1046	193	116	90
5/29/79 (23)	2	.76	3.2	1.1	9.3	.26	1.4	2.1	.4	19.7	15	19	2.1	124	163	128	1181
5/29/79 (23)	3	.33	5.6	1.2	1.4	.2	.7	1.6	1.8	71.3	23	6.5	35	32	106	377	70
6/4/79 (29)	1	.33	.6	1.7	1.8	.13	5.0	3.0	6.0	17	10.9	16	10.7	144	225	153	227
6/4/79 (29)	2	.53	.6	1.3	.3	.4	1.1	.63	3.3	.1	2.8	6.2	5	2440	872	392	485
6/4/79 (29)	3	.5	1.2	1.3	.53	.57	4.3	.7	1.3	8.9	11.7	7.7	1.2	273	209	316	2034
6/11/79 (36)	1	1.3	5.4	2.2	4.1	1.8	4.4	6.8	4.0	10.6	11.3	11.6	7.4	230	215	210	331
6/11/79 (36)	2	.87	3.8	1.2	3.5	.8	.7	2.6	6.5	9.6	9.1	15.7	7.4	254	267	156	328
6/11/79 (36)	3	.8	2.5	.93	.15	.23	3.2	.8	3.4	9.8	10.8	11.3	9.8	250	227	215	250
6/18/79 (43)	1	1.6	4.7	.81	2.2	1.7	2.6	4.7	9.3	42.7	34	11.6	6	57	72	210	405
6/18/79 (43)	2	2.1	.7	.17	11	2.7	2.7	.5	4.8	38	7.2	15.7	2.3	64	339	156	1061
6/18/79 (43)	3	3.0	1.4	.6	6	1.0	5.1	2.2	4.3	4.3	3.2	13.3	12.5	572	763	183	195
6/25/79 (50)	1									11.7	10.6	9	24.6	140	231	272	99
6/25/79 (50)	2									3.7	8.2	4.8	9.1	666	299	505	268
6/25/79 (50)	3									15.4	11.1	4.7	17	158	220	519	144

a: 1 = top; 2 = Mid; 3 = Bottom b:column 1=control; column 2 = Oil; column 3=Dispersant; column 4=oil-dispersant, this sequence is used for all following data entries.

Date	Naphthalene Mineralization ng/hr.				T/f Naph. weeks				Total Hydrocarbon ppb				Temp. °C	Salinity ppt
(1)	20.3	20.3	22	3.3	70	70	65	437	89	230	9598	3611	10.6	31
(1)	.77	1.3	39.6	21.7	1863	1099	36	66	326	44	20082	941	10.6	31
(1)	59.7	25.	43.3	34.8	24	57	33	41	89	46	3992	304	10.6	31
(8)	20.6	4.1	8.6	15.1	70	351	167	95	332	355	1215	252	11.9	28
(8)	1.7	15.3	33.9	1.4	857	94	42	997	342	539	3071	257	11.9	28
(8)	22.1	4.2	1.5	9.6	65	344	974	149	356	303	949	2043	11.9	28
(15)	73.3	4.3	13.1	8.6	13	330	109	167	515	415	319	637	13.7	30.5
(15)	2.8	18	39.3	13.7	504	79.	36	105	416	406	306	897	13.7	30.5
(15)	20.3	14.8	2	1.8	70	97	714	816	507	402	515	624	13.7	30.5
(23)	25	16.5	1.2	69.7	57	87	1224	21	106	197	99	60	14.8	
(23)	68.5	30.7	36.7	34.7	21	47	39	41	76		104	56	14.8	
(23)	235	43.7	5.4	81.3	6	33	266	18	75	77	79	87	14.8	
(29)	15.7	2	11.6	9.4	91	726	124	152					16.6	27
(29)	.7	2.4	2.3	5.	2198	595	612	284					16.6	27
(29)	7.3	6.2	39	1.7	195	229	37	840					16.6	27
(36)									103	1170	11,499	2066	18.7	29
(36)									116	1639	5,723	1834	18.7	29
(36)									110	301	1,344	2235	18.7	29
(43)	17.3	17.6	150.5	4.2	82	81	10	340	354	436	352	318		
(43)	19	28.6	196.5	3.4	75	50	7	424	369	346	306	330		
(43)	3.5	6.8	4	1	414	209	362	1429	246	213	351	333		
(50)	2	.8	12.7	11.1	726	1863	.12	129	206	166	216	201	17.2	30
(50)	4	1	.7	12.2	360	1478	2040	117					17.2	30
(50)	7	6.2	.8	18	205	230	1863	80					17.2	30

Date	PO_4 ug/ml				NH_4^+ uM			
(1)	.3	.17	.3	.19	32	30	47	60
(1)	.3	.3	.1	.3	40	30	30	30
(1)	.11	.11	.1	.11	54	24	30	60
(8)	0	0	0	0	30	30	25	55
(8)	0	0	0	0	22	65	30	77
(8)	0	0	0	0	29	50	100	65
(15)	0	.12	.14	0	65	66	40	45
(15)	0	0	0	0	60	43	43	60
(15)	.39	0	.69	.17	60	33	40	28
(23)	.71	.43	.46	0	17	5	8	9
(23)	.52	.57	.68	0	11	37	20	8
(23)	.64	.43	.47	.1	27	42	17	27
(29)	.9	.4	.4	1.2	11	12	11	10
(29)	.5	.5	.6	0	15	20	11	11
(29)	.6	.4	.4	.4	24	11	22	12
(36)	0	1.2	1.5	.3	27	27	29	23
(36)	0	.2	1.4	.3	18	33	27	19
(36)	0	.3	2.9	.4	20	37	32	33
(43)	0	1	0		26	21	13	26
(43)	0	.5	0		26	21	27	27
(43)	0	.3	0		28	17	35	26
(50)								
(50)								
(50)								

Table 8.7 Mean Values from the Jerusalem Flow Thru Tests

Tank	No Bact x 10^3 Hetero	No Bact x 10^3 Hydrocarb	Hexadec* mineral ng/hr.	Hexadec* T/f weeks	Naph* mineral ng/hr.	Naph* T/f weeks	Total Hydrocar ppb	Total mineral rate	D/f, hrs. Total hydrocarbon
Control	5.3	2.8	11.99	373	19.58	205	107	(31.48)	3.4
Oil	6.2	4.1	10.25	342	8.34	253	279	(18.59)	15.0
Dispersant	3.5	2.5	9.84	275	16.72	261	1534	(26.56)	57.8
Oil and Dispersant	8.2	6.3	8.62	344	11.09	193	475	(19.71)	9.8

*Tested against ≠/mg substrate

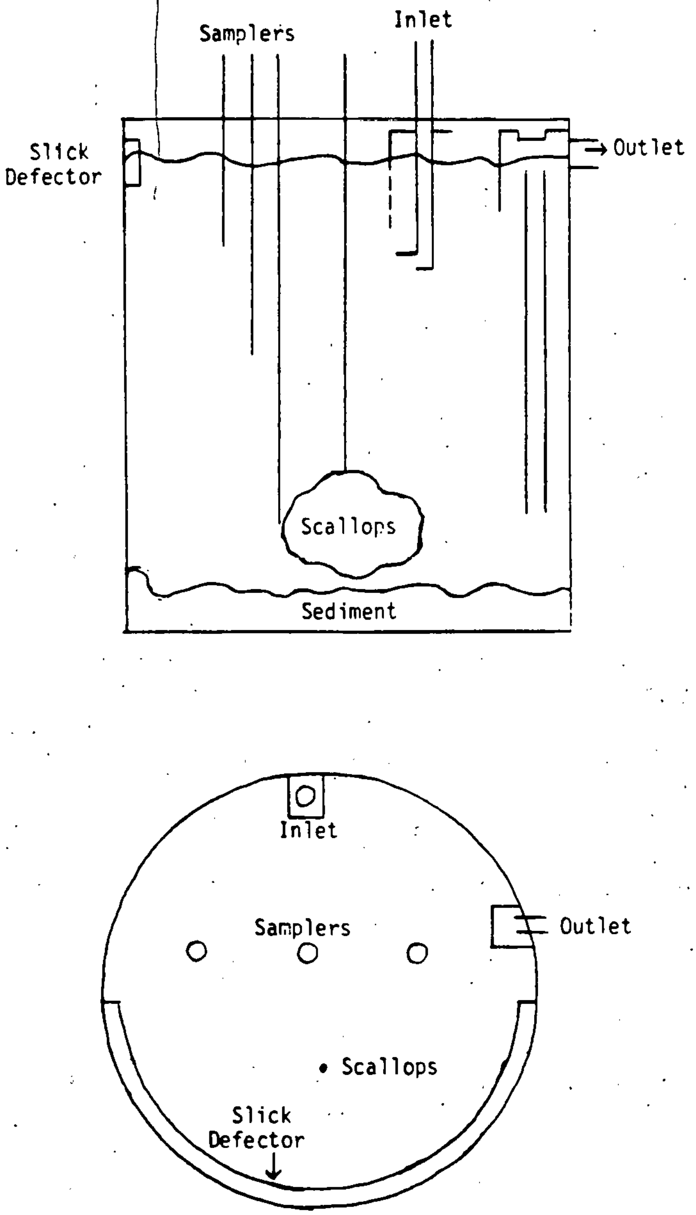


Figure 8.28 Test System for 55 Gallon Microcosm Flow Thru Experiment

in the presence of higher concentrations of hydrocarbon or dispersant. This observation cannot be explained with the existing data.

There was a significant correlation between the number of total heterotrophic and total hydrocarbanoclastic bacteria in the various test tanks. The numbers of hydrocarbanoclastic bacteria were always lower than total heterotrophic bacteria, but approach unity in the oil and dispersant treated tanks (1.3) and are further from unity in the seawater control tank (1.8). These data do indicate selection for hydrocarbanoclastic bacteria in tanks containing oil and/or dispersant.

There was a decrease in hydrocarbon turnover time in the oil and/or dispersant tanks which is most apparent for turn over of aliphatic hydrocarbons whereas the effect is less apparent for aromatic hydrocarbons. Generally, however, aromatic hydrocarbons are mineralized more effectively than the aliphatic constituents. It must be noted, however, that the aromatic hydrocarbons turned over in this series represent lower molecular material than the turned over aliphatic material that was turned over.

Since the actual mineralization rates show little variation the degradation time in a particular situation becomes primarily a function of hydrocarbon concentration. It now becomes apparent that degradation potential is a fairly constant value in the marine environment. The changes in temperature, salinity phosphate and ammonia nitrogen are more apparent than real. For example, the highest phosphate and ammonia values are limiting for the amount of carbon in the environment and hence do not manifest a measurable effect upon the test parameters. The temperature span was only 8.1°C which is significantly below the 10°C span for a Q_{10} value of 2 normally expected. However, it has been shown previously (Traxler and Cundell, 1975) that the Q_{10} values for hydrocarbon utilization in marine systems vary between 1.3 and 1.8. Therefore with the 8.1°C span we would not expect to measure a significant temperature effect. Salinity changes were not significant for bacterial activity.

Four meso-scale tank experiments were performed in May, June and July 1980 to compare two dispersants, Corexit 9527 and BP 1100WD. In experiment 1 (5/19 - 5/23) the two test tanks (N and S) were dosed with 120 ml of Kuwait crude oil and 6 ml of Corexit 9527. The oil and dispersant were premixed at the test site and applied to the top of the water column. The agitators were run for an 8 hour on, 16 hour off cycle for the 5 day test period. Experiments 2, 3 and 4 were conducted as a direct comparison of the two dispersants. The north tank contained 120 ml of Kuwait crude oil plus 6 ml of Corexit 9527 while the south tank was dosed with 120 ml of Kuwait crude oil and 6 ml of BP 1100WD. Water samples were collected from the top port located in the mixing zone and from the outlet port for bottom samples.

Hydrocarbon analyses were performed using a quantitative gas chromatography method (Butler and Levy, 1978) which involved 12 hour continuous liquid-liquid extraction of the samples with n-pentane followed by a 12 hour extraction with benzene. These extracts were desulfured by passing through copper shavings, concentrated by flash evaporation and placed on a silica gel over alumina column. The alkanes were eluted with n-pentane and the aromatics with benzene. Both fractions were concentrated to 0.5 ml and 2 ul injected onto the proper column with a predetermined temperature program for chromatography. Samples were spiked with a known quantity of pristane and anthracene prior to extraction (internal standards) and all determinations were computer integrated against the internal standards. External standards were determined using the same quantity of pristane and anthracene for calculation of extraction efficiency. This method provided the concentration of total aliphatics in ppb and total aromatics in ppb. Addition of these two values provided total hydrocarbon in ppb.

Quantitative gas chromatography was used to determine the total peak area of Corexit 9527 in the water stock solutions used in the scallop experiments presented in Section 9 of this report. This value was then converted to mg 1^{-1} as oil and substracted from the integrated total hydrocarbon in the oil dispersant mixture. The results of these quantitative determinations are shown in Table 8.8. These results show ratios of oil to dispersant identical to those determined by the infra-red method (Table 4.5.4 this report).

Microbiological activity was measured in the mixing zone of all tanks and degradative activity determined as mineralization rate for total hydrocarbon using hexadecane, naphthalene and benzo (a) pyrene as representative hydrocarbons. These were used to spike 50 ul of Kuwait crude oil in their ratio present in the oil (1.0:0.5:0.1). The challenge was against the test tank microflora in 3 hour determinations.

The quantitative data for hydrocarbon concentration in the meso-scale tanks are summarized in Tables 8.9-8.12. The amount of oil in the untreated seawater ranged from 103-121 ppb except for one determination thought to be contaminated in the laboratory extraction process. Dispersant carried considerable oil into the water at the mixing zone during day one. Elevated levels of oil remained in the mixing zone during the course of all experiments. The values varied from experiment to experiment but generally were found to be in thousands of ppb. The ratio of aliphatic to aromatic hydrocarbon also varied in the various samples and different experiments.

In these experiments, there was little oil carried to the bottom of the test tanks, the values being 2 to 3 times the control water values but manyfold less than the mixing zone values. These experiments confirm earlier data which suggest essentially the same phenomenon of dilution through the water column. Both dispersants (Corexit and BP) respond alike in the entrainment of oil in the mixing zone and dilution through the water column. The toxicity tests to scallops are discussed in the biology section and indicate no effect at these measured concentrations of oil. The scallops from the control tank were combined and extracted as a unit then analyzed for hydrocarbon content. The composite of the test scallops were also analyzed in the same fashion.

The result of oil analyses on the scallops (Table 8.9-8.12) show identical low values (6ppb) in experiment 1, slightly elevated levels in the BP 1100WD treated scallops in experiment 2 and 3 but still well below anticipated toxicity values. These animals were exposed to oil levels well above those detected in the animals. The data suggests that the scallops do not accumulate oil.

Table 8.8 Hydrocarbon Concentration in Behavioral Test Stock Solutions

	Hydrocarbon mg/Liter		
Stock Solution	Aromatic	Aliphatic	Total
Kuwait Crude Oil	26.34	18.28	44.62
Corexit 9527	19.54	13.88	33.42
Kuwait Crude Oil Plus Corexit 9527	39.14	20.78	59.92
Oil in Mixture	19.60	6.9	26.5

Table 8.9 Experiment 1:
Hydrocarbon Content of Water and Scallop Samples

Date	Tank	ppb Aliphatic	ppb Aromatic	ppb Hydrocarbon
5/19	ST	269	340	609
	SB	27	180	207
5/21	ST	-	-	-
	SB	173	148	321
5/22	ST	1647	126	1773
	SB	-	-	-
5/19	NT	1009	429	1438
	NB	69	lost	lost
5/21	NT	633	533	1166
	NB	-	-	-
5/22	NT	GC Abort	40	-
	NB	-	-	-
5/19	CT	64	52	116
	CB	1	5	6
5/23	Cont. Scallops	2	4	6
5/23	Test Scallops	4	2	6

N and S tanks were dosed with 120 ml oil and 6 ml Corexit 9527 (1:20) premixed. Agitator used. Extraction efficiency 91%.

Table 8.10
Experiment 2. Hydrocarbon Content of Water and Scallop Samples

Date	Tank	ppb Aliphatic	ppb Aromatic	ppb Hydrocarbon
6/3	ST	280	560	840
	NT	4,500	1,760	6,260
	CT	10	93	103
6/4	ST	13,000	2,300	15,300
	NT	9,040	760	9,800
	CT	460	88	548
6/5	ST	2,280	500	2,780
	SB	53	70	123
	NB	2,552	18	2,570
	CB	15	-	-
6/6	ST	22,780	1,520	24,300
	NT	4,100	500	4,600
6/9	ST	1,696	520	2,216
	SB	21	178	199
	NT	640	1,760	2,400
	NB	16	-	-
	CT	40	30	70
6/9	Cont Scallops	5	14	19
	S Scallops	6	26	32
	N Scallops	2	14	16

N Tank dosed 120 ml oil and 6 ml Corexit 9527
S Tank dosed 120 ml oil and 6 ml BP 1100 WD
Oil and dispersants premixed. Agitator used. Extraction efficiency 96%.

Table 8.11
Experiment 3: Hydrocarbon Content of Water and Scallop Samples

DATE	Tank	ppb Aliphatic	ppb Aromatic	ppb Hydrocarbon
6/16	ST	180	1480	1660
	NT	60	2840	2900
	NB	6	21	27
6/17	NT	180	399	579
6/18	NB	6	50	56
6/19	ST	100	2040	2140
	NT	20	4540	4560
6/20	ST	40	1000	1040
	NT	180	500	680
	CB	8	113	121
6/19	Scallops Con	8	89	97
	Scallops N	9	1	10
	Scallops S	4	82	86

N tank dosed 120 ml Kuwait and 6 ml Corexit 9527. S tank dosed 120 ml Kuwait and 6 ml BP 1100 WD.

Table 8.12
Experiment 4. Hydrocarbon Content of Water and Scallop Samples

Date	Tank	ppb Aliphatic	ppb Aromatic	ppb Hydrocarbon
7/7	ST	140	400	540
	NT	200	500	700
	NB	8	-	-
7/8	ST	60	640	700
	NT	40	1680	1720
	CT	60	640	700
7/9	ST	-	20	-
	SB	-	1.25	-
	NT	40	20	60
7/11	ST	60	20	80
	NT	-	66	-
	NB	1.25	1.25	2.5
7/11	Scallops N	1	104	105
	Scallops S	-	78	-
	Scallops Cont	88	28	116

N Tank dosed 120 ml Kuwait and 6 ml Corexit 9527
S Tank dosed 120 ml Kuwait and 6 ml BP 1100 WD.

The biodegradation data is summarized in Table 8.13. Calculation of turnover time was based on recovered radioactivity and is expressed as T/f·R in hours. In these experiments, we measured not only mineralization but also the hydrocarbon converted to low molecular weight water soluble products and alcohol soluble products. This is a more accurate measurement of degradative potential than mineralization alone. We challenged the microbial populations with a constant quantity of substrate oil (50 μl) which eliminates the tank variable of oil concentration and allows full expression of the potential. The organisms in the control tank yield constant T/f·R values of approximately 7 hours. This is the time required to completely turnover a standard amount (55.8 ng) of the challenge ^{14}C hydrocarbon mixture. This factor is therefore a measure of biological activity against a fixed amount of substrate and can be used to estimate the degradation potential or time required to degrade the amount of oil in the sample. We find by inspection of the data that there is not much variation in the oil concentrations in the different samples.

The results obtained in this study indicate that the introduction of oil or dispersed oil into seawater does not invoke a significant change in the size of the heterotrophic bacterial population in seawater. There is a change in the percentage of hydrocarbanoclastic bacteria within the heterotrophic population indicative of a natural selection for organisms able to metabolize hydrocarbon components. This modified population does have a slightly greater potential for hydrocarbon utilization, but in terms of the vastly increased hydrocarbon content, little overall enhanced significance in relation to degradation time. The reason for this limited microbial response to oil in the water column is, of course, the nutrient limited nature of seawater in terms of its nitrogen, phosphorus and iron content. Active cell growth and maximum rates of nutrient turnover (hydrocarbon in this case) will not occur in a nutrient limited system. This study has demonstrated that the modest increase in the size of the hydrocarbanoclastic bacterial population, as a result of oil entrainment in the water column, does not have a profound effect on degradation potential.

An explanation for the above observations is the recently proposed hypothesis for bacterial dormancy in aquatic systems (Stevenson, 1978). It is proposed that dormancy is an important physiological adaptation for the survival of bacterial suspended in the water column and for this case, is termed exogenous dormancy in which development is delayed due to some unfavorable chemical or physical condition of the environment. The "dormant cells" are generally small and ovoid as demonstrated by Anderson and Hefferman (165) and Wright (1973) and functionally turned-off. This need not imply no activity but a state below maximum potential in a satisfactory environment. It appears that this phenomenon could function in the water column to a greater extent than in sediments or the microlayer where nutrient enrichment occurs.

An obvious approach to increased degradation potential is nutrient supplementation. Oleophilic nitrogen, phosphorus and iron supplements have been proposed to stimulate bacterial growth in marine water column populations. A tank experiment was performed to test the response of bacterial populations to supplemented vs. non-supplemented Kuwait-Corexit mixtures in seawater. The results are summarized in Table 8.14. The bacterial population size deteriorated with time in the seawater control

Table 8.13
Experiment 1. Total Hydrocarbon Concentration and Degradation Potential of Meso-Scale Experiments

Test Tank	Test Time Hrs.	T/f R (Hrs)	Total Hydrocarbon ppb	Degradation Potential (Hrs)
Control Sewater	24	6.93	116	14.4
Kuwait and Corexit	24	16.66	1024	305
Control Seawater	72	7.22	116	15
Kuwait and Corexit 9527	72	7.84	1773	249

Experiment 2

Test Tank	Test Time Hrs	T/f R (Hrs)	Hydrocarbon ppb	Degradation Potential Hrs.
Control Seawater	48	6.93	103	12.6
Kuwait and BP 1100 WD	48	22.89	15,300	6276
Kuwait and Corexit 9527	48	6.17	9800	1083
Kuwait and BP 1100 WD	168	274.7	2216	10,909
Kuwait and Corexit 9527	166	126.3	2400	5432

Experiment 3 Test Tank				
Control Seawater	48	6.93	109	13.5
Kuwait Corexit 9527	48	9.68	579	100
Kuwait + BP 1100	48	12.08	1660	359
Kuwait + Corexit 9527	120	10.28	680	125
Kuwait BP 1100 WD	120	9.27	1040	172

Experiment 4				
Control Seawater	48	6.93	109	13.5
Kuwait Corexit (N)	48	6.86	1680	206
Kuwait BP 1100 WD	48	8.52	640	97
Kuwait Corexit	120	13.72	60	14.8
Kuwait + BP	120	13.42	80	19.2

*T/f.R determined for a total of 55.8 ppb of ^{14}C-hydrocarbons.

Table 8.14 Heterotrophic Bacteria in Nutrient vs. Non-Nutrient Supplemented Tanks

Time (Hrs)	Seawater Control	Unsupplemented Kuwait & Corexit	N & P Supplemented Kuwait & Corexit
0	1.3×10^5	1.1×10^6	2.4×10^6
24	2.7×10^5	3.0×10^4	1.9×10^7
48	5.0×10^5	2.0×10^4	1.9×10^8

and unsupplemented test tanks. In the nitrogen and phosphate supplemented tank there was a definite increase in total heterotrophic bacteria. Examination of colony types further demonstrated a definite selection for hydrocarbanoclastic bacteria in the enhanced population of the nutrient supplemented tank. Significantly increasing the size of the hydrocarbanoclastic population via an active growth response would be expected to also increase the hydrocarbon turnover rate and expedite degradation.

It is important to sound a warning which needs to be tested under environmental conditions. The process of disease is a quantitative inter-relationship between the number of bacteria, virulence of the bacteria and host resistance as expressed by the formula:

$$D = \frac{NV}{R}$$

In the normal marine environment the sea creatures evolve to a delicate balance between these three factors. If we upset this balance, disease could result with far more damaging consequences to the marine fauna than the described toxicity of oil and/or dispersant. This is strongly supported by the work of Stinson and Talburt (1978) who showed a 3-log increase in virulence of hydrocarbon grown Pseudomonas aeruginosa over that of the same strain grown on glucose. This virulence was linked with the development of a new lipo-protein in the outer membrane of the hexadecane grown cells. Therefore, we must conclude that as tempting as fertilization might be as a mechanism to increase degradation potential, it must be tested under controlled conditions to determine whether or not pathogenicity does result from the increased bacterial numbers.

8.4 Conclusions

Both the viable plate count (VPC) and most probable number (MPN) methods were suitable for enumeration of marine heterotrophic bacteria and hydrocarbanoclastic bacteria.

The MPN method while yielding slightly higher total numbers than the VPC method had no greater accuracy than the VPC method, imposed greater logistical demands and did not yield colonies which were required for other apsects of the project.

Use of these methods demonstrated that the percentage of oil degraders within the "total heterotrophic population" increased with exposure time of the "total population" to oil and/or dispersant.

Oxygen depletion by the modified BOD method is a valuable tool which provides a general picture of biological response to materials suspended in the water column. The procedure was used to demonstrate the biodegradable nature of Corexit 9527 and provide a rough index of degradation potential. This method confirmed VPC and chemistry data in the mesoscale tank experiments. Essentially, there is little water column activity in oil treated tanks but biological activity in the tank zones containing elevated hydrocarbon concentrations.

Oxygen depletion has certain limitations, the greatest being that it cannot be directly correlated with actual oil degradation rate or the rate of degradation of specific oil components. An alternate approach is chemical analysis by gas chromatography which has been used in this project. The use of this technique for water column samples, while quantitative for bulk oil has certain limitations for component analysis. It is possible to demonstrate loss of classes of compounds by this method but is too expensive and time consuming for routine degradation rate determinations. The use of ^{14}C labeled hydrocarbons allows a rapid and fairly simple method for measuring mineralization (conversion of organic carbon to carbon dioxide by metabolism) as an index of biodegradation. Representative hydrocarbons provide an estimate for the rate at which the mixed natural population achieve mineralization of aliphatic and aromatic hydrocarbons. The mineralization rate studies demonstrate turnover rates ranging from approximately 20 to 90 mg of substrate per hour. These values compare with results by other investigators in similar systems.

A more accurate approach using ^{14}C methodology is to measure not only mineralization, but also the production of water soluble intermediates which carry the ^{14}C label and the amount of ^{14}C incorporated into cell biomass. The importance of this approach is apparent from the data from one typical experiment. The average disintegration per minute (DPM) in the CO_2 traps were 4.3×10^3, 3.2×10^4 DPM for the cell bound activity and 7.1×10^4 DPM for the water soluble products. This data shows clearly that mineralization is an index of biological activity but not a reliable quantitative tool for hydrocarbon turnover or degradation time.

Studies by the VPC method for the surface film, water column and sediment were performed as 13 and 4°C. The bacterial numbers increased in the surface film during day 1 and 2 then remained essentially constant throughout the 21 day experiment. We interpret this increase not as bacterial growth per se but rather the formation of the microlayer.

The sediment bacterial population increased through day 9 in the control, dispersant and oil-dispersant tanks but not in the oil tank. The numbers remain constant in the sediment of the oil-dispersant tank after day 9 but decline in the control and dispersant tanks.

Oil destroys the surface microlayer as such because the oil is imposed between the water and air interface, and we believe that hydrocarbon degrading bacteria tend to be carried into the oil film and thus removing them from an active role at the oil-water interface.

The water column studies at 4° and 13°C provide evidence for two different bacterial populations in the natural seawater which was at 1°C. The total heterotrophic populations shift somewhat but the most significant observations is a rapid increase in the number of hydrocarbanoclastic bacteria through day 7 followed by a decline to original numbers, due, we conclude, to exhaustion of the nitrogen, phosphorus and iron content of the seawater.

Studies showed a decline in colony diversity with time in the tank system suggesting enrichment for specific organisms which is supported by the studies on the ratio of hydrocarbanoclastic to heterotrophic bacteria. Population dominance is more significant than population size which is a fairly constant value.

The long term flow-through experiment showed no significant correlation between the number of total heterotrophic bacteria and hydrocarbon concentration, but a significant correlation was found between total heterotrophic and total hydrocarbanoclastic bacteria which indicated selection for hydrocarbon-utilizing bacteria.

A negative relationship was found between hydrocarbon content and hexadecane or naphthalene mineralization rates, suggesting inhibition of mineralization at high hydrocarbon and/or dispersant values. However, there was a decrease in hydrocarbon turnover time (T/f) in the oil and/or dispersant tanks. This decrease in T/f is more apparent for aliphatic hydrocarbons than for aromatic hydrocarbons.

The variation in mineralization rates is minimal ranging from 8.6 to 11.9 ng/hr for hexadecane and 8.3 to 19.6 ng/hr for naphthalene. Thus, in the determination of degradation time the most important function is hydrocarbon concentration.

Investigation of phosphate and nitrogen in the test systems reveal values which were always nutrient limiting for the amount of degradable carbon available.

It is our conclusion that hydrocarbon degradation potential in nutrient limited seawater is a relatively constant value independent of the presence or absence of oil in the water column. There is selection for hydrocarbanoclastic bacteria with time but their overall degradation activity as a mixed population is not significantly affected by the enrichment process. Preliminary evidence indicates that nutrient supplements (nitrogen, phosphorus and iron) do have a significant effect on the size of the seawater microbial population and yield a rather homogenous population of hydrocarbon utilizing bacteria in the presence of oil.

A brief discussion of nutrient seeding suggests this is not a viable approach to increased hydrocarbon degradation potential. The danger of increased pathogenicity in nutrient enriched oil-water systems is a real possibility which must be more fully investigated.

Natural microbial hydrocarbon degradative processes are active in the water column of dispersed or non-dispersed oil. These processes will eventually lead to the turnover of the biodegradable oil components. The rate at which oil degradation occurs is not materially enhanced by the dispersion process but dispersion of the oil into small micelles (1-2 μm) suspended in the water column does make the oil available to microbial action in the water column. Due to the physical inaccessibility of microorganisms to the bulk of the oil in a heavy slick, dispersion of the oil is an adjunct to the hydrocarbon degradative capacity of a mixed natural marine water column population.

This project has not shed much light on the affect of microbial populations on dispersed oil entrained into sediments or oil solubilized or suspended as sub-micron micelles in surface microlayers. Limited data from this project indicates that hydrocarbon degradative potentials in sediments and the surface microlayer may be significantly higher than degradative potentials in the water column.

It is our conclusion that future studies of hydrocarbon degradation of dispersed vs. non-dispersed oils in the marine environment should center on the following topics listed in a general order of priority:

1. Degradative potentials in sediments.
2. Degradative potentials in surface microlayers.
3. The possible enhanced pathogenicity of nutrient enriched oil.
4. The degradative potentials at water-ice and sediment-ice interfaces.

9.0 Biological Investigations

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PREFACE

The information from our research efforts is presented in three major sections, each dealing with and answering questions about related but different aspects of the scallop predator-prey system and the impact of oil and dispersant on this system.

In Section (9.1), the actual bioassay experiments are described. Sections (9.2) and (9.3) present our biological investigations and techniques which form a foundation for all of the sublethal bioassay work. In Section 9.4, the response of a simple predator-prey community to oil, dispersant, and oil-dispersant mixtures. Instead of redescribing methods in Section I, reference is made to either Section II or III where techniques are described in full.

9.1 Section I Lethal and Sublethal effects of short term acute doses of Kuwait Crude Oil and a dispersant Corexit 9527 on Bay Scallops, Argopecten irradians (Lamarck) and two predators at different temperatures

ABSTRACT

Investigations of short term acute exposure of bay scallops, Argopecten irradians and two scallop predators, the oyster drill Urosalpinx cinerea and the common starfish Asterias forbesi, to oil, dispersant, and oil-dispersant mixtures (Kuwait Crude Oil and Corexit 9527) suggested that predator and prey have different lethal susceptibilities. Scallops were most sensitive to dispersant and dispersant mixed with oil, starfish were only sensitive to dispersant while the oyster drill seemed unaffected even though all were exposed to dilutions of identically prepared stock solutions. Scallops were least susceptible during winter months and most susceptible at summer temperatures. Treatment had less effect on predators than on scallops at summer temperatures. Sublethal concentrations of dispersant and oil-dispersant mixtures diminished the behavioral ability of scallops to recognize drills and starfish. The degree of effect increased with temperature. Predator detection of prey at the same concentrations was more complex. The feeding response or posturing reflex of starfish was significantly slowed by all treatments. In contrast, drills were unaffected in their recognition of scallop effluent in a choice chamber after treatment.

9.1.1 INTRODUCTION

There have been many recent investigations of lethal (Anderson et al., 1974; Griffin & Calder, 1977; Lee et al., 1977), as well as sublethal (Dicks, 1976; Percy, 1977; Percy & Mullin, 1977) effects of oils on marine invertebrates. Similarly, much attention has been given to the lethal (Portmann & Connor, 1968; Baker & Crapp, 1974; Wilson, 1977) and sublethal (Swedmark et al., 1971; Hagstrom & Lonning, 1977) effects of dispersants alone. In contrast, the comparative effects of oil, dispersant, and oil-dispersant treatments have received less attention (Hargrave & Newcombe, 1973; Avolizi & Nuwayhid, 1974).

This study was concerned with assessment of lethal and sublethal effects of API standard Kuwait Crude Oil and a dispersant, Corexit 9527 on the bay scallop Argopecten irradians (Lamarck) and two scallop predators; the starfish Asterias forbesi (Desor), and the oyster drill Urosalpinx cinerea (Say). Scallops were chosen because they are a commercially important marine species. Young of the year were used because of their high reproductive potential, which makes them important to the continued survival of scallop populations (Russell, 1973). Scallops have a well documented, predator specific, stereotyped escape response (Curtis, 1966; Mackie, 1970; Moore & Trueman, 1971; Thomas & Gruffydd, 1971; Ordzie & Garofalo, 1980a, see also section II) which we used to assess sublethal effects of oil and dispersant because it is easily quantified and is important to scallop survival. The oyster drill Urosalpinx cinerea has recently been found to be an active predator of scallops (Ordzie & Garofalo, 1980b, see also section III) and scallops show a vigorous escape response when confronted with this predatory drill.

Starfish are well known predators of scallops (Galtsoff & Loosanoff, 1939). Both predators are found in the coastal ponds of Rhode Island where large bay scallop beds are abundant.

It is our design to investigate the effects of oil, dispersant, and oil-dispersant mixtures on the bay scallop and two predators at lethal and sublethal levels at various temperatures. Such a study will provide information on the susceptibility of an ecologically important predator-prey system.

9.1.2 METHODS & RESULTS

9.1.3 Lethal Effects

Methods

Bay scallops, Argopecten irradians, oyster drills, Urosalpinx cinerea, starfish, Asterias forbesi, periwinkles, Littorina littorea (Lamarck) and purple sea urchins, Arbacia punctulate (Lamarck) were collected from Point Judith Pond or Ninigret Pond, Rhode Island, by dredging or diving. All test animals were maintained in the laboratory with running, unfiltered, ambient temperature sea water from Point Judith Pond. Temperatures ranged from -1.5^{0} to 24.2^{0}C and salinity ranged from 27 to 32 $^{0}/00$ during this study.

Bay scallop, and two scallop predators, the starfish and the oyster drill, were exposed to various concentrations of stock solutions of oil, dispersant, and an oil-dispersant mixture. Stock solutions were prepared in three 55 liter all glass aquaria according to the schedule in Table I. The appropriate amount of oil was poured onto 49.5 liter of ambient temperature sea water. The dispersant was sprayed onto the appropriate mixing tanks after four hours later to allow weathering of the oil. These mixing tanks were set in an ambient temperature, running sea water bath for temperature control at the beginning of the mixing period. Each solution was aerated with a Silent Giant diaphragm pump for the first 20 hours and allowed to settle for the last six hours. Solutions were then withdrawn from below the slick with a PVC siphon inserted prior to addition of oil or dispersant.

Dosing solutions were then prepared by mixing the appropriate volume of stock solution with ambient temperature sea water to make a volume of 20 liters. The concentrations used for the scallop, starfish, and drill bioassays are shown in Table II. Each dosing tank was placed into a common, ambient temperature water bath. At this point, animals were added to dosing tanks for six hours. Aeration was provided for the entire dosing period. Five control tanks, each with 20 liters of sea water, were also placed in the water bath. In both scallop and drill bioassays, 20 animals were used in each of the dosing and control tanks. Because of their tendency to crawl out of tanks, it was necessary to cage the drills in a mesh ban to keep them in the dosing solution. Due to the large size of starfish, ten individuals were placed in each dosing tank. Test animals of approximately equal size were used for each replicate to eliminate presumed differences due to size.

Table I. Proportions (liters) of sea water, oil, and dispersant used to make the treatment stock solutions.

Solution	Proportion (liters) of: W	 O	 D	Air mix	Settle
C	50.0 :	--- :	---	20 hours	6 hours
O	49.5 :	0.5 :	---	20 hours	6 hours
D	49.5 :	--- :	0.1*	20 hours	6 hours
OD	49.5 :	0.5 :	0.1*	20 hours	6 hours

*Dispersant was added four hours after the beginning of mixing.

W - Sea water

O - Kuwait Crude Oil

D - Corexit 9527 Dispersant

Table II. Volumes of stock solutions mixed with sea water to make the appropriate dilutions of stock solution used for all bioassay experiments.

Concentration % of stock solution	Amount of stock solution (Liters)	Sea water (Liters)
100	20	0
70	14	6
50	10	10
25	5	15
12.5	2.5	17.5
6.25	1.25	18.75

After the six hour dosing period, test animals from each treatment and concentration were separately placed into respective 40 liter aquaria each independently supplied with running sea water at a flow rate of 30 ml/sec for a depuration period of five days. The number of survivors in each treatment and concentration and control were counted at the end of the five day period. The number of replicates at each temperature for each organism are presented in Table III.

2. Results

Scallop susceptibility to oil during the six hour dosing regime was not evident even at the highest concentration (100% stock solution). Indeed, at all three temperatures (2^o, 10^o, and 20^oC) survivorship in control and oil treatments was high and essentially identical at 100% (Figure 1). Measurement of total extractable hydrocarbon using the infrared spectrophotometric technique with carbon tetrachloride as the extracting solvent, gave values of 1-4 ppm for the water below the slick of the oil stock solution. Solutions containing dispersant could not be reliably measured at the concentrations used, so all values for these solutions were designated as nominal concentrations. Scallop survivorship was significantly decreased in all treatments involving dispersant. As the concentration of dispersant and oil-dispersant stock solution increased, scallop survivorship decreased at all temperatures.

Scallop survivorship was temperature related in dispersant and oil-dispersant treatments. As temperature increased, scallop survivorship decreased (Figure 2 & 3). There was no significant difference in the effect of the dispersant and oil-dispersant treatments on bay scallops. Probit analysis (Figure 4) used to estimate LD_{50} values and 95% fudicial limits for scallops also revealed that there was no significant difference between LD_{50} values for dispersant and oil-dispersant treatments at any temperature. There was, however, a strong concentration-temperature interaction. As temperature increased, the concentration of Corexit 9527 required to kill 50% of the scallops decreased. The LD_{50} was lowest at summer temperatures.

Starfish showed no appreciable change in survivorship in any except dispersant treatments for tests conducted at 15^o and 20^oC (Figure 5). Even when exposed to full strength stock solution at these high temperatures, survivorship of starfish was always better than 50 percent.

It should be noted that starfish in the oil dosing tanks spawned during exposure at 15^oC. Starfish in control tanks spawned a few days later. No spawning was observed during the 20^oC experiment. A further observation on the condition of starfish suggests that animals exposed to dispersant and oil-dispersant were physically stressed. Many starfish from these treatments had everted stomachs. No other starfish from other treatments were found with this condition.

There were no treatment related oyster drill deaths observed during experiments run at 20^oC (Figure 6). Of 480 drills tested, only two died during the experiment. During dosing, drills in the controls and all concentrations of the oil treatment appeared to exhibit normal crawling behavior while drills in all concentrations of the dispersant and oil-dispersant treatments were retracted into their shells.

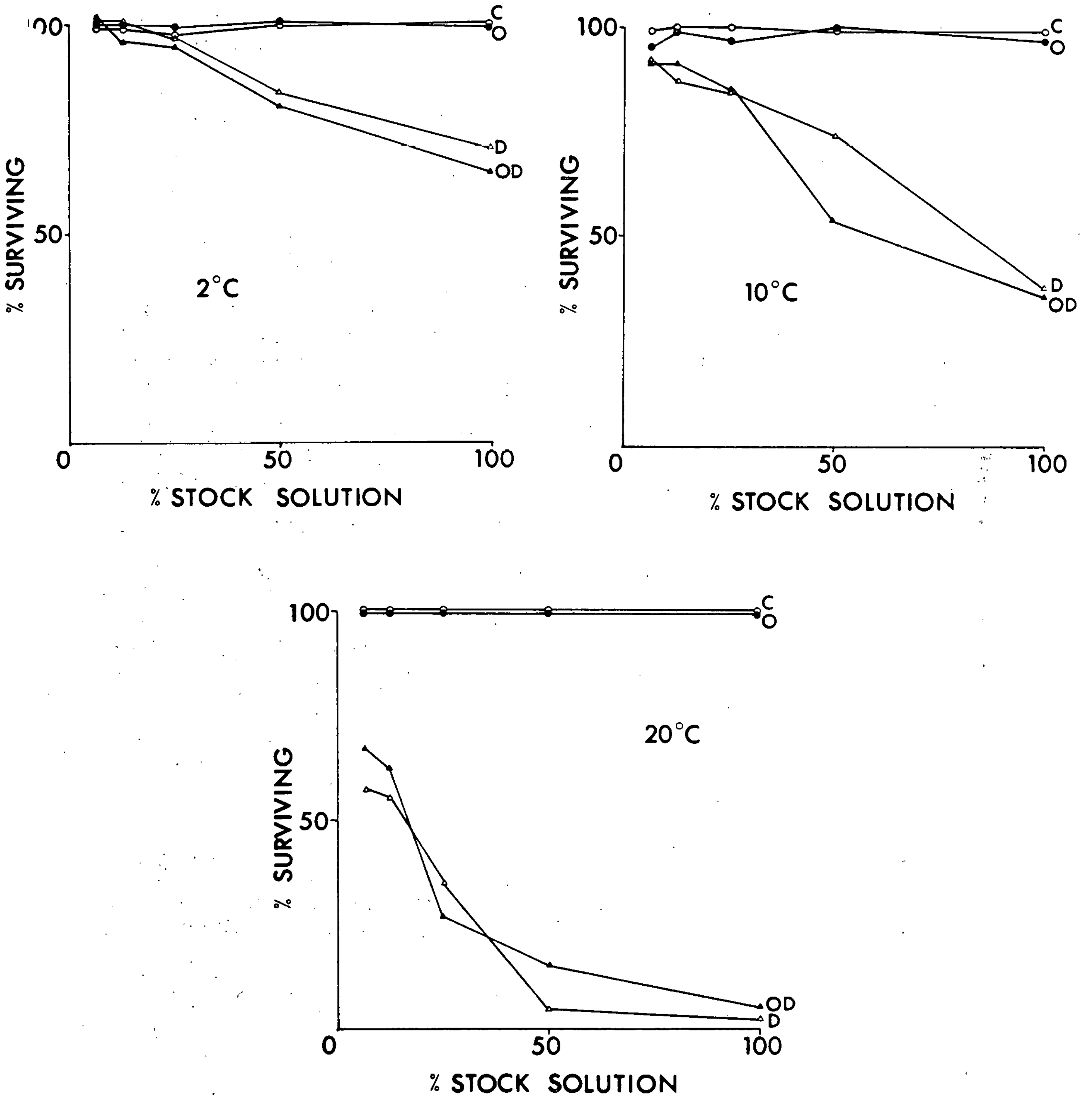

Fig. 1. Scallop survivorship for five concentrations of four treatments at three temperatures, 2°, 10°, and 20°C: C-Control, O-Kuwait Crude Oil, D-Corexit 9527 Dispersant, OD-Oil and Dispersant.

Table III. Temperatures, dates, and organisms used for lethal bioassay.

	Temperature °C	Date	Replicate Number
Scallops (Argopecten irradians)			
	2°	1/31/78	1
	2°	2/28/78	2
	2°	3/5/79	3
	2°	3/12/79	4
	10°	11/16/77	1
	10°	5/17/78	2
	10°	11/14/78	3
	10°	5/7/79	4
	20°	8/21/78	1
	20°	7/16/79	2
Starfish (*Asterias forbesi*)	15°	5/29/79	1
	20°	8/6/79	2
Snails (*Urosalpinx cinerea*)	20°	7/23/79	1
	20°	7/30/79	2

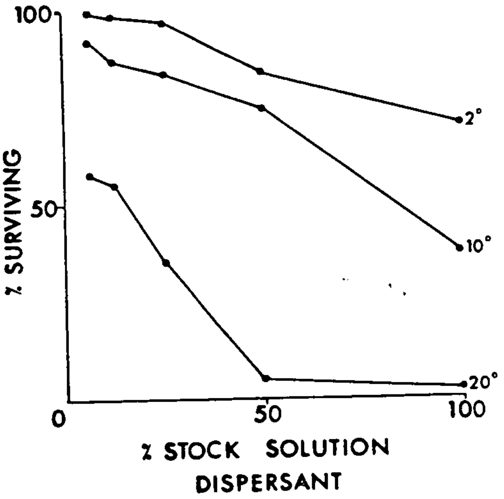

Fig. 2 Scallop Survivorship for five concentrations of dispersant stock solution at three temperatures, 2°, 10°, and 20°C.

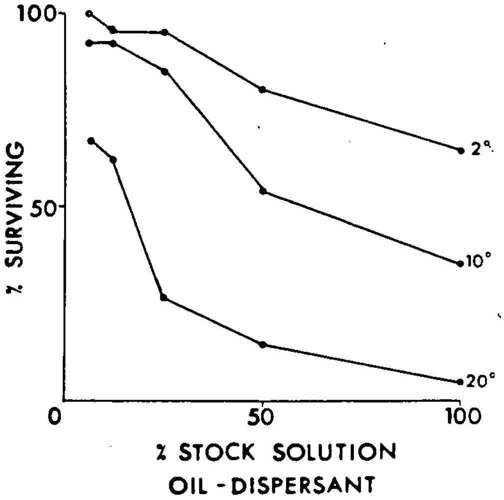

Fig. 3. Scallop survivorship for five concentrations of oil and dispersant stock solution at three temperatures, 2°, 10°, and 20°C.

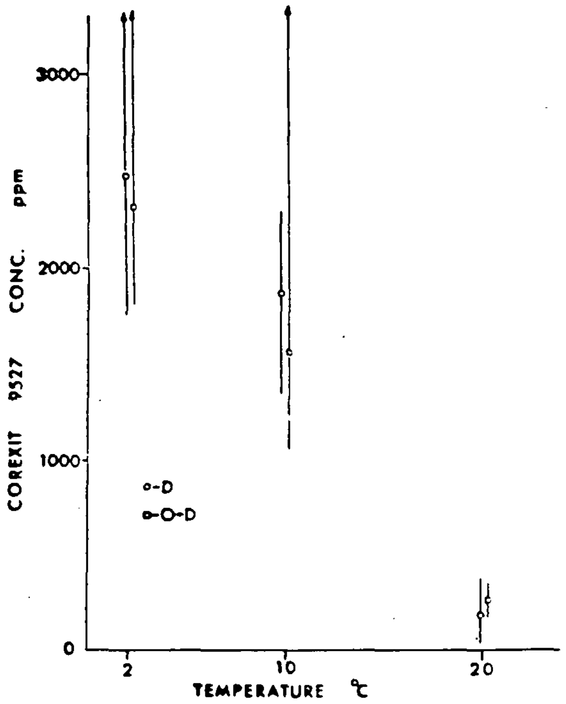

Fig. 4. Probit estimates of 6 hour LC_{50} for bay scallops at nominal dispersant and oil-dispersant concentrations for 2°, 10°, and 20°C. Vertical lines represent 95% fudicial limits: D-Corexit 9527 Dispersant, OD-Kuwait Crude Oil and Corexit 9527 Dispersant.

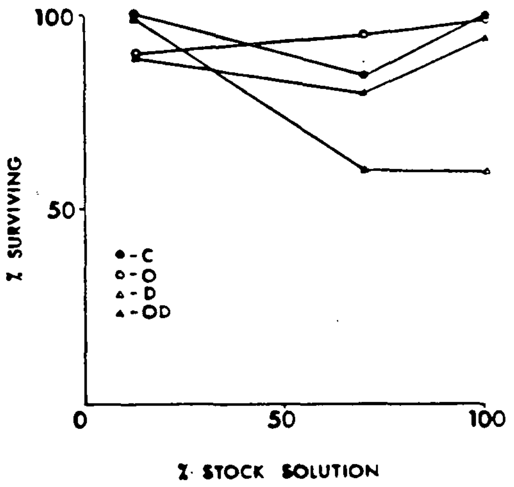

Fig. 5. Combined results of starfish survivorship at 15° and 20°C when exposed to four experimental treatments at various concentrations of stock solution: C-Control, O-Kuwait Crude Oil, D-Corexit 9527 Dispersant, OD-Oil and Dispersant.

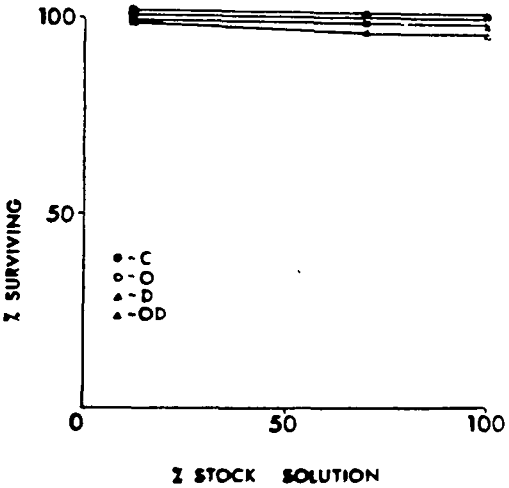

Fig. 6. Oyster Drill survivorship at 20°C when exposed to four experimental treatments at various concentrations of stock solution: C-Control, O-Kuwait Crude Oil, D-Corexit 9527 Dispersant, OD-Oil and Dispersant.

9.1.4 Sublethal Effects

1. Scallop Detection of Predators

a. Methods

Scallops from the 12.5% concentration of each treatment and a control were tested for their behavioral recognition of molluscan and echinoderm predators during the five day depuration period which followed dosing. The behavioral escape response and apparatus used were described previously (Ordzie & Garofalo, 1980a, see also section II). Scallops were tested for their behavioral discrimination between a non-predatory gastropod, *Littorina littorea* and a predatory gastropod, *Urosalpinx cinerea*. Also, scallop discrimination between a non-predatory echinoderm, *Arbacia punctulata* and a predatory echinoderm, *Asterias forbesi* was tested. In each case, the non-predator was presented first to avoid sensitizing scallops.

Scallop stimulation was accomplished by touching the test animal to the scallop mantle margin at the anterior wing. Two aspects of the scallop escape response, response time and swimming claps, were quantified. Response time, defined as the time from beginning of stimulation until first valve movement, was measured in seconds with a stopwatch. Swimming claps were simply counts of the number of valve adductions of closures during a response. It was previously determined that bay scallops respond to predators with a short response time and a high number of swimming claps (Ordzie & Garofalo, 1980a, see also Section II). In contrast, scallops respond to non-predators with long response times and less than one swimming clap. In this way scallops behaviorally discriminate between predators and non-predators. We then studied the effects of oil, dispersant, and oil-dispersant treatments on this sensitive escape response which is so essential to scallop survival.

All 20 scallops from each treatment were tested with non-predator and predator. Each individual scallop was tested five times during the depuration period. Temperatures, replicates, and test species used in sublethal studies are shown in Table IV.

An index was employed to allow simultaneous consideration of scallop responses to predator and non-predator. Response to predator was subtracted from response to non-predator, was divided by their sum, and was then multiplied by 100 as follows:

$$\text{Response Index} = \frac{\text{Non-predator} - \text{Predator}}{\text{Non-predator} + \text{Predator}} \times 100$$

Response time and number of swimming claps were independently analyzed using this index. The index value changes with changes in behavioral discrimination. As behavioral discrimination increases, the index values move away from zero and conversely, as behavioral discrimination decreases, the index values approach zero. Indices for response time and swimming claps were independently analyzed using a two-way analysis of variance test with treatment and temperature as main effects. Data from tests with gastropods and echinoderms were considered separately.

Table IV. Temperatures, dates, and organisms used to test the escape response of treated and untreated scallops.

Tested with *L. littorea and U. cinerea*

Temperature	Date	Replicate Number
10°	5/17/78	1
10°	11/14/78	2
15°	6/7/78	1
15°	6/18/78	2
20°	8/21/78	1
20°	7/16/79	2

Tested with *A. punctulata and A. forbesi*

Temperature	Date	Replicate Number
10°	5/7/79	1
10°	5/14/79	2
20°	7/23/79	1
20°	7/23/79	2

b. Results

Scallop discrimination of Urosalpinx cinerea from Littorina littorea as measured by the time index was significantly decreased by dispersant and oil-dispersant treatments at 12.5% of the stock solution (Figure 7). As temperature increased from 10° to 20°C, discrimination increased in all treatments (ANOVA, F=66.5, d.f.=2,468, $P < .001$). Compared to controls, the oil treatment appeared to have no effect on the scallop response time index. However, dispersant and oil-dispersant treatments both significantly lowered the response time index and thus discrimination (ANOVA, F=26.4, d.f.=3,468, $P<.001$). There was also a significant temperature-treatment interaction evidenced by the greater effect on discrimination at higher temperatures (ANOVA, F=2.5, d.f.=6,468, $P<.02$). Scallop behavioral discrimination between the two snails as measured by claps was unaffected by treatment at 10° and 20°C (Figure 8). All values were similar to those for controls. The only temperature (ANOVA, F=20.8, d.f.=2,468, $P< .001$) and treatment effects (ANOVA, F=5.7, d.f.= 3,468, $P<.0009$) were found at 15°C where all three treatments differed significantly from the control. There was no significant temperature-treatment interaction.

The same indices were used to test scallop discrimination between the starfish, Asterias forbesi and the sea urchin, Arbacia punctulata. Dispersant and oil-dispersant were found to significantly affect the scallop response time index at both 10° and 20°C (ANOVA, F=24.7, d.f.= 3,312, $P<.0001$). Scallops were less able to behaviorally discriminate the predatory starfish from the non-predatory sea urchin after exposure to either treatment (Figure 9). There was no temperature effect on discrimination, however, there was a temperature-treatment interaction (ANOVA, F=2.9, d.f.= 3,312, $P<.04$) demonstrated by the greater interference with discrimination at higher temperatures.

The swimming clap index was only affected by the oil treatment at 20°C and in this case discrimination increased compared to controls (ANOVA, F=3.79, d.f.= 3,312, $P<.01$) (Figure 10). No temperature effect was found, but there was a temperature-treatment interaction (ANOVA, F=3.08, d.f.=3,312, $P<.03$) owing to increased discrimination of scallops exposed to oil at 20°C.

2. Predator Detection of Scallops

2.1 Starfish (Asterias forbesi)

a. Methods

Starfish were tested for sublethal behavioral effects using part of the feeding response described as the "posturing reflex" (Heeb, 1973). Starfish "posture" over their prey prior to feeding by elevating their aboral surface which leaves them in a humped posture.

To examine this reponse an epoxy coated plywood box (30 cm long x 27 cm wide x 13.5 cm deep) fitted with a drain and a glass false bottom was filled with sea water at ambient temperature. A starfish was placed on the glass plate then the water level was adjusted so the water surface just touched the highest part of the aboral surface of the starfish at

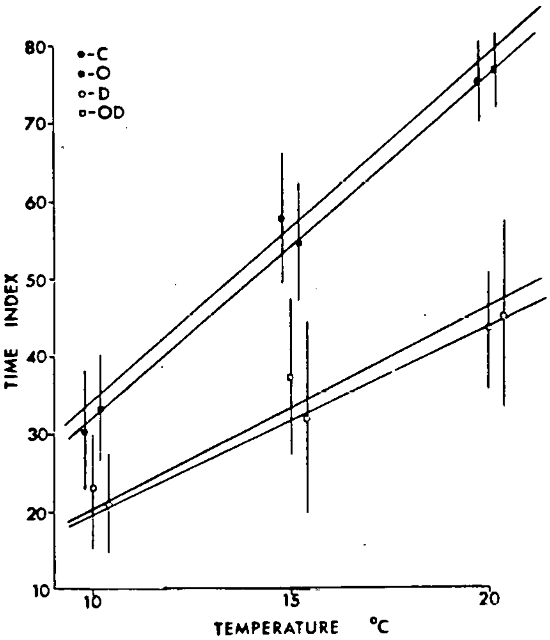

Fig. 7. Response time index for scallop response to Littorina littorea and Urosalpinx cinerea at each of the four experimental treatments at 10C, 15C, and 20°C. Vertical lines represent 2 s.e. on either side of the mean. C-Control, O-Kuwait Crude Oil, D-Corexit 9527 dispersant, OD-Oil and Dispersant.

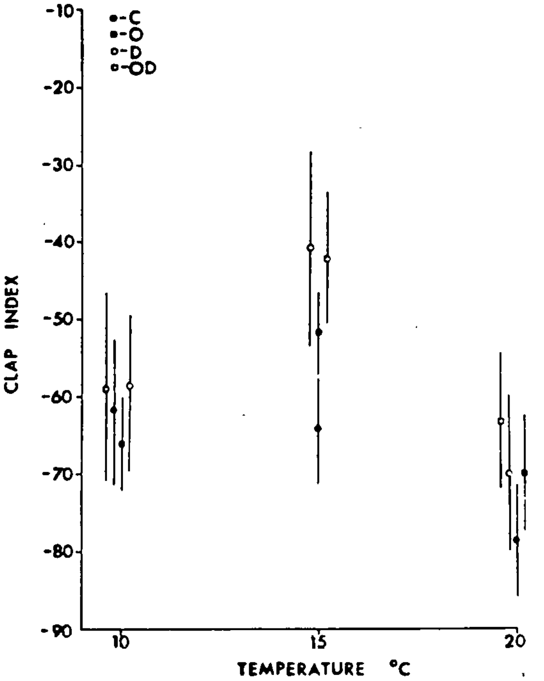

Fig. 8. Swimming clap index for scallop response to Littorina littorea and Urosalpinx cinerea at each of the four experimental treatments at 10C, 15C, and 20°C. Vertical lines represent 2 s.e. on either side of the mean. C-Control, O-Kuwait Crude Oil, D-Corexit 9527 Dispersant, OD-Oil and Dispersant.

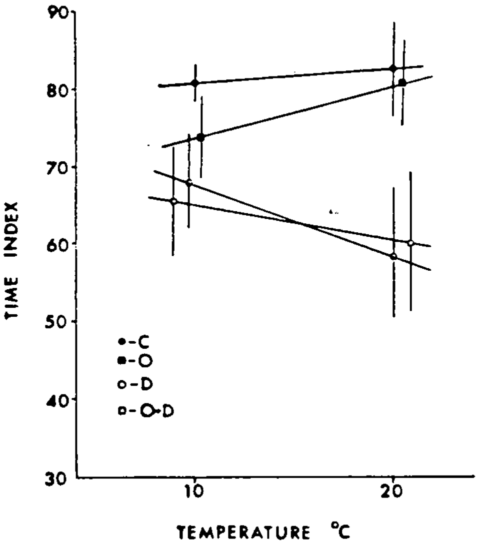

Fig. 9. Response time index for scallop response to Arbacia punctulata and Asterias forbesi at each of the four treatments at 10C and 20°C. Vertical lines represent 2 s.e. on either side of the mean. C-Control, O-Kuwait Crude Oil, D-Corexit 9527 Dispersant, OD-Oil and Dispersant.

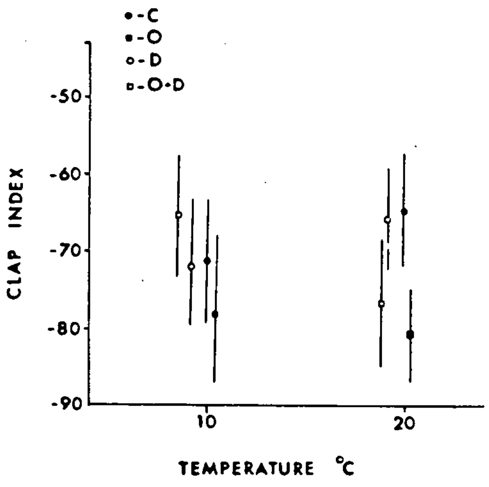

Fig. 10. Swimming clap index for scallop response to Arbacia punctulata and Asterias forbesi at each of the four treatments at 10C and 20°C. Vertical lines represent 2 s.e. on either side of the mean. C-Control, O-Kuwait Crude Oil, D-Corexit 9527 Dispersant, OD-Oil and Dispersant.

rest. Scallop homogenate was made by liquifying tissues from five whole scallops with 15 ml of sea water in a blender. Half a ml of this homogenate was then presented by pipette under the oral surface to stimulate the posturing reflex. The time from initial stimulation to the first upward movement, noted when the aboral surface broke the water-air interface, was measured in seconds up to a 60 second cutoff time. The box was flushed with sea water after each test. Each starfish from the 12.5% concentration of all treatments and control were tested in this manner eight times during the five day depuration period. Plain sea water was also presented by pipette to control for mechanical stimulation of the oral surface in 20 starfish. This experiment was performed at 15°C (5/29/79) and 20°C (8/6/79). Data were analyzed with a one-way analysis of variance test.

b. Results

Combined data from replicates 1 and 2 (15° and 20°C) respectively (Table V), showed that response times for initiation of the posturing reflex in all treated starfish were significantly slower than response times of controls (ANOVA, F=9.53, d.f.=3,615, P<.001; LSD=4.26, d.f.=615, P=.05). Thus at sublethal exposures of just six hours to all treatments, starfish were affected in response to and possibly recognition of food presented as a homogenate. Starfish showed no response to the mechanical stimulation of plain sea water.

Table V. Starfish response time (sec) for posturing reflex for treated and untreated starfish at 15° and 20°C.

	Treatment			
	C	O	D	OD
$\bar{X}$ (sec)	13.5	20.5	22.2	24.2
S.E.	1.1	1.6	1.7	1.7
N	160	155	160	144

C - Control

O - Kuwait Crude Oil

D - Corexit 9527 Dispersant

OD - Oil and Dispersant

3. Oyster Drill (Urosalpinx cinerea)

a. Methods

Oyster drills were tested for behavioral recognition of scallop effluent using the plywood choice chamber described in a previous paper (Ordzie & Garofalo, 1980b, see also section III). This chamber is used to demonstrate the ability of the drills to choose between scallop effluent and plain sea water. All twenty drills from the 12.5% concentration of each treatment and a control were tested in the apparatus. Animals from the four different treatments were tested in a random order each day.

Three U. cinerea, marked with nail polish for identification, were started in the center of the apparatus with their long axis perpendicular to the long axis of the chamber. Each drill was allowed an hour to respond. Distance moved in cm was recorded after an hour. If a drill reached the end of the ramp in less than one hour, distance and time in minutes were recorded. The distance moved was designated positive if drills moved toward the scallop effluent, and negative if they moved toward plain sea water. Daily testing was done four times during the depuration period and this experiment was replicated twice at 20°C (7/23/79) and 7/30/79). Distances traveled by drills from each treatment were analyzed with a one-way analysis of variance test. Rates (cm/min) traveled toward both scallop effluent and plain sea water were determined for each animal tested. A one-way analysis of variance test was used to determine treatment effect on rate of travel.

Previously we (Ordzie & Garofalo, 1980b, see also section III) performed blank tests in which untreated drills were tested for any left-right bias in the choice chamber. To do this, we presented plain sea water on both sides. Results showed no detectable bias at the behavioral level studied and it was then concluded unlikely that the apparatus would interfere with the observed results.

b. Results

Because there was no significant difference between replicates, results of both were combined. The net positive distance moved by treated drills was not significantly different (ANOVA) from distances moved by controls (Table VI). Compared to the net distance moved in blank tests, treated and control drills exhibit a large net positive movement toward scallop effluent. Similarly, there was no significant difference between treated and control drills for rates of travel toward scallop effluent (ANOVA).

Table VI. Distance traveled (cm) by treated and untreated drills toward scallop effluent in a choice chamber at 20^oC.

	Treatment			
	C	O	D	OD
$\bar{X}$ (cm)	5.1	5.0	5.1	4.6
S.E.	.9	1.0	1.0	.9
N	145	149	151	146

C - Control

O - Kuwait Crude Oil

D - Corexit 9527 Dispersant

OD - Oil and Dispersant

9.1.5 Discussion

The goal of this study was to examine effects of oil and dispersant on a predator-prey system during selected ambient water temperatures. It was not the purpose here to evaluate the relative toxic dangers of either substance to natural populations, but rather, to study how this predator-prey system responds, and to examine the merits of using such an ecological system in bioassay work.

At high concentrations of treatment solutions, each member of the scallop predator-prey system was affected differently. Scallop survivorship was decreased by any treatment solution which contained dispersant. Starfish were less affected, but when they were, they were susceptible only to the dispersant treatment while survivorship of the oyster drill was unaffected by any treatment. This differential susceptibility to high concentrations of solutions prepared in identical ways points to a problem biologists face when dealing with bioassay. Because not all animals are affected by the same chemicals at the same concentration and that animals have ecological relationships which should also be considered, knowing the response of one species to a number of pollutants is not always sufficient for ecological assessment.

The sequence for susceptibility at sublethal levels is somewhat different for each species tested. Scallops suffered decreased predator recognition when exposed to any treatment with dispersant, starfish were hindered in their recognition of scallops as food when exposed to any treatment, while drills showed no measureable effect of any treatment on their ability to detect and move toward scallops. Ultimately, in a disrupted system, scallop populations may suffer more than the direct impact of a pollutant which selectively affects scallops but not all of the scallop predators.

This is a partial picture of what to expect from differential susceptibilities in a predator-prey system because information on long term consequences is also needed. Eisler (1973) noticed lower predation rates for Iranian Crude Oil and dispersant treated bivalve prey, as well as fecundity in predatory drills which fed on contaminated prey. In the future, studies which consider animals in more complete ecological context will provide better information about the impact of oil pollutants.

In light of the differential susceptibility demonstrated in this simple three animal system, the concept of an indicator species is difficult to defend. It would seem that because each organism can have its own array of chemical compound and concentration response, that there is no logical reason to assume that one animal could possibly be used to accurately judge susceptibility arrays for other species.

One major reason drills survived dosing is that they withdrew into their shells upon exposure, effectively isolating themselves from the environment. Dicks (1976) has suggested that withdrawn snails may suffer higher mortality in areas with high mechanical energy due to surf action. However, in areas with no violent mechanical action where scallops are found (coastal ponds) the survival of drills could be much higher than on the exposed coast.

In order to accurately assess biological effects of a pollutant event, we need to know susceptibilities of animals for different seasons. Seasonal sensitivity can be quite dramatic. Dispersant concentrations which are not lethal to scallops during winter temperatures cause greater than 50% mortality at summer temperatures. Although temperature of ambient water could be a significant predictor of scallop susceptibility to dispersant exposure, one should not generalize to other organisms. This issue becomes more complex because either the "pollutant toxicity" or "animal sensitivity" can be affected by temperature (Rice et al., 1977). Accordingly, the temperature related susceptibility can be different for each organism, making broad generalizations dangerous.

9.2 Section II

Behavioral Recognition of Mollusc and Echinoderm Predators by the Bay Scallop, Argopecten irradians (Lamarck) at two temperatures

Abstract

In an investigation of predator stimulated responses, bay scallops *Argopecten irradians* (Lamarck) were least sensitive on the dorsal side of their shell periphery. Scallops discriminated predatory from non-predatory gastropod molluscs and echinoderms based on scallop response times and swimming claps. Predatory test species *Urosalpinx cinerea* (Say) *Asterias forbesi* (Desor), *Eupleura caudata* (Say), *Thais lapillus* (L.), and *Busycon canaliculatum (L.)* provoked stereotypic escape responses. Although temperature had little effect on predator recognition, scallops required more time to respond to predators at 12°C than at 20°C. Once initiated, escape responses appeared to be temperature independent. It would seem predator recognition contributes to an efficient time-energy budget.

9.2.1 Introduction

Predatory starfish have been shown to evoke dramatic, predictable, escape responses from a variety of marine invertebrates (Bullock, 1953; Feder, 1967; Mackie, 1970; Ansell, 1969) including scallops (Thomas & Gruffydd, 1971; Feder, 1972; Stephens, 1978). Several molluscs (Bullock, 1953) and the scallop *Pecten maximus* (Thomas & Gruffydd, 1971) have been shown to differentiate, by touch, predatory from non-predatory starfish. They demonstrated that, although not as effective as contact, crude extracts of starfish were sufficient stimuli for provoking escape responses from *P. maximus*. Work on starfish substances responsible for evoking escape responses has shown that they come from tube feet (Feder & Lasker, 1964) and that they are surface active agents identified as "saponin-like" (Mackie *et al.*, 1968) or steroid glycosides (Mackie, 1970). Among the echinoderms examined by Yasumoto *et al.* (1966), saponins were only present in starfish and were found to vary seasonally.

Although reports of starfish evoked escape responses are common in the literature, reports of predatory molluscs which elicit escape behavior are less frequent (Ansell, 1969; Gore, 1966). In this paper, we quantify and examine bay scallop, *Argopecten irradians* (Broom. 1976) responses to predatory and non-predatory echinoderms and gastropod molluscs at two temperatures.

9.2.2 Materials and Methods

A. Test Species

Bay scallops, *A. irradians*, were dredged or collected by diving in Point Judith Pond, Rhode Island. Scallop shell height averaged 50.1 ± 4.4 mm (mean ± s.e.). Scallops were maintained in a laboratory with running, unfiltered sea water from Point Judith Pond where the salinity averaged 31.7 ± .4 ppt. Predatory snails, *Busycon canaliculatum,* Eupleura caudata, Urosalpinx cinerea, non-predatory snails Littorina littorea (L.), Ilyanassa obsoleta (Say), and a predatory starfish Asterias forbesi were collected from Point Judith Pond. Another predatory snail, Thais lapillus and a non-predatory sea urchin Arbacia punctulata (Lamarck) were collected from an exposed intertidal jetty outside the pond. All test invertebrates were maintained either in unfiltered, running sea water at ambient (10^{o} - 20^{o}C) temperature or in a 30 liter all glass aquarium, fitted with aeration and temperature control. Water was changed every three days in the aquarium.

B. Scallop Behavior

Stimulation was accomplished by allowing the foot of a restrained snail to contact the mantle margin of an unrestrained scallop. The snail was held stationary by pressing the shell apex into a flexible tube, attached to the end of a rigid tube, which was suspended by an adjustable cross bar over the observation tray. A snail so stabilized could be positioned at any desired location and still have full foot mobility for stimulation.

Two aspects of scallop behavioral responses were measured. Response time, defined as the time from initial stimulation to first valve adduction, was measured in seconds with a stopwatch. If no response occurred within one minute, the observation was terminated and the scallop credited with a 60 second response time. The number of swimming claps was measured by counting valve adductions during a response.

It was necessary to first determine relative sensitivity of different sites on the scallop mantle margin before further testing. A priori four peripheral areas; dorsal, ventral, anterior wing, and posterior wing were chosen to test sensitivity to stimulation with a predator, U. cinerea (Fig. 1). Scallops were kept in a 50 liter all glass aquarium, with aeration and temperature at 12^{o}C for seven days prior to testing. Aquarium water was replaced daily with fresh sea water throughout the experiment.

Each of four, epoxy coated, plywood observation trays contained five separate compartments (each compartment measured 27.5 cm long x 10.5 cm wide x 5 cm deep) to isolate individual scallops and eliminate presumed chemical communication. All scallops were allowed at least two minutes after handling to acclimate in the observation trays at 12^{o}C before stimulation.

Twenty scallops were stimulated first at one area of the mantle margin, then the same twenty scallops were stimulated at another site, until all four areas had been tested. This procedure was replicated six times. The sequence for testing the four areas was changed for each replicate. Water in observation trays was replaced after each trial.

Scallop responses to all test species were measured at ambient temperatures of 20^{o}C (August 1978) and 12^{o}C (October 1978). Test species were brought in contact with the scallop mantle margin at the anterior wing. All snails, except B. canaliculatum, were presented using the plastic tube and crossbar apparatus described above. B. canaliculatum, because of its bulk, was hand held during stimulation as were starfish and sea urchins. Stimulation began when either snail foot or echinoderm tube feet touched the scallop.

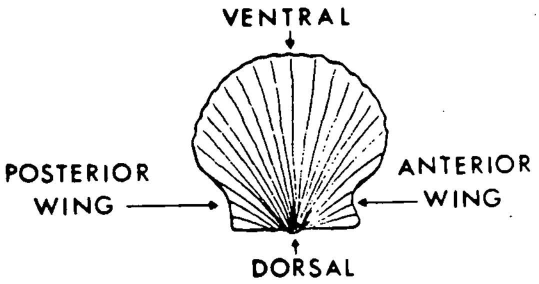

Fig. 1. Diagram of the bay scallop Argopecten irradians, with the four peripheral areas selected for stimulation as viewed from outside of left valve.

Twenty scallops were exposed to each test species. In all, eight different groups of twenty scallops were exposed to eight species. This was replicated three times. Presentation of test organisms was changed for each replicate so that no group of scallops was stimulated more than once by the same species. Both scallops and test species were maintained in running sea water at ambient temperatures. Sea water in observation trays was replaced after each test.

Data for both experiments, consisting of means of response times and swimming claps for groups of five scallops, were analyzed using the analysis of variance test (ANOVA). To examine effects of stimulation on four peripheral areas, a one-way ANOVA and the least significant difference (LSD) tests (Snedecor & Cochran, 1967; Sokal & Rohlf, 1969) were employed to identify differences among means. A two-way ANOVA and t-test were used to identify significant effects of test species and temperatures on scallop responses.

9.2.3 Results

A. Peripheral Sensitivity

Scallops showed varying sensitivity to stimulation with the predatory gastropod, U. cinerea, at selected sites on the mantle margin (Table I). Stimulation at either posterior or anterior wing resulted in significantly lower response times compared to results for dorsal or ventral sites and dorsal and ventral sites were different (ANOVA, F = 137.7, df = 3, 69, p .01; LSD = 4.5, df = 92 p = .05). While scallops stimulated at the dorsal site responded with significantly fewer swimming claps than for any other site, scallops stimulated at the anterior wing responded with the highest mean number of swimming claps (ANOVA, F = 47.7, df = 3, 69, p .01; LSD = 1.1, df = 92, p = .05). Based on these results, the anterior wing was selected as the site for all subsequent stimulation because scallops exhibited the most vigorous, least variable response at this location on the mantle periphery (Table I).

We observed predator proximity was not sufficient to consistently elicit escape behavior, therefore, all trials were performed with test organisms in physical contact with scallops.

Table I: Mean response time and mean number of swimming claps from scallops stimulated with *Urosalpinx cinerea* at four selected sites on the shell periphery.

	Peripheral Stimulation Sites			
	ventral	dorsal	posterior	anterior
Response Time				
$\bar{x}$	25.9	55.1	16.4	14.8
2 s.e.	4.6	3.2	4.2	3.2
Swimming Claps				
$\bar{x}$	5.6	0.8	5.6	7.1
2 s.e.	1.0	0.6	1.0	1.0

Table II: Mean scallop response times to eight test species at 12° and 20°C. (•indicates predators)

Test species	Temperature	
	12°C	20°C
Littorina littorea		
$\bar{x}$	36.3	40.6
2 s.e.	7.4	4.8
Arbacia punctulata		
$\bar{x}$	55.6	56.5
2 s.e.	4.2	2.6
Ilyanassa obsoleta		
$\bar{x}$	36.1	35.2
2 s.e.	8.2	5.4
•*Urosalpinx cinerea*		
$\bar{x}$	14.5	9.5
2 s.e.	4.8	3.0
•*Asterias forbesi*		
$\bar{x}$	12.5	8.5
2 s.e.	2.2	2.4
•*Eupleura caudata*		
$\bar{x}$	23.2	15.1
2 s.e.	4.6	3.4
•*Thais lapillus*		
$\bar{x}$	13.8	12.0
2 s.e.	4.2	3.2
•*Busycon canaliculatum*		
$\bar{x}$	24.5	20.0
2 s.e.	8.2	5.0

Table III: Mean number of scallop swimming claps in response to eight test species at 12° and 20°C. (• indicates predators)

Test Species	Temperature	
	12°C	20°C
Littorina littorea		
$\bar{x}$	1.4	1.2
2 s.e.	0.6	0.6
Arbacia punctulata		
$\bar{x}$	0.2	0.3
2 s.e.	0.2	0.2
Ilyanassa obsoleta		
$\bar{x}$	1.5	1.7
2 s.e.	0.8	0.6
•*Urosalpinx cinerea*		
$\bar{x}$	7.3	6.8
2 s.e.	1.0	1.0
•*Asterias forbesi*		
$\bar{x}$	4.3	3.8
2 s.e.	0.6	0.6
•*Eupleura caudata*		
$\bar{x}$	5.6	6.2
2 s.e.	1.4	0.8
•*Thais lapillus*		
$\bar{x}$	8.0	7.1
2 s.e.	1.4	1.2
•*Busycon canalicilatum*		
$\bar{x}$	6.5	5.1
2 s.e.	1.2	1.0

B. Response to Test Species

Quantified behavioral responses showed that scallops distinguished the predatory snails, U. cinerea, E. caudata, T. lapillus and B. canaliculatum and the predatory starfish A. forbesi, from the non-predatory snails, L. littorea and I. obsoleta and the non-predatory sea urchin, A. punctulata (Tables II and III).

There was a distinct difference among scallop responses to test species. When response time was plotted against number of claps (Fig. 2), two separate groups representing scallop responses to predators and non-predators became evident. Characteristically, scallops responded to predators quickly and vigorously as evidenced by lower mean response times and higher mean number of swimming claps. Further, scallops were able to carry out this discrimination and consistently distinguish predators from non-predators at both 12^{o} and 20^{o}C.

When responses to non-predators alone were examined, there was a significant effect on scallop behavior (Table IV). Mean response times were higher and mean number of swimming claps were lower when scallops were stimulated with A. punctulata compared to responses to either I. obsoleta or L. littorea (Fig. 2).

Responses to predators as a group were also significantly influenced by the test species used (Table IV) but were more varied (Fig. 2). Scallops responded to the starfish A. forbesi with fewer swimming claps than to any other test predator (t-test). However, response times to this starfish were similar to those for most predatory snails with the exception of higher response times to E. caudata (at 12^{o}C) and B. canaliculatum (t-test). Scallops exhibited the highest number of swimming claps when stimulated with T. lapillus and U. cinerea.

The significant temperature effect (Table IV) was evidenced by consistently lower mean response times to predators at 20^{o}C (Table II). No significant interactions between the effects of test species and temperature were observed.

9.2.4 Discussion

Sensitivity of four selected peripheral regions of the bay scallop, A. irradians, was variable and suggested that U. cinerea, at least, can successfully attack scallops from the dorsal hinge without evoking an escape response. In this region, the mantle is behind the hinge with no tentacles to contact an intruder. Responses to U. cinerea touching the dorsal hinge appeared to be due mainly to mechanical stimulation, evidenced by long response times and less than one swimming clap. Typical escape behavior which resulted from stimulation at three other areas, suggested scallops mechanically and chemically recognize U. cinerea primarily through tentacle contact with the snail rather than from chemical information in the water column. Others have found that physical contact with a predator provokes more reliable responses from various molluscs (Gore, 1966: Thomas & Gruffydd, 1971; Bullock, 1953; Turner, 1955).

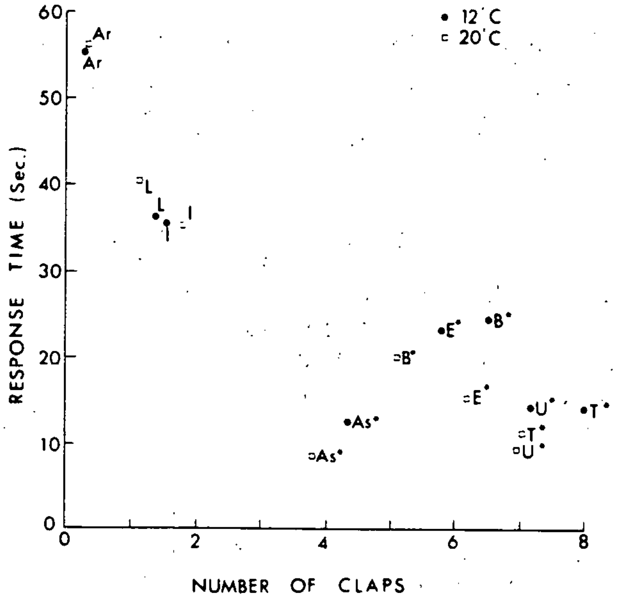

Fig. 2. Scattergram of mean scallop response time vs. mean number of swimming claps when stimulated with various test species at 12 and 20^{o}C: Ar. Arbacia punculata: L. Littorina littorea; I. Ilyanassa obsoleta; As*. Asterias forbesi: B*. Busycon canaliculatum: E*. Eupleura caudata; U*. Urosalpinx cinerea; T*, Thais lapillus; *, predators.

Table IV: A summary of F values and degrees of freedom (in parenthesis) for six analysis of variance tests. (* indicates p < .05)

	All Data	Non-Predators	Predators
RESPONSE TIME			
Test Species (S)	*75.05 (7,165)	*26.31 (2,55)	*11.35 (4,99)
Temperature (T)	3.29 (1,165)	0.33 (1,55)	*12.31 (1.99)
Interaction (SxT)	1.08 (7,165)	0.37 (2,55)	0.55 (4,99)
SWIMMING CLAPS			
Test Species (S)	*82.20 (7,165)	*13.71 (2,55)	*13.75 (4,99)
Temperature (T)	2.37 (1,165)	0.02 (1,55)	3.06 (1,99)
Interaction (SxT)	0.91 (7,165)	0.43 (2,55)	0.79 (4,99)

The feeding habits of the test species are quite varied. We observed U. cinerea, E. caudata and A. forbesi actively feeding on scallops during dives in Point Judith Pond. Although we did not observe B. canaliculatum, a known predator of scallops (Magalhaes, 1948), feeding, we captured a single individual near the scallop beds. Thais lapillus, however, is an unlikely predator of scallops because they are predominantly found in exposed, rocky intertidal habitats where they preferentially feed on barnacles (Connell, 1961). We never observed T. lapillus in or near the estuarine scallop beds in Point Judith Pond. Both non-predatory snails L. littorea, whose food preference is Ulva, Enteromorpha, and diatoms, (Newell, 1958) and I. obsoleta, which feeds mainly on microflora on the sediment on intertidal flats (Scheltema, 1964) were found on the scallop beds, while the sea urchin A. punctulata, which feeds primarily on Laminaria and Fucus (Lawrence, 1975) was not.

The ability of bay scallops to recognize predators through escape responses has been demonstrated here. While Thomas & Gruffydd (1971) have shown the scallop P. maximus capable of distinguishing predatory from non-predatory starfish, our results demonstrated bay scallops were capable of discriminating predatory from non-predatory gastropod molluscs. Further, bay scallops appeared equipped to recognize and escape from T. lapillus, even though this gastropod feeds in a different habitat. Appearance of escape responses then was generally correlated with feeding habits of the stimulating species and not with probability of encounter. Yarnall (1964) came to a similar conclusion for the escape response of Tegula funebralis.

Although scallops discriminated a starfish from a sea urchin, responses to these echinoderms were less vigorous compared with scallop responses to gastropod molluscs. A partial explanation may be that echinoderms and gastropods provide scallops with very different chemical and mechanical stimuli for discrimination.

Ecologically, it is not surprising that bay scallops recognized predators at both 12° and 20°C because scallop predators actively feed at these temperatures (Carriker & Van Zandt, 1972; Manzi, 1970; MacKenzie, 1969; Hanks, 1957). However, temperature did influence scallop response time to predators. Scallops took longer to respond at 12°C. At low temperatures, chemical sensitivity of the tentacles may decrease, or the amount of active substance from predators may be lower (Yasumoto, et al. 1966) or both. Whereas the number of swimming claps, caused by rhythmic activity in the adductor muscle and maintained by motor output from a stretcher receptor feedback system (Stephens, 1978), seemed temperature independent, once initiated.

Predator discrimination, besides allowing prey to escape predators (Feder, 1963), could also reduce time and energy wasted on needless escape responses. Filter feeders are usually food limited and, as a consequence, their time-energy budget is such that they need to invest most of their time feeding (Wilson, 1975). Predator recognition could be used by scallops to minimize feeding interruptions. Thomas & Gruffydd (1971) have further reasoned that, since the scallop, P. maximus, often lives in depressions in the substrate, unnecessary escape responses could easily carry it out of a depression, forcing the scallop to invest extra time and energy in construction of a new depression. A similar case can be made for bay scallops which are often found in shallow depressions.

9.3 Section III.

Predation, attack success, and attraction to the Bay Scallop, Argopecten irradians by the Oyster Drill Urosalpinx cinerea

Abstract

Investigation of the intensity of predation by the oyster drill, Urosalpinx cinerea (Say), on the bay scallop, Argopecten irradians (Lamarck), was carried out in field and laboratory studies. Field measurements of densities of the oyster drill and the bay scallop were respectively, 3.6 m^{-2}, and 21.1 m^{-2} on a scallop bed in Ninigret Pond, Charlestown, Rhode Island. The mean density of snails attacking scallops was 1.7 m^{-2}. In a laboratory study of attack success, an average of 72.3 percent of drill attacks led to death of the scallop. Snails were also shown to be strongly attracted to scallop effluent in a choice chamber.

9.3. Introduction

Barnacles, oysters, and mussels are often listed as primary prey for the oyster drill, Urosalpinx cinerea (Say) (Wood, 1968; Carriker & Van Zandt, 1972). It is also known that drills are guided by olfactory cues to their common prey (Wood, 1968; Pratt, 1974) but evidence that drills attack scallops is scarce although Marshall (1960) found that many U. cinerea were attracted to caged bay scallops in a Connecticut estuary. Our purpose was to determine the importance of U. cinerea as a predator of the bay scallop Argopecten irradians (Lamarck), on a natural scallop bed, to study drill attack success, and to examine the effect of scallop effluent on oyster drills in a choice chamber.

9.3.2 Methods & Results

9.3.3 Field Study

1. Methods

Field studies were carried out using SCUBA during July 1979 on a natural scallop bed in Ninigret Pond, Charlestown, Rhode Island. Square meter quadrats were randomly placed to measure scallop and oyster drill densities as well as the density of drill attacks. Attacks were defined as single or multiple occurrences of Urosalpinx cinerea attached to a live scallop. Densities were measured by removing all scallops and oyster drills from a m^2 quadrat after noting the number of drill attacks. Counts for each m^2 were made at the surface. Animals touching the square meter frame were considered to be within the quadrat. Mean densities were estimated from 21 m^2 quadrats. Temperature measurements ranged from 23° - 26°C while salinity was constant at 28 ‰. Scallops and drills collected during this phase were held in ambient running sea water for subsequent laboratory studies.

2. Results

The mean (+ 2 s.e.) scallop density on a scallop bed in Ninigret Pond was 21.2 ± 2.3 per m^2, while the density of oyster drills was 3.6 ± 1.2 per m^2. No other major predators, including the starfish *Asterias forbesi* (Desor), were observed during data collection. Although one blue crab, *Callinectes sapidus* (Rathbun), was found eating scallop remains, there was no evidence to show that the crab actually killed the scallop. The mean (+ 2 s.e.) density of attacks by *Urosalpinx cinerea* was 1.7 ± 0.6 per m^2. Our calculations show that 7.9 percent of the scallops on this bed were being attacked by 47.0 percent of the drill population and that 6.8 percent of these scallops were attacked by more than one drill.

9.3.4 Laboratory Assessment of Oyster Drill Attack Success

1. Methods

To examine attack success, drills and scallops collected from Ninigret Pond, were placed in a tank (118 x 240 x 27 cm), with a bottom area of 2.8 m^2. Only drills measuring 1.5 - 2 cm from apex to siphon were used. Prior to testing, all drills were provided with liberal numbers of live scallops on which to feed. After 24 hours, each scallop with a drill on its shell was isolated in a 40 liter tank with running sea water where the fate of each scallop could be monitored. Attacks were considered unsuccessful when a snail was found off of the scallop and successful if examination of a dead scallop revealed a completed borehole. Dead scallops with boreholes were assumed to have died directly or indirectly as a result of a snail attack. This procedure was replicated three times with different snails at a mean (± 2 s.e.) water temperature of 19.9 ± .8°C and a mean (± 2 s.e.) salinity of 30.0± .4 $^0/_{00}$ during August and September 1979.

2. Results

Of the attacking oyster drills, an average ($\bar{x}$ ± 2 s.e.) of 72.3 ± 9.8 percent succeeded with their attacks culminating in scallop death while only an average ($\bar{x}$ ± 2 s.e.) of 25.9 ± 12.2 percent of scallops survived attacks. Results of the three replicates are displayed in Table I. Although both replicates performed at 20°C appear to be the same, attack success of snails at 17.7°C tends to be lower even though it is not significantly different (chi-square). The mean time for success is similar at all temperatures, averaging 6.1 days (range: 2 - 15 days) with the majority of successful attacks occurring between day 4 and day 7.

9.3.5 Oyster Drill Response to Scallop Effluent

1. Methods

Scallop and oyster drills collected as previously described from Ninigret Pond were held in ambient temperature, unfiltered, running sea water for two weeks prior to experimentation. Oyster drills were supplied with live scallops for food. During the experiments, temperatures and salinities averaged (X± 2 s.e.) 21.3 ± 2.0°C and 30.0 ± .4 $^0/_{00}$ respectively.

TABLE I

Laboratory assessment of the percentage of successful attacks by the oyster drill, Urosalpinx cinerea, on the bay scallop, Argopecten irradians, and mean time required to complete the attack.

	n	% successful attacks	% unsuccessful attacks	$\bar{X} \pm 2$ s.e. days until scallop death	$\bar{X} \pm 2$ s.e. temp. °C
Replicate 1 8/22 - 9/5	18	77.8	16.7	6.1 ± 1.5	20.9 ± 0.8
Replicate 2 8/29 - 9/4	17	76.5	23.5	5.9 ± 1.3	20.6 ± 0.8
Replicate 3 9/20 - 10/1	16	62.5	37.5	6.3 ± 2.1	17.7 ± 0.7
		$\bar{X} = 72.3$ 2.s.e. = 9.8	X = 25.9 2.s.e. = 12.2	X = 6.1 ± 0.9	$\bar{x} = 19.9 \pm 0.7$

Trials were carried out with epoxy coated plywood choice chambers designed by Pratt (1974). Continuously running sea water was first fed into two reservoirs (21 x 19 x 22 cm) from which the water was gravity fed into wells on both sides of the choice chamber. During tests, scallop effluent was introduced into sea water by placing thirty live scallops into one of the reservoirs. Water from the wells overflowed down both ramps a distance of 19.5 cm to exit through holes in a drain plate at the center of the apparatus. Flow rates to the wells were set with valves at 250 ml per minute. Dye experiments showed that mixing occurred only in a limited area over the drain plate holes. To eliminate possible directional bias, scallop effluent was presented on different sides of the choice chamber after six drills were tested.

Trials were performed by starting three marked snails directly in the center of the drain plate with their long axes perpendicular to the chamber length. After one hour, the distance in cm each drill traveled away from the start was measured from the center of the chamber to the tip of the drill siphon. Drills were replaced with new snails after they responded or if they failed to move from the starting position after an hour. Although Wood (1968) found that *Urosalpinx cinerea* do not follow each others trails, as a precautionary measure, ramps were scrubbed after every six drills tested with sea water during each trial. If a snail reached the well in less than an hour, both distance and time in minutes were recorded. During the first of two trials, 88 different drills were presented with plain sea water on both sides of the chamber to test for chamber bias. In the second trial, 100 different drills were presented with a choice between scallop effluent and plain sea water to measure drill response to scallops. Data were analyzed using the chi-square and t-test.

2. Results

When presented with a choice between plain sea water versus plain sea water in trial 1 (Table II), the number of *Urosalpinx cinerea* responding and moving greater than halfway up the ramp (10 cm) was the same for both sides of the chamber (chi-square). Measurements of the distance traveled and the rate that drills moved up either ramp showed no difference between sides, further indicating that there was no significant apparatus bias (t-test).

Responses of drills presented with a choice between sea water containing scallop effluent and plain sea water in trial 2 (Table II) showed a significant number of snails responded to scallop effluent compared to those responding to plain sea water (chi-square). The number of snails moving more than 10 cm was also greater in water containing scallop effluent (chi-square). Further, drills traveled twice the distance and speed in scallop effluent compared to distances traveled in plain sea water.

9.3.6 Discussion

Urosalpinx cinerea is an active predator of *Argopecten irradians* in Ninigret Pond, Rhode Island and was the only predator found during our observations. Although other predators have been listed as preying on scallops (Marshall, 1960) we have no data on their actual or potential

TABLE II

Responses of *Urosalpinx cinerea* to bay scallop effluent
and plain sea water in the choice chamber

	Water Presented		Significance			
	Trial 1	n = 88				
	Plain Sea Water	Plain Sea Water	χ^2	t-test	d.f.	P
number responding	44	44	0.0	--	1	.99
number moving $\geq$10 cm	4	6	0.4	--	1	<0.1
$\bar{X} \pm 2$ s.e. cm traveled	2.6 ± 1.4	3.8 ± 1.8	--	1.04	86	>0.2
$\bar{X} \pm 2$ s.e. rate of movement (cm/min)	0.08 ± 0.07	0.09 ± 0.05	--	0.22	86	>0.5
	Trial 2	n = 100				
	Scallop Effluent	Plain Sea Water				
number responding	65	35	9.0	--	1	<0.005
number moving $\geq$10 cm	33	7	16.7	--	1	<0.005
$\bar{X} \pm 2$ s.e. cm traveled	10.8 ± 2.0	5.4 ± 2.2	--	3.36	98	<0.001
$\bar{X} \pm 2$ s.e. rate of movement (cm/min)	0.35 ± 0.1	0.17 ± 0.11	--	2.19	98	<0.05
	Trial 2	n = 100				
	Scallop Effluent	Plain Sea Water				
number responding	65	35	9.0	--	1	0.005
number moving 10 cm	33	7	16.7	--	1	0.005
$X \pm 2$ s.e. cm traveled	10.8 ± 2.0	5.4 ± 2.2	--	3.36	98	0.001
$X \pm 2$ s.e. rate of movement (cm/min)	0.35 ± 0.1	0.17 ± 0.11	--	2.19	98	0.05

impact in Ninigret Pond. During the spring, when water temperatures were 10°C, we observed Asterias forbesi preying on scallops in the study area. However, starfish were conspicuously absent from our summer observations, possibly owing to their inability to cope with temperatures above 25°C (Mackenzie, 1969). Further, our observations on laboratory held starfish confirm that mortalities were unusually high when ambient water temperature was above 20°C. U. cinerea, unlike starfish, feeds at a maximum rate (Hanks, 1957; Manzi, 1970) at the salinities and temperatures encountered during our observations.

Our laboratory studies show that not all drill attacks reach a successful conclusion. More than one quarter of all drill attacks on scallops are not successful and may be a direct result of the vigorous escape response (Ordzie and Garofalo, 1980) which bay scallops employ when attacked. Our observations indicate that the rapid movements of the scallop valves during this response were sufficient to shake off an attached drill. Further, we have observed live scallops in the field with complete and incomplete boreholes. Calculations of predation by U. cinerea on scallops based only on observed attacks without correction for unsuccessful attacks would lead to an overestimation of predation intensity.

Our measurements of time required to successfully drill scallops is an agreement with rates for U. cinerea to drill oysters, (Carriker and Van Zandt, 1972) and are similar to those found for Ocinebra japonica (Chew, 1960).

Environmental parameters have such strong influences on feeding rates of predatory snails (Menge, 1978) that predation rates differ between habitats and even between individuals. Such observations make it difficult to generalize about predation rates. The impact of predation is very specific for habitat location and environmental conditions.

We have also shown that U. cinerea move toward water containing scallop effluent. This strong attraction was heretofore only observed when drills were presented with barnacle effluent and is unusually strong compared to other bivalve species tested, including oysters (Wood, 1968; Pratt, 1974). Further, once stimulated, oyster drills proceed to double their rate of locomotion toward the scallops. Moving faster toward prey effluent increases the probability of prey encounter in a shorter time period. By decreasing the time between recognition of prey effluent and contact with mobile prey, drills also increase the probability of being able to execute an attack before the prey changed location.

9.4.1 Introduction

Investigations of community type responses were stimulated by results from previous work (Section 9.1) which suggested that sublethal concentrations of dispersants had adverse effects on scallop behavioral escape responses and starfish posturing reflex. These results led us to create a simple community and ask what would happen if both predator and prey were dosed and placed together in large laboratory tanks. How many scallops would survive in each treatment? Can we detect changes in individual spacing with treatment? The purpose here was to study a scallop-starfish community interaction after dosing under laboratory conditions.

9.4.2 Methods and Materials

Preparation of dosing stock solutions was identical to the method already described (Section 9.1). Stock solutions of each treatment, oil, dispersant, and oil-dispersant were diluted to make dosing mixtures of 12.5% stock solution and 87.5% sea water. This concentration was previously determined to be sublethal at 10°C for scallops (Section 9.1). Forty scallops and six starfish were statically dosed together in 20 liters of treatment solution for six hours with aeration. After dosing, all animals from each treatment, plus a control with starfish and a control without starfish were removed and randomly placed into respective 2.8m^2 epoxy coated plywood tanks filled to a height of 18 cm. A constant flow of ambient temperature sea water (20 liters/min) was provided to each of the five tanks representing each treatment. This experiment was replicated twice with temperatures and salinities averaging ($X \pm 2$ s.e.) 12.1 ± 1.2°C and $30.5 \pm .4$0/00 respectively during the experiments.

Scallops in the 2.8 m^2 tanks were at a density of 15 per m^2, well within the natural densities we found on a scallop bed (section 9.3). Since no data was available for starfish densities, we chose to use six.

After dosing, the number of living scallops in each tank was recorded for 15 days. Survivorship results were analyzed using the chi-square statistical test. Additionally, nearest neighbor distance (cm) of scallops was recorded for each treatment tank during the 15 days. The analysis of variance test was used to analyze the nearest neighbor data. Dead scallops were not removed until the end of the experiment to approximate field conditions.

9.4.3 Results

A. Survivorship

Data from both replicates was combined since no significant replicate difference was found. Scallop survivorship at day five for the community experiment was compared to a five day survivorship experiment previously completed (Section 9.1) at 10°C for scallops exposed to 12.5% stock solution without starfish (Table 1). 10°C was chosen since the average temperature for the community experiment was 13.1°C. Each treatment, oil, dispersant and oil-dispersant, was independently compared to the control for the experiment. There was no significant difference

TABLE 1 Scallop Survivorship (Percent Surviving) for the 12.5% Concentration of the Four Experimental Treatments; Without Starfish at Day Five and with Starfish at Day Five.
C - Control,) - Kuwait Crude Oil, D - Corexit 9527 Dispersant, OD - Oil and Dispersant, *, $P < 0.05$

	Five Day Survivorship without starfish n = 80	Significance			Five Day Survivorship with starfish n = 80	Significance		
		X^2	d.f.	P		X^2	d.f.	P
Treatments								
C	100				93.8			
	99	.01	1	.95	87.6	.21	1	<.9
D	87.5	.83	1	.5	65*	5.22	1	<.05
OD	92.5	.29	1	.9	61.3*	5.82	1	<.01

in survivorship between the control and the treatments when starfish were absent (10°C) (X^2). However, with starfish present, survivorship in the dispersant and oil-dispersant treatments was significantly lower than for controls (X^2). At day 15 after dosing, with starfish present, scallop survivorship in the dispersant and oil-dispersant treatments was also significantly lower than controls (X^2) (Table 2).

There were no starfish mortalities in any treatment during the entire community experiment.

TABLE 2 Scallop Survivorship at (Percent Surviving) at 15 Days for the 12.5% concentration of the Four Experimental Treatments with Starfish. C - Control, O - Oil, D - Dispersant, OD - Oil-Dispersant, *, Significantly Different from control

		Percent Surviving with Starfish	Significance		
			X^2	d.f.	P
	C	90			
TREATMENT	O	74.1	1.54	1	< .5
	D	48.8	12.22*	1	< .001
	OD	53.8	9.12*	1	< .01

9.44 Spacing

Scallop spacing was found to be significantly different in the oil-dispersant treated scallops (ANNOVA Table 3). The mean distance to nearest neighbor in the oil-dispersant tank was significantly higher than both the control without starfish and the control with starfish (ANOVA, F = 7.11, d.f. = 4, 50, P .0001; LST = 6.75, d.f. = 50, P = .05). Nearest neighbor distance for the oil treated and the dispersant treated scallops was not different from the controls.

TABLE 3 Spacing of scallops in $\overline{X}$ cm to Nearest Neighbor for Five Experimental Treatments: C - control without starfish, C starfish - Control with starfish,) - oil, D - Dispersant, OD - Oil and Dispersant. *P .05 <.05 ANOVA

	C	C Starfish	O	D	OD
$\overline{X}$ cm	12.7	10.2	10.4	16.1	25.5*
2 S.E.	.95	1.64	1.44	3.62	9.7

9.4.5 Discussion

The goal of this study was to determine how a simple predator-prey community would be affected by oil, dispersant and an oil-dispersant treatment. Scallops and starfish had previously been tested separately with these same treatments and the behavioral changes (Section 9.1) suggested a community type experiment.

In our previous study, scallops were found to have diminished discrimination between predators and non-predators when treated with dispersant and oil-dispersant, but that oil treated animals were not significantly different from the control animals. Response to food by starfish was significantly slowed by all treatments. When both predator and prey were treated as a community, scallop survivorship was significantly reduced in the dispersant and oil-dispersant treatments beyond that expected because of hydrocarbon treatment or starfish predation alone. Since scallop survivorship in the oil treatment was not different from controls, the slowed ability of the starfish to respond to food did not appear to affect their ability to feed on scallops. This again shows the differential susceptibility of the test animals to pollutants (section 9.1).

Scallops were significantly farther apart in the oil-dispersant treatment. Perhaps it is a behavioral advantage at this time of year for scallops not affected by treatment to be closer together during spawning (personal communication, John Karlsson).

The two measured aspects of this experiment, survivorship and spacing, appeared to be affected, but not always by the same treatments. Only additional studies could begin to unravel the details of the various community responses reported. One overriding observation remains: at concentrations far below the LD 50, dispersant treated scallops suffer greater than 50 percent mortality in the presence of starfish. These results are not predicted by classical bioassay methods. Community studies are rare to non-existent in bioassay work but could prove extremely useful in the prediction of ecological impacts by dispersants.

ADDENDUM

Analysis of Hydrocarbons in Stock Solutions

Oil (Kuwait Crude)
Aromatic
26.34 mg/liter
Aliphatic
18.28 mg/liter
Total Hydrocarbons
44.62 mg/liter

Dispersant
Aromatic
19.54 mg/liter
Aliphatic
13.88 mg/liter
Total Hydrocarbons
33.42 mg/liter

Oil & Dispersant
Aromatic
39.14 mg/liter
Aliphatic
20.78 mg/liter
Total Hydrocarbons
59.92 mg/liter

Oil in mixture by difference
Aromatic
19.6 mg/liter
Aliphatic
6.9 mg/liter
Total Hydrocarbons
26.5 mg/liter

Seawater Control

Aromatic
0.46 mg/liter
Aliphatic
0.024 mg/liter

Total Hydrocarbons
.484 mg/liter

10.0 References

10.1 Section 2 References

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11.2.1 Bibliography I: Fisheries and Biological References
11.2.2 Bibliography II: Behavior and Effects of Hydrocarbons
11.2.3 Bibliography III: Mathematics and Descriptions of Physical Phenomena

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12.0 Appendices

12.1 Section 2 Appendices

12.1.1 Appendix A Error Analysis
12.1.2 Appendix B Measurement of Interfacial Tension
12.1.3 Power Input

Section 2. Appendix A - Error Analysis

The error in the measurement or calculation that appears in any quantity in an investigation is the net result of different errors in the measurements or calculations preceding it. Thus the average drop-size, hold-up and interfacial area carries errors in them that depend on the experimental technique involved in measuring them or the use of quantities that have errors in calculating them.

The drop-size was measured using a microscope, and the size could be measured up to 0.25 microns. Thus the maximum possible error that could have arisen in the measurement of drop-size was ±0.25 microns.

The hold-up was measured using an Infra-red Spectrometer and within the range of measurement, the maximum error possible was ±1 ppm.

Thus due to an error in the measurement of drop-size the Sauter mean was in error as follows.

$$\varepsilon_{SM} = \frac{\Sigma n_i (d_i + \varepsilon_i)^3}{n_i (d_i + \varepsilon_i)^2} = 0\ (\varepsilon_i)$$

Interfacial area was given by

$$A = \frac{6 \times \phi}{SM}$$

Due to an error in the measurement of hold-up and Sauter mean, the interfacial area could have an error up to

$$\frac{6(\phi + \varepsilon_{\phi})}{(SM + \varepsilon_{SM})} = 0\ (0.4 m^2/m^3)$$

The experiments at room temperature varied over a range of about 2.5 C. The variation in viscosity over such a small range of temperature is less than 5 percent (45). The interfacial tension over the same range of temperature is estimated to vary by about 1 dyne/cm. The effect of temperature on the drop-size can be estimated by the correlation of Shinnar (32). The error in the average drop-size due to temperature is found to be

$$\text{constant} \times (\sigma + \varepsilon_{\sigma})^{5/8} = 0\ (0.25 \text{ microns})$$

From the above discussion, it can be seen that the maximum error that could be expected in the measurement of the drop-size is of the order of ± 0.5 microns. The hold-up is estimated to be accurate to within ±1 ppm and the interfacial area accurate to within 0.4 m^2/m^3.

Section 2. Appendix B - Measurement of Interfacial Tension

Interfacial tension of Kuwait crude oil-sea water system was investigated in the presence of a dispersant. The interfacial tension is an important parameter when studying the stability of liquid-liquid systems. A lower value of interfacial tension means that the energy necessary to break up the dispersed phase will be proportionally lower and the dispersion will be stable.

Molecules in the bulk liquid phase experience the same average force in all directions. But at the interface this is not the case. Since the molecules across the interface are of a different species the forces are not evenly balanced. This results in a condition in which the interface is in a state of tension. The name "Surface Tension" is used when the interface is between a liquid and a vapor, and "Interfacial Tension" when the interface is between two liquids or a liquid and a solid.

When it is desired to separate two liquid phases after they have been brought into intimate contact (e.g., in liquid-liquid extraction) the interfacial tension should be high so that the coalescence is rapid. On the other hand, when one liquid is to be dispersed in another liquid, the interfacial tension should be low so that the break up is rapid and the dispersion is stable.

With few exceptions, a third component tends to reduce the interfacial tension between two pure components. The reducing effect is more pronounced if the third component is more concentrated at the interface than in the bulk. This is the case when surfactants and dispersants are used. The interfacial tensions between two liquids is highest when pure, and falls off to zero at plait point.

When a liquid surface (or liquid-liquid interface) is newly formed, a finite time is needed for establishing the state of equilibrium. During this period surface tension (or interfacial tension) is time dependent. In the case of the formation of pure liquid interfaces, it has not yet been possible to measure tension before the final value has been achieved, because the time involved is very small. However, when dealing with solutions the time factors involved are quite large and it is possible to measure the interfacial tension in the transient state. Surface tension or interfacial tension before equilibrium has been established is called "dynamic" to distinguish it from the equilibrium or "static" value.

Methods of Measurement

1) Capillary height-method. This is probably the simplest method available. When a capillary is inserted below the interface of a two liquid system, due to the excess free energy of the interface, the liquid in the lower layer rises to a higher level within the capillary.

But for the crude oil water system under study, this method could not be used as the darker upper layer of the crude prevents observation of the capillary height which should be known to correlate the interfacial tension.

2) Drop Weight Method. In this method drops are allowed to form at the top of a capillary immersed in another liquid. From a knowledge of the dimensions of the drop and its weight it is possible to calculate the interfacial tension. Since drops have to be formed at a finite site this method is not applicable in systems where a surfactant is present.

3) Ring Method. A platinum ring is pulled up from the interface of the liquids whose interfacial tension is to be measured. The force that is necessary is measured by a torsion balance. Again this method is inapplicable as this is a dynamic method, for the reasons given above.

4) Bubble Pressure Method. The pressure difference across a bubble or drop in another liquid is proportional to the interfacial tensions. Therefore, if it is possible to measure the pressure difference across the bubble we should be able to calculate the interfacial tension. Being a dynamic method this had to be discarded in favor of a semi-static method.

5) Pendant Drop Method. Pendant drop method consists of making a drop form at the tip of a capillary tube and let it hang in the second fluid. If the density difference is not appropriate, the drop can be made to rise up from the tip of the capillary rather than let it hang. The shape of the drop reflects a balance between interfacial tension and the gravitational forces and can be used to measure the interfacial tension. The static nature of the method makes it suitable for use where diffusional effects are involved.

The shape of the pendant drop is determined by the fact that the change in the hydrostatic pressure in the vertical direction is balanced by an equivalent change in the Laplace pressure

$$\Delta P_Q = \frac{2\gamma}{b}$$

where b is the radius of curvature at the apex of the drop.

At point P, a distance z below the apex, the pressure drop is given

$$\Delta P_{p} = \gamma \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{2\gamma}{b} + (\rho_1 - \rho_2)\, gz$$

where R_1 and R_2 are the radii of curvature. The above equation is rearranged into the following dimensionless form:

$$\frac{1}{R_{1/b}} + \frac{\text{Sin }\theta}{x/b} = 2 + \frac{\Delta\rho g b^2}{\gamma} \left(2/_{b}\right) = 2 + \frac{z}{b}\,\beta$$

where $\beta = \frac{\Delta\rho g b^2}{\gamma}$

and $$R_1 = \left[1 + \frac{dz}{dx}\;{}^{2}\;{}^{3/2}\right] \Big/ \frac{d^2z}{dx^2}$$

Bashforth and Adams carried out the numerical integration of the above equation for a number of values of B. As the radius b is difficult to determine experimentally, Bashforth and Adams presented a table of x_e/b as a function of B, where x_e is the equation radius. i.e.,

$$x_e\ b = f(\beta)$$

so that

$$\gamma = \Delta\rho g x_e^2 / \beta \left[f\ (\beta)\right]^2$$

For larger drops only, the radius of curvature in the plane of the paper need be considered. In this case, the equation for γ becomes

$$\gamma = \Delta\rho g h^2/2$$

and this represented a limiting case where h is the distance from the apex to the equatorial line of the drop.

Porter made use of the tables of Bashforth and Adams to show that the differences in $h^2/2x_e^2$ and $a^2/2x_e^2$ is accurately represented by

$$h^2/2x_e^2 - a^2/2x_e^2 = 0.3047\ (h^3/x_e^3)\ (1 - 4h^2/x_e^2)$$

where

$$a^2 = 2\gamma/\Delta\rho g$$

This permits the direct calculation of the surface tension from knowledge of h and x_e, both of which are accurately measurable quantities.

β can also be written as

$\beta = \Delta\rho g d_e^2/H$, where

$H_2 - \beta\ (d_e/b)^2$

The Bashforth and Adams tables were re-worked by several authors into a form giving $1/H$ as a function of $S = d_s/d_e$.

It should not be thought that the ratio S is unique. Any other well-defined dimensions of the drop can be employed. Winkel has suggested that d_{min}/d_e can be used, where d_{min} is the smallest diameter which is observed above the d_e plane for a certain range of shapes (26). However, such a choice seems to be disadvantageous because the minimum diameter is often near the tip of the capillary and it may be affected by the irregularities in its shape. In order to alleviate this problem, Roc, Bacchetta and Wong defined a series of diameters as given by:

$$Z_n = (n/10)\ d_e$$

where n = 8...........12 and the characteristic shape factor is given by:

$$S_n = dn/d_e$$

A series of tables giving $1/h$ as a function of S_n has been computed by the integration of the fundamental differential equation by a digital computer.

Apparatus and Measurement Method

The apparatus consists of a capillary tube of approximately 0.1 cm diameter as shown in Figure 1. The tube was bent into the shape of 'L' and connected to a small reservoir. The reservoir has an overflow port

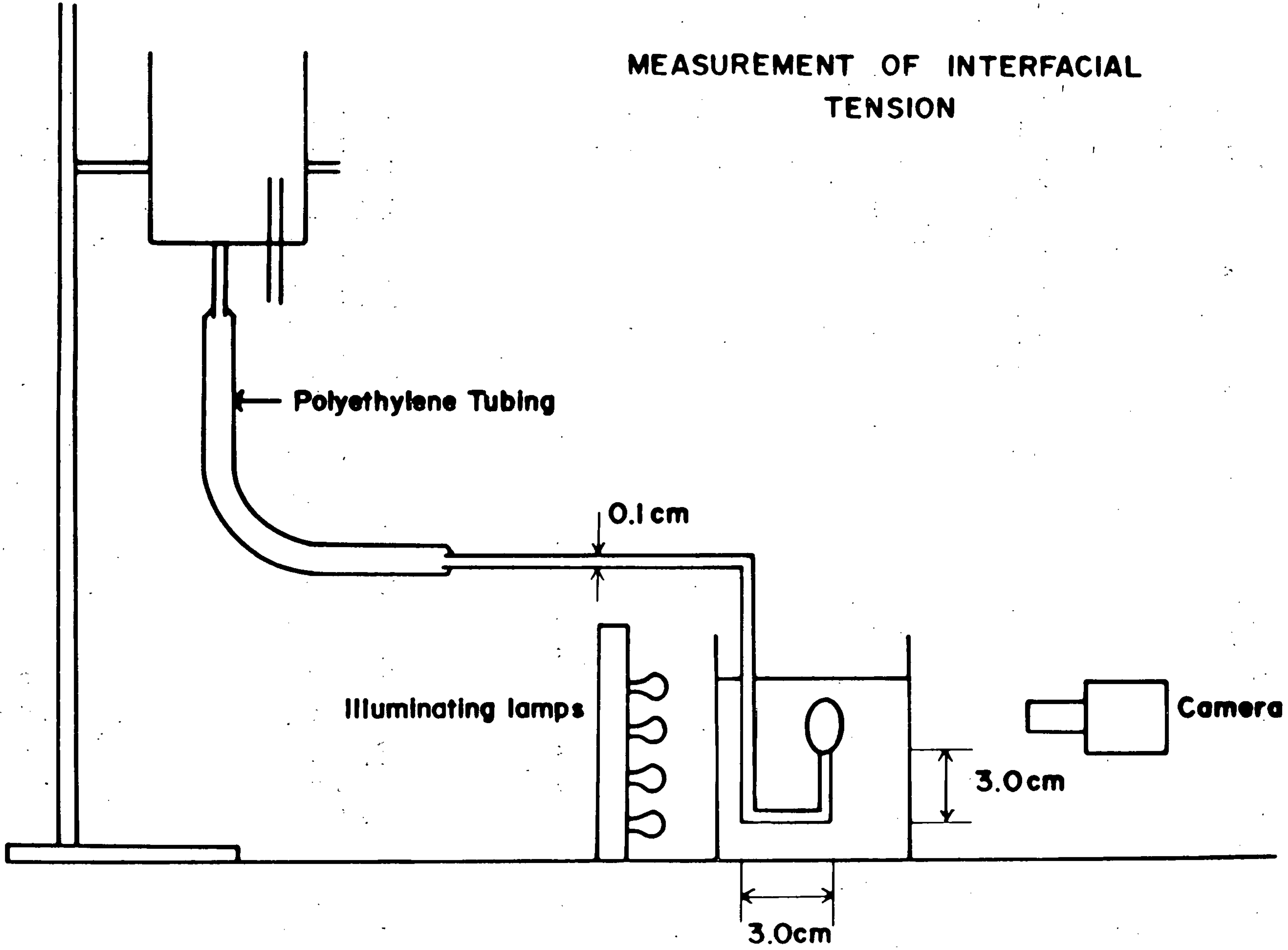
MEASUREMENT OF INTERFACIAL TENSION
Polyethylene Tubing
0.1 cm
Illuminating lamps
Camera
3.0cm
3.0cm

FIGURE 1.

and the crude oil is admitted to the reservoir in drops. The overflow port allows any excess crude to overflow thereby maintaining a constant head. The capillary tube is kept immersed in sea water.

Photographs were taken by a Mamiya Sekor camera provided with extension tubes for greater magnification. Magnification was indirectly determined by simultaneously photographing a steel ruler marked in 1/32" divisions.

Constant temperature could be maintained by a Haake EK11 refrigeration and cooling system of 200W capacity. A Versa Therm temperature probe and electronic relay (sensitivity 0.005 F) ensured that temperature was maintained under close control.

The tube and the reservoir were cleaned using a powerful laboratory cleaner "Micro," and then they were repeatedly rinsed in hot water to ensure that no traces of the cleaner remained on the capillary and the reservoir. The apparatus was then perfectly dried in an oven at 110 C. After each experiment, the apparatus was first washed using carbon tetrachloride and then the above procedure for cleaning was repeated.

A known volume of Corexit 9527 was added to the sea water (or to crude oil) and drops were allowed to form at the tip of the capillary at the rate of approximately one per minute. For each concentration level, 20 photographs were taken.

The photographs were projected on a screen and the largest diameter of each drop d_e was determined; d_s was measured at a distance of d_e from the vertex of the drop. The shape factor was determined and the corresponding value of 1/H was read from tables. Interfacial tensions were calculated using the formula:

$$\gamma = \frac{g \Delta \rho d_e^2}{H}$$

It is seen that, as shown, in Figure 2, the interfacial tension falls off rapidly as the concentration of the dispersant is increased. The decrease was most pronounced for the addition of the first 0.01% of the dispersant. Thereafter, the decrease in the interfacial tension is less rapid and it levels off at around 0.04% by volume of dispersant.

Results and Discussion

The interfacial tension data on the range 5°C to 22°C, as shown in Figures 2 an 4, shows the usual trends that would be expected with variations in temperature and concentration of the dispersant. The highest observed interfacial tension was 27.5×10^{-3} Newtons/Meter at 5 C and without dispersant, and the lowest was 2.75×10^{-3} Newtons/Meter at 22 C and 0.1 vol. % Corexit. Although 0.1 vol. % of Corexit is low when compared with usual dosages of surfactants, higher concentrations have not been used. At higher concentrations, the water becomes cloudy as the

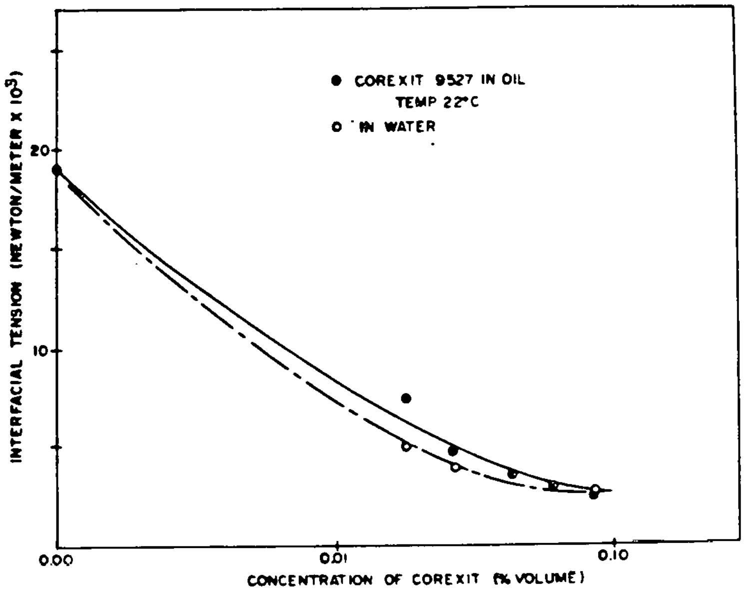

FIGURE 2.

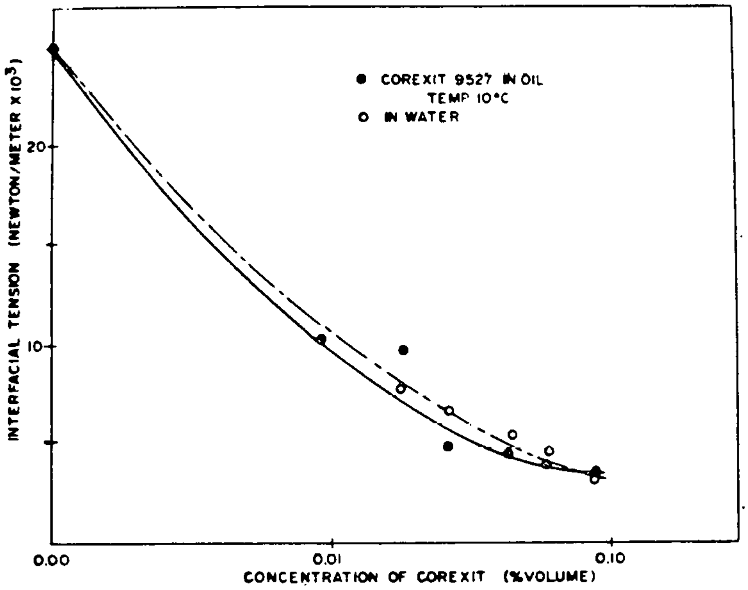

FIGURE 3.

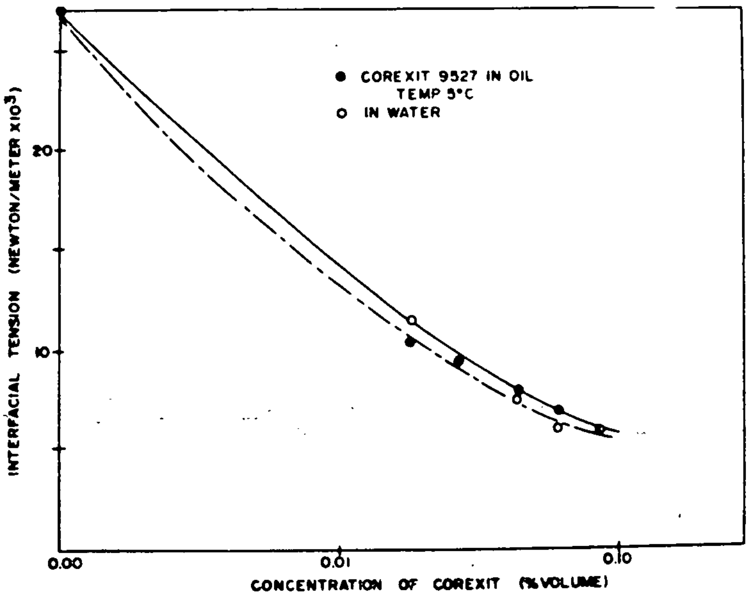

Figure 4.

concentration increases beyond the Critical Micelli Concentration and Tyndall effect becomes pronounced. Under these conditions, it is not possible to use the photographic method.

In analyzing the data, it was found that certain trends are unmistakable. It is seen that the largest drop in the interfacial tension is during the addition of the first 0 - 0.01 vol. % of Corexit. Thereafter the decrease is less with each incremental addition of Corexit and a plot of interfacial tension decreased by about 8.0 x 10^{-3} Newtons/Meter for the addition of the first 0.01 vol. % of Corexit. It should be possible to get lower values of interfacial tension by using a larger proportion of the dispersant. It has been observed in the past that concentrations as high as 1% (10 times the amount used in the present experiment) has been used.

Another fact which stands out is that it is immaterial in which phase the Corexit is added, as shown in Figures 2 and 4. Within limits of experimental error, it is seen that the interfacial tension observed are nearly equal. This is encouraging, as it is far easier to apply the dispersant on the oil, which is the top layer, than to apply it in water. Moreover, in the ocean, larger quantities of dispersant would be necessary, if the dispersant were to be applied on water.

The variation of interfacial tension with temperature, as shown in Figures 5 and 6, is what would normally be expected. There is a steady decrease in interfacial tension with increase in temperature. This is because the cohesion forces between the molecules falls off rapidly with increase in temperature and the interfacial tension is due to the attraction force between the molecules at the interface. Unlike the variation of interfacial tension with concentration, which is rapid with the first increase in concentration, the decrease in interfacial tension with temperature is more or less uniform. On an average, the interfacial tension decreased by about 1 X 10^{-3} Newtons/Meter.

It was observed that at a given concentration level of Corexit and temperature, it did not matter to which phase Corexit was added. This could be because the intermolecular forces are reduced to the same degree in either phase at the same concentration level of Corexit and temperature (and interfacial tension is due to the net intermolecular forces at the interface). However, from a purely economical point of view, it might be advantageous to add Corexit to the oil phase, as in the ocean, because it takes a much larger quantity of Corexit in the aqueous phase to maintain the same concentration level.

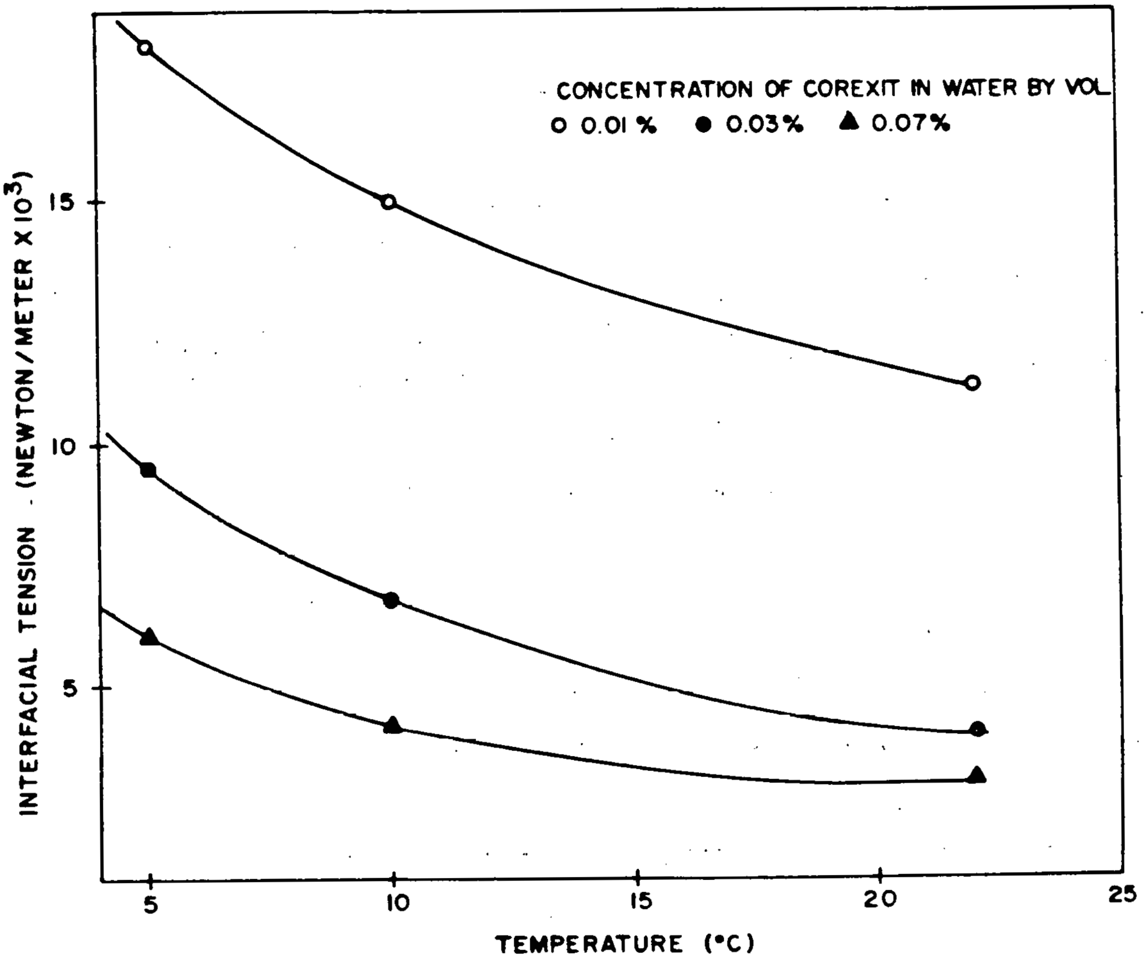

FIGURE 5.

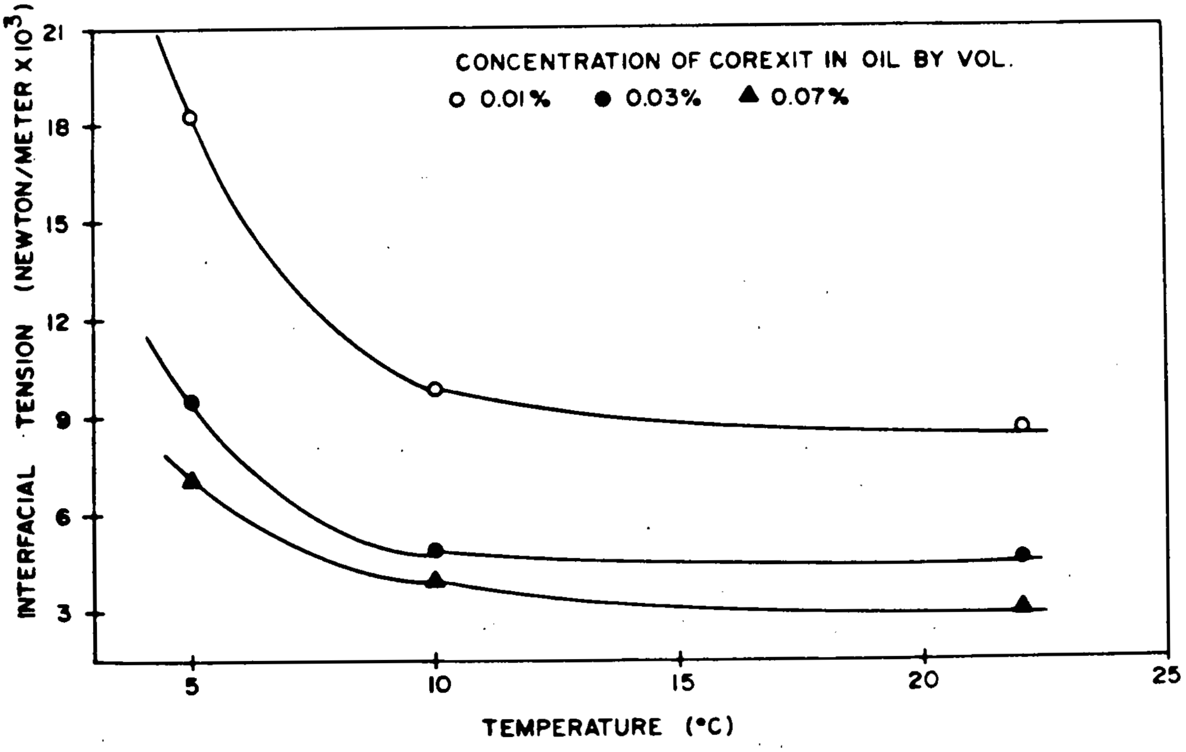

FIGURE 6.

INTERFACIAL TENSION

CONCENTRATION % VOLUME	COREXIT IN OIL 5°C	 10°C	 22°C	COREXIT IN WATER 5°C	 10°C	 22°C
	(x 10³ Newtons/Meter)			(x 10³ Newtons/Meter)		
0.00	27.10	25.10	19.10	27.10	25.10	19.10
0.01	18.40	10.50	8.75	18.40	15.00	11.20
0.02	11.59	9.80	7.50	11.47	8.00	5.10
0.03	9.51	5.00	4.90	9.54	6.80	4.10
0.05	8.14	4.72	3.74	7.60	4.54	3.73
0.07	7.15	4.11	3.11	6.16	4.18	3.15
0.10	6.16	3.91	2.74	6.01	3.73	2.75

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Section 2. Appendix C

Run No:	RPM	Rate of Power Input (Joules)	Work Input for Inter-facial Area (Joules)	Percent Energy Utilized
1	150	52.31	33.90	4.32
2	150	52.31	161.82	9.24
10	300	99.30	52.05	6.63
14	300	99.30	196.79	25.08
9	100	11.30	43.13	5.50
13	100	11.30	156.46	19.93

12.2 Section 4.0 Appendices

APPENDIX A

Computer Programs

Program name: STREAM

FNU(y^+) computes u^+ when y^+ is known from

$$y^+ = u^+ + A[\exp(\kappa u^+)-1-\kappa u^+)^2/2-(\kappa u^+)^3/6-(\kappa u^+)^4/24]$$

FNG(Re_x) computes ξ when Re_x is given from

$$Re_x = \int_0^{\xi} G(z)dz$$

FNF(ξ) computes G(ξ)

The program starts by asking for Re_x(=X). It then computes

$$\left.\begin{aligned} S &= \xi \\ Y0 &= y^+ \end{aligned}\right\} \text{which is printed}$$

It also computes the maximum permissible value for Re_y (based on the condition that $y^+ < y^+_o$) since the algebraic relations cease to be valid when $y^+ > y^+_o$.

For Re_y = Y1 to Re_y = Y8 in steps of Y3 will the program compute the following quantities:

U = u^+

Y5 = y^+

P = Ψ^*

P1 = $\Psi^* + \xi\beta/\lambda$

U5 = $\bar{u}/U_c$

V5 = $\bar{v}/U_c$

Program name: GSTREAM

The program operates at one specific value of y which is more or less determined by the input value ξ_o. From this input the position Re_{x_o} and the value of $y^+_{o,o}$ are computed. The program then proceeds to compute $\bar{u}/U_o$, $\bar{v}/U_o$, v_∞/U_o and $\tau/\rho U_o^2$ for increasing values of Re_x (defined through increasing values of ξ) whereby y is kept constant.

FNR(ξ) computes Re_x with ξ as input Part 4.2: Eq.(2.10)
(See program: STREAM)

FNY(u^+) computes y^+ with u^+ as input

FNF(ξ) computes G(ξ) with ξ as input Part 4.3: Eq.(2.5)

FNU(y^+) computes u^+ with y^+ as input (See program: STREAM)

PROGRAM NAME: STREAM

```
>>OLD:STREAM
>>LIST

00100     DEF FNF(T)
00110     A = 0.1108
00120     K = 0.4
00130     T1 = T*K
00150     G1 = 2+T1**3*(1/3+T1*(1/4+T1*(1/10+T1/36)))
00160     G = T**3/3+A*(EXP(T1)*(T1**2-2*T1+2)-G1)/(K*K)
00170     FNF = G
00180     FNEND
00360     DEF FNU(S)
00370     K = 0.4
00380     A = 0.1108
00390     Z = 30
00400     Z1 = Z*K
00410     S1 = Z+A*(EXP(Z1)-1-Z1-Z1**2/2-Z1**3/6-Z1**4/24)
00420     D2 = 1+A*K*(EXP(Z1)-1-Z1-Z1**2/2-Z1**3/6)
00430     D3 = S1-S
00440     D1 = ABS(D3)
00450 IF D1 < 0.001 THEN GO TO 490
00460     Z = Z-D1/D2
00470     PAUSE
00480 IF D1 > 0.001 THEN GO TO 400
00490     FNU = Z
00500     FNEND
00550     DEF FNG(S)
00560     K = 0.4
00570     A = 0.1108
00580     Z = 30
00590     N = 0
00600     Z1 = Z*K
00610     S4 = 6+2*Z1+Z1**4*(1/12+Z1*(1/20+Z1*(1/60+Z1/252)))
00620     S3 = EXP(Z1)*(Z1**2-4*Z1+6)-S4
00630     S1 = Z**4/12+A*S3/(K**3)
00640     D4 = 2+Z1**3*(1/3+Z1*(1/4+Z1*(1/10+Z1/36)))
00650     D3 = EXP(Z1)*(Z1**2-2*Z1+2)-D4
00660     D2 = Z**3/3+A*D3/(K**2)
00670     D3 = S1-S
00680     D1 = ABS(D3)
00690 IF D1 < 0.001 THEN GO TO 750
00700     Z = Z-D1/D2
00710     N = N+1
00720 IF N > 20 THEN GO TO 750
00730     PAUSE
00740 IF D1 > 0.001 THEN GO TO 600
00750     FNG = Z
00760     FNEND
00800     A = 0.1108
00810     K = 0.4
00820     PRINT ´PARTICLE SIZE P2=?´
00830     INPUT P2
00840     PRINT ´REX=?´
```

```
00850      INPUT X
00860      S = FNG(X)
00870      X1 = X*K
00880      S1 = S*K
00890      Y0 = S+A*(EXP(S1)-1-S1*(1+S1/2*(1+S1/3*(1+S1/4))))
00900      Y9 = Y0*S
00910      PRINT 'Y0='Y0,'KSI='S,'STOP VALUE Y9='Y9
00920      PRINT 'START VALUE Y1=?'
00930      INPUT Y1
00940      PRINT 'STEP Y3=?'
00950      INPUT Y3
00953      PRINT 'END VALUE Y8=?'
00955      INPUT Y8
00960       FOR Y = Y1 TO Y8 STEP Y3
00970      Y5 = Y/S
00980      U = FNU(Y5)
00990      U1 = U*K
01000      P3 = U1**2*(1/2+U1*(1/3+U1*(1/8+U1/30)))
01010      P = U**2/2+A*(EXP(U1)*(U1-1)-P3)
01020      P1 = P+P2*X
01021      U5 = U/S
01022      V5 = Y5*U/(S*FNF(S))
01030      PRINT Y,U5,V5,P,P1
01040      NEXT Y
01050      END
```

```
>>OLD:GSTREAM
>>LIST

00010     DEF FNR(L)
00020     A = 0.1108
00030     K = 0.4
00040     S1 = L*K
00050     R4 = 6+2*S1+S1**4*(1/12+S1*(1/20+S1*(1/60+S1/252)))
00060     R3 = EXP(S1)*(S1**2-4*S1+6)-R4
00070     R = L**4/12+A*R3/(K**3)
00080     FNR = R
00090     FNEND
00100     DEF FNY(J)
00110     A = 0.1108
00120     K = 0.4
00130     J1 = J*K
00140     Y = J+A*(EXP(J1)-1-J1*(1+J1*(1/2+J1*(1/6+J1/24))))
00150     FNY = Y
00160     FNEND
00170     DEF FNF(T)
00180     A = 0.1108
00190     K = 0.4
00200     T1 = T*K
00210     G1 = 2+T1**3*(1/3+T1*(1/4+T1*(1/10+T1/36)))
00220     G = T**3/3+A*(EXP(T1)*(T1**2-2*T1+2)-G1)/(K*K)
00230     FNF = G
00240     FNEND
00250     DEF FNU(F)
00260     K = 0.4
00270     A = 0.1108
00280     Z = 30
00290     Z1 = Z*K
00300     F1 = Z+A*(EXP(Z1)-1-Z1-Z1**2/2-Z1**3/6-Z1**4/24)
00310     D2 = 1+A*K*(EXP(Z1)-1-Z1-Z1**2/2-Z1**3/6)
00320     D3 = F1-F
00330     D1 = ABS(D3)
00340 IF D1 < 0.001 THEN GO TO 380
00350     Z = Z-D1/D2
00360     PAUSE
00370 IF D1 > 0.001 THEN GO TO 290
00380     FNU = Z
00390     FNEND
00400     DEF FNG(H)
00410     K = 0.4
00420     A = 0.1108
00430     Z = 30
00440     N = 0
00450     Z1 = Z*K
00460     H4 = 6+2*Z1+Z1**4*(1/12+Z1*(1/20+Z1*(1/60+Z1/252)))
00470     H3 = EXP(Z1)*(Z1**2-4*Z1+6)-H4
00480     H1 = Z**4/12+A*H3/(K**3)
00490     D4 = 2+Z1**3*(1/3+Z1*(1/4+Z1*(1/10+Z1/36)))
00500     D3 = EXP(Z1)*(Z1**2-2*Z1+2)-D4
00510     D2 = Z**3/3+A*D3/(K**2)
00520     D3 = H1-H
00530     D1 = ABS(D3)
00540 IF D1 < 0.001 THEN GO TO 600
00550     Z = Z-D1/D2
00560     N = N+1
00570 IF N > 20 THEN GO TO 600
00580     PAUSE
00590 IF D1 > 0.001 THEN GO TO 450
00600     FNG = Z
00610     FNEND
```

```
00620     A = 0.1108
00630     K = 0.4
00640     PRINT 'KSINULL =?'
00650     INPUT S0
00660     S1 = S0*K
00670     Y0 = FNY(S0)
00675     R0 = FNR(S0)
00676     V0 = Y0*FNU(Y0)/(S0*FNF(S0))
00677     PRINT 'VNULL='V0
00680     PRINT 'KSINULL='S0, 'YNULL='Y0,'REYNULL='R0
00690     PRINT 'END VALUE KSI=?'
00700     INPUT S9
00710     PRINT 'STEP KSI=?'
00720     INPUT S5
00730     FOR S = S0 TO S9 STEP S5
00740     Y = Y0*S0/S
00750     U = FNU(Y)/S
00751     P1 = U*S
00752     P2 = FNF(P1)/FNF(S)
00753     P = (1-P2)/(S*S)
00760     V1 = S*FNF(S)
00764     Y9 = FNY(S)
00765     V9 = Y9*FNU(Y9)/(V1*V0)
00770     V = Y*FNU(Y)/(V1*V0)
00775     R = FNR(S)-R0
00780     PRINT S,P,U,V,R
00790     NEXT S
00800     END
```

Print-out for Fig. 3

```
KSINULL =?
[ >15
VNULL= .00703263
KSINULL= 15    YNULL= 46.957908             REYNULL= 12629.96
END VALUE KSI=?
[ >20
STEP KSI=?
[ >0.5
 15            0            1            1            0            1
 15.5          .00115406    .96158019    .7084875     3838.0247    .9070911
 16            .00186284    .92571157    .50312827    8878.9309    .82728601
 16.5          .00227983    .89215284    .35824054    15497.236    .75837591
 17            .00250648    .86069193    .25581189    24179.827    .69852602
 17.5          .00260981    .83114171    .18322563    35558.227    .64622587
 18            .00263406    .80333643    .13164788    50449.782    .60023773
 18.5          .00260838    .77712878    .09489072    69910.219    .55954812
 19            .002552      .7523874     .06861478    95300.586    .52333076
 19.5          .00247752    .72899485    .04977179    128372.43    .49090863
 20            .00239319    .70684572    .03621569    171376.17    .46172682
```

PRINT OUT FOR FIG. 4

```
KSINULL =?
[ >18
VNULL= .00422125
KSINULL= 18    YNULL= 143.32901              REYNULL= 63079.742
END VALUE KSI=?
[ >25
STEP KSI=?
[ 0.5
> 18          -1.894839E-08   1.0000006     1             0             1
 18.5         .00076668       .96918672     .72214019     19460.437     .93221088
 19           .00125915       .94008651     .52315133     44850.804     .87187251
 19.5         .00156637       .91256516     .38019468     77922.646     .81785701
 20           .00174857       .88649923     .27716206     120926.39     .76923993
 20.5         .0018466        .86177837     .20266502     176748.9      .72526075
 21           .00188823       .83830301     .14862894     249088.18     .68529128
 21.5         .00189237       .81598306     .10931142     342674.99     .64880993
 22           .00187191       .79473688     .08061594     463553.37     .61538148
 22.5         .00183567       .77449024     .05961064     619436.23     .58464061
 23           .00178965       .75517554     .04419039     820155.5      .55627881
 23.5         .00173792       .73673112     .03283879     1078230.4     .53003404
 24           .00168326       .71910054     .02446001     1409587.4     .50568231
 24.5         .00162752       .70223214     .01825965     1834467.4     .48303115
 25           .00157196       .68607848     .01366004     2378572.5     .46191407
```

PRINT OUT FOR FIG. 5

```
KSINULL =?
[ >26
VNULL= .00178863
KSINULL= 26    YNULL= 3584.8098              REYNULL= 4026709.8
END VALUE KSI=?
[ >30
STEP KSI=?
[ >0.5
 26           0               1             1             0             1
 26.5         .00033301       .9793503      .75331917     1134665.1     .95913873
 27           .0005654        .9594982      .56849313     2581174.1     .9207629
 27.5         .00072512       .94039904     .4297397      4423392.3     .88466672
 28           .00083233       .92201132     .32537806     6767345.5     .8506668
 28.5         .00090164       .90429662     .24674257     9746983.4     .81859909
 29           .00094362       .88721917     .1873893      13531445.     .78831623
 29.5         .00096596       .87074568     .14251616     18334167      .75968551
 30           .00097423       .85484512     .10853686     24424341      .73258681
```

FNG(Re_x) computes ξ with Re_x as input Part 4.2: Eq.(2.10)

With S(=) as variable from S = S0 to S = S9 in steps of S5 the program computes.

$\bar{u}/U_0 = U$ Part 4.2: Eq.(2.3)

$\bar{v}/U_0 = V$ Part 4.2: Eq.(2.9)

$Re_x - Re_{x_0} = R$ Part 4.2: Eq.(2.10)

$\tau/\rho U_0^2 = P$ Part 4.2: Eq.(2.16)

$\bar{v}_\infty/U_0 = V9$ Part 4.2: Eq.(2.9)

<u>Program name: OIL2</u>

The program operates at one specific value of X(=ξ) which it asks for as input to start the computations. It computes the velocity components $\bar{u}$ and $\bar{v}$, the stream function Ψ and the path-function Θ and runs a table for running argument y/A.

FNF(η) COMPUTES:

FNF(η) = $f(\eta) = exp(-\eta^2)-2B\eta^2/(\sqrt{\pi}(B^2+\eta^2)^2)$ Part 4.2: Eq. (4.3)

FNE(η) COMPUTES:

FNE(η) = $\frac{1}{2}\sqrt{\pi}erf(\eta)$

With Z1 as the input variable from Z1 Z0 to Z1=Z9 in steps of Z3 the following quantities are computed:

y/A	$Z1 = Y/A$ (input variable)	
η	$Z = \frac{y}{A}(1+\xi^2)^{-\frac{1}{2}}$	Part 4.2: Eq.(4.2)
$\bar{u}/U_0$	$U = f(\eta)(1+\xi^2)^{-\frac{1}{4}}$	Part 4.2: Eq.(4.1)
$\int f(\eta)d\eta$	$V5 = \frac{1}{2}\sqrt{\pi}erf(\eta) + [\frac{\eta/B}{1+(\eta/B)^2} - arc\ tan(\eta/B)]/\sqrt{\pi}$	Part 4.2: Eq.(4.5)
	$V1 = 2\eta f(\eta) - \int f(z)dz$	
$\bar{v}/U_0$	$V = \frac{1}{2}\xi[(2\eta f(\eta) - \int f(z)dz](1+\xi^2)^{-\frac{3}{4}}$	Part 4.2: Eq.(4.1)
Ψ^*	$P = (1+\xi^2)^{\frac{1}{4}}\int f(z)dz$	Part 4.2: Eq.(4.7)
Θ	$P1 = \Psi^* + \xi\beta/\lambda$	Part 4.3: Eq.(2.22)

PROGRAM NAME: OIL2

```
>>OLD:OIL2
>>LIST

00010     DEF FNF(A)
00015     B = 5
00020     C1 = EXP(-A**2)
00030     C2 = 2*B*A**2
00040     C3 = (B**2+A**2)**2
00050     C4 = ATN(1)*4
00060     C5 = C4**0.5
00070     FNF = C1-C2/(C5*C3)
00080     FNEND
00090     DEF FNE(D)
00091     IF D > 3.0 GO TO 165
00100     B = 5
00101     N = 0
00105     D3 = D
00106     D2 = D
00110     D2 = -D2*D**2*(2*N+1)/((2*N+3)*(N+1))
00120    D3 = D3+D2
00130    D4 = D2/D3
00140    N = N+1
00150    D5 = ABS(D4)
00160 IF D5 > 0.00001 THEN GO TO 110
00161     IF D5 < 0.00001 THEN GO TO 170
00165     D3 = 0.88623
00170    FNE = D3
00180    FNEND
00209     PRINT 'PARTICLE SIZE P2=?'
00210     INPUT P2
00211     PRINT 'Z0=?'
00212     INPUT Z0
00213     PRINT 'Z9=?'
00214     INPUT Z9
00215     PRINT 'Z3=?'
00216     INPUT Z3
00217     PRINT 'X=?'
00218     INPUT X
00220     FOR Z1 = Z0 TO Z9 STEP Z3
00225     N1 = 0.5
00230     Z = Z1/((X**2+1)**0.5*2*N1)
00240     U = FNF(Z)/((X**2+1)**0.25)
00250     V2 = (ATN(1)*4)**0.5
00260     V3 = Z/B
00270     V4 = V3/(1+V3**2)-ATN(V3)
00280     V5 = FNE(Z)+V4/V2
00290     V1 = 2*Z*FNF(Z)-V5
00292     P = V5*(1+X**2)**0.25
00293     V = V1*X*N1/((1+X**2)**0.75)
00294     P1 = P+P2*X
00300     PRINT Z1,U,V,P,P1
00310     NEXT Z1
00320     END
```

APPENDIX B

Distinction between Crude Oil and Dispersant by Means of Infrared Spectrophotometry

by

Mathew Cherian, Ted Kawazoe and Leif N. Persen

Distinction between Crude Oil and Dispersant by means of Infrared Spectrophotometry

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In investigations involving the use of a dispersant to influence the fate of an oil spill at sea (or on lakes) samples are usually taken from the water column. The hydrocarbons in the samples are extracted by some standard method and the concentration of hydrocarbons can be determined. If gas chromatography is used it is comparatively easy to determine how much of the hydrocarbons in the sample originates from the crude oil and how much from the dispersant, even though the process may be somewhat time consuming and requires expensive equipment. Apart from the obvious interest such distinction between oil and dispersant has when judging the effect of the dispersant the possible difference in toxicity of the two compounds makes this distinction important.

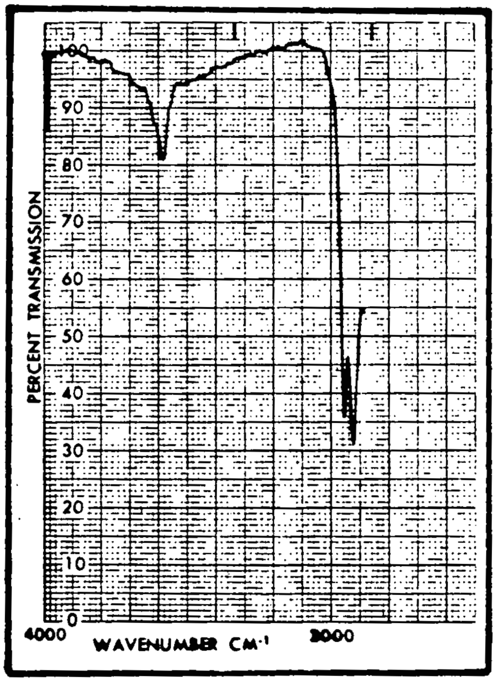

Fig. 1. The peaks at 3600 [cm^{-1}] and at 2930 [cm^{-1}] of Corexit 9527.

When a large number of samples are to be handled within a certain time limit a quick method which allows a distinction to be made between dispersant and crude oil recovered in the water samples is desirable. The following is a presentation of a method developed for infrared spectrophotometry.

The dispersant to be used is Corexit 9527 and the oil is standard Kuwait Crude. The extraction is supposed to utilize carbontetrachloride (CCl_4) and all samples in this investigation are prepared with this solvent. If Kuwait Crude is scanned in the infrared spectrophotometer one finds the usual peak at a wave number of 2930 [cm^{-1}]. If however Corexit 9527 is scanned one finds an additional peak at a wave number of 3600 [cm^{-1}] as shown in Fig. 1. Most dispersants available commercially should give a peak at 3600 [cm^{-1}]. This peak is due to the OH stretching, while the peak at 2930 is due to CH stretching. Since no peak is present for Kuwait Crude at the latterwave number, one has a possible basis for establishing the desired method.

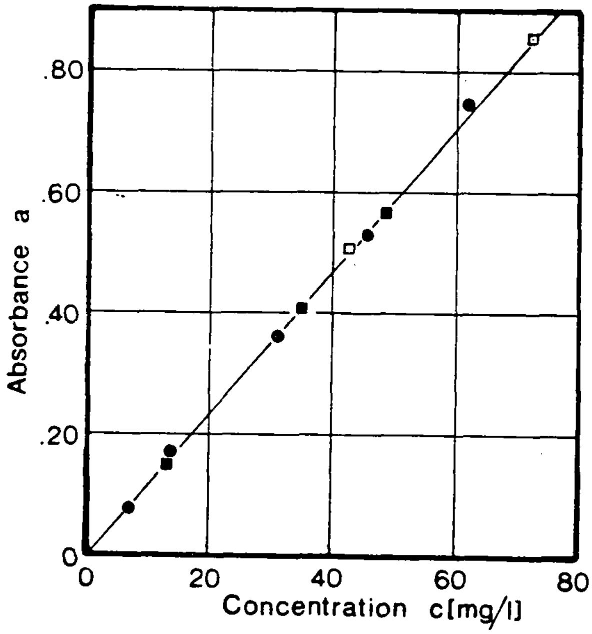

Fig. 2. Calibration curve for Kuwait Crude scanned at 2930 [cm^{-1}]

First, the calibration curve for Kuwait Crude is established as shown in Fig. 2. Samples with different concentrations c_o of oil in CCl_4 are prepared and scanned at a wave number of 2930 [cm^{-1}]. From the transmittence z thus obtained the absorbance a is computed

$$a = log_{10}(100/z) \tag{1}$$

The results are shown in Fig. 2 which indicate a linear relationship between a and c. A linear regression based on the data obtained gives

$$a = 0.01179\, c_o - 0.00299 \pm 0.00316 \tag{2}$$

This is a standard result and the only comment one might add is that the accuracy is satisfying for concentrations down to 3-5 [mg "oil"/l CCl_4]

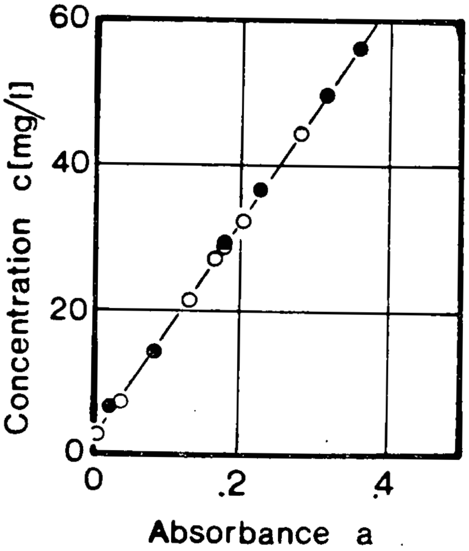

Fig. 3. Calibration curve for Corexit 9527 scanned at 2930 [cm^{-1}].

The next step is to prepare samples with Corexit 9527 in different concentrations c_C in CCl_4. Scanning these at a wave number of 2930 [cm^{-1}] and computing the absorbance one obtained the results shown in Fig. 3. Again a linear relationship between the concentration and the absorbance is evident and a linear regression applied to the data gives

$$a = 0.00665\, c_C - 0.01516 \pm 0.00314 \tag{3}$$

Again this is a result which could be expected, the only obvious remark being that the sensitivity to concentrations of Corexit 9527 is lower than to Kuwait Crude.

If samples with Corexit alone is scanned at a wave number of 3600 [cm^{-1}] a calibration curve as shown in Fig. 4A is found:

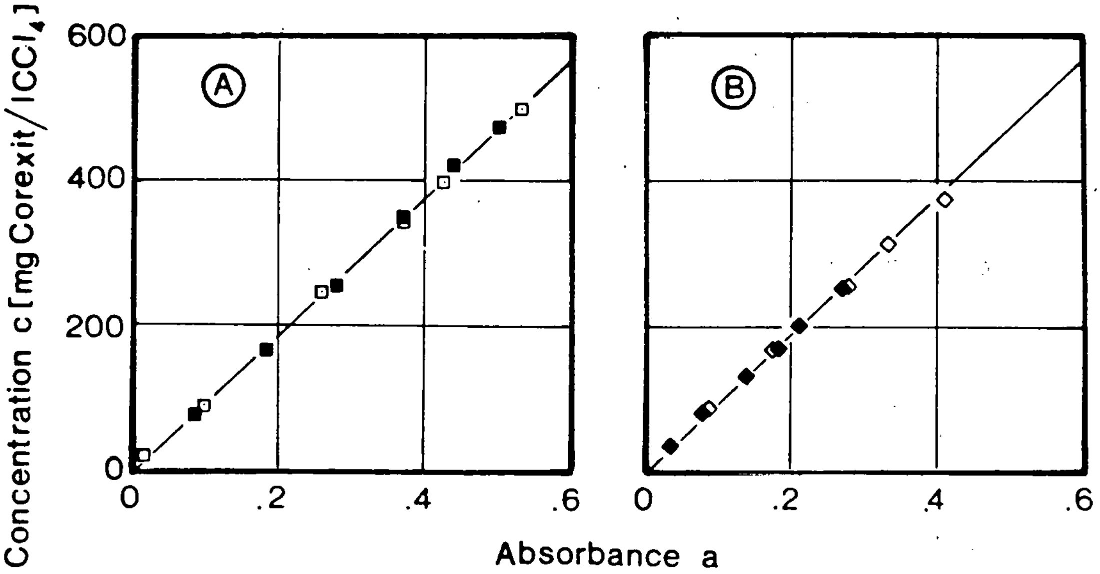

Fig. 4. Calibration curve for Corexit 9527 alone at 3600 [cm^{-1}] Ⓐ
Mixtures compared with the calibration curve Ⓑ

$$a = 0.00108 \quad c_C - 0.00576 \pm 0.00530 \qquad (4)$$

Attention is here drawn to the fact that very high values of concentration is needed to give the desired calibration curve, and that this limits the usefulness of the present approach to cases where the concentration of Corexit in the solvent CCl_4 is high. This however is the case in the investigations where the present method is to be applied.

Now, mixtures are prepared, i.e. a mixture of known ratio Corexit/Kuwait Crude is dissolved in CCl_4 in different concentrations. When these samples are scanned at 3600 [cm^{-1}] values for the absorbance is obtained and since the concentration of Corexit in the mixture is known, the results can be compared with the straight line calibration curve obtained in Fig. 4A. This is done in Fig. 4B. The accuracy with which the amount of Corexit in the mixtures is predicted by the calibration curve shows that the infrared spectrophotometer "sees" only the Corexit at the wave number 3600 [cm^{-1}] One has thus a method of determining c_C in a mixture of unknown ratio.

A series of different mixtures are now prepared and scanned at 2930 [cm^{-1}]. The results are shown in Fig. 5 where the slope of the straight line calibration curves depend on the ratio Corexit/Kuwait Crude.

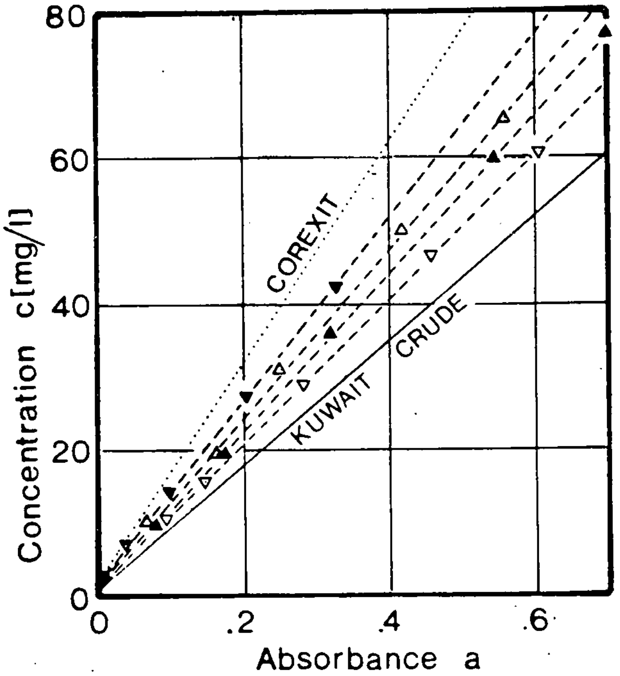

Fig. 5. Calibration curves at 2930[cm^{-1}] for different mixtures

Figure 5 also shows the previously established calibration curves for Corexit alone and Kuwait Crude alone.

One may now gather the information obtained. The concentration c_m of a mixture of ratio r = mg Corexit/mg Kuwait Crude may be given as

$$c_m = c_C + c_o \tag{5}$$

and the ratio will be

$$r = c_C / c_o \tag{6}$$

The result of the scanning at 2930 [cm^{-1}] may be given as

$$a = \lambda(r)\ c_m \tag{7}$$

where the slope λ of the calibration curve is a function of r. This relationship is shown in Fig. 6

$$\frac{\lambda - \lambda_\infty}{\lambda_0 - \lambda_\infty} = (1+r/0.425)^{-0.75} \tag{8}$$

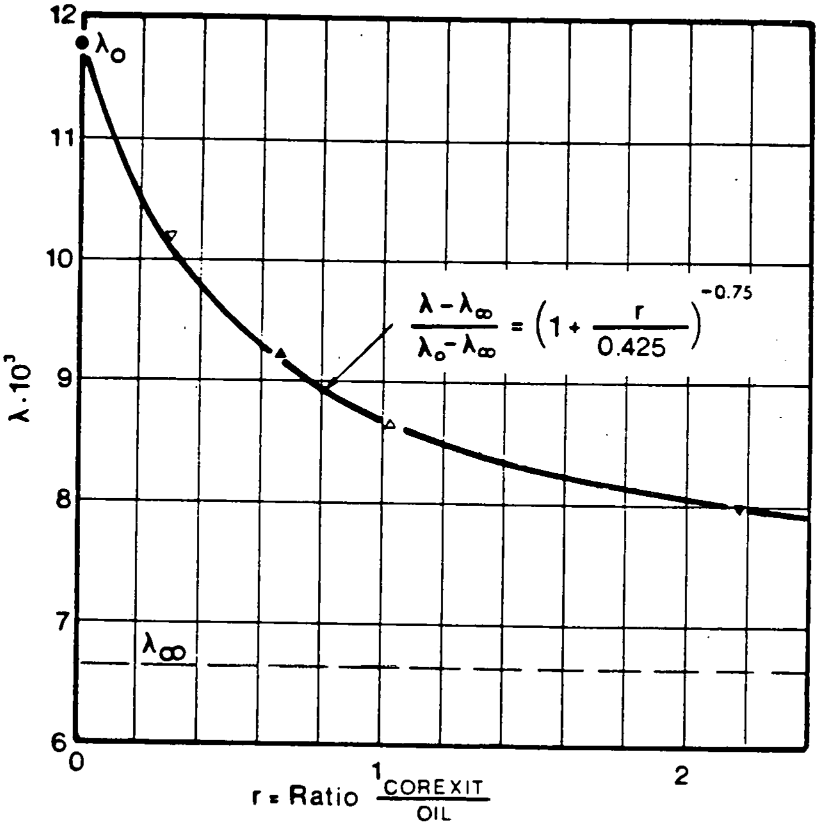

Fig. 6. The slope of the calibration curve as function of the ratio r of the mixture

where

λ_0 = slope for oil alone
λ_∞ = slope for Corexit alone
λ = slope for a mixture of ratio r

This is the end result of the investigation, and it is emphasized that eq. (8) is a curve fit only and that no theoretical basis is used. It may be that it can be improved and that another expression in other circumstances may be preferable. This however does not change the fact that this investigation gives a method whereby the content of hydrocarbons in a sample can be split-up into one part originating from the dispersant and one part originating from the oil. The data used to obtain this may now be used as examples.

In Table I the measured values of c_m, c_C, c_o, a_m and $r_{meas.}$ are given. Each one of these samples may be treated as an original case

TABLE I.

Series	No	c_m [mg/ℓ]	c_C [mg/ℓ]	c_o [mg/ℓ]	a_m	$r_{meas.}$	$r_{comp.}$
P2	Ba	65.51	33.15	32.36	.558	1.0244	1.060
	Bb	49.84	25.22	24.62	.419		1.083
	Bc	30.94	15.66	15.28	.248		1.174
	Bd	19.69	9.96	9.73	.163		1.111
	Be	10.15	5.14	5.01	.077		1.295
P3	Ca	76.76	29.68	47.08	.699		.644
	Cb	59.81	23.13	36.68	.545	.6304	.643
	Cc	35.98	13.91	22.07	.319		.668
	Cd	19.63	7.59	12.04	.176		.658
	Ce	9.90	3.83	6.07	.082		.735
P4	IIIa	60.58	13.88	46.70	.606	.2973	.301
	IIIb	10.72	2.46	8.26	.097		.338
	IIIc	15.73	3.60	12.13	.146		.327
	IIId	29.15	6.68	22.47	.282		.313
	IIIe	46.36	10.62	35.74	.456		.307
P5	IIa	42.77	29.28	13.49	.328	2.17	2.388
	IIb	7.00	4.79	2.21	.042		5.314
	IIc	14.41	9.86	4.55	.100		3.141
	IId	27.75	19.00	8.75	.203		2.704
	IIe	-					
Pla	10					.8109	
	11	10.98	4.92	6.06	.097		.829
	12						
	13	22.54	10.09	12.45	.201		.816
	14	34.17	15.30	18.87	.301		.831
	15	46.17	20.67	25.50	.415		.807
	16	57.41	25.71	31.70	.530		.776
	17	82.24	36.83	45.41	(.757)		

where only c_C and a_m are known. The value of c_C is supposedly known from scanning at 3600 [cm^{-1}] and a_m is the absorbance found from scanning at 2930 [cm^{-1}]. With these two as only input data the following procedure is followed:

1.) An initial ratio $r=r_1$ is assumed

2.) Then the corresponding $\lambda=\lambda_1$ is computed from eq. (8)

3.) The corresponding concentration of the mixture $c_{m,1}$ is found from:

$$c_{m,1} = a_m / \lambda_1$$

4.) The corresponding concentration of oil is found from:

$$c_{o,1} = c_{m,1} - c_C$$

5.) The corresponding ratio $r_2 = c_C / c_{o,1}$ is computed

6.) The value r_2 is compared with r_1. If the difference is too great one repeats steps 2.) . . . 6.) until the ratio introduced is close to the one obtained.

This procedure is used to obtain the values r_{comp} in Table I. The procedure works very well provided:

a.) the concentration c_C is not too low

b.) the ratio $o \leq r \leq 1$

How the procedure breaks down when this is not the case is well brought out by the data in Table I. The break down of the method for large values of r is of course due to the assymptotic behavior of the curve in Fig. 6.

The application of the method presented here may meet with difficulties. The use of CCl_4 as a solvent for the extraction shows that the peak at 3600 [cm^{-1}] is highly influenced by water. This can be extracted, using say anhydrous Sodium Sulfate (Na_2SO_4) to "dry" the aliquot, i.e. to extract the water without seriously affecting the peaks at 3600 [cm^{-1}] and at 2930 [cm^{-1}] as shown by the example displayed in Fig. 7. This is however a rather time

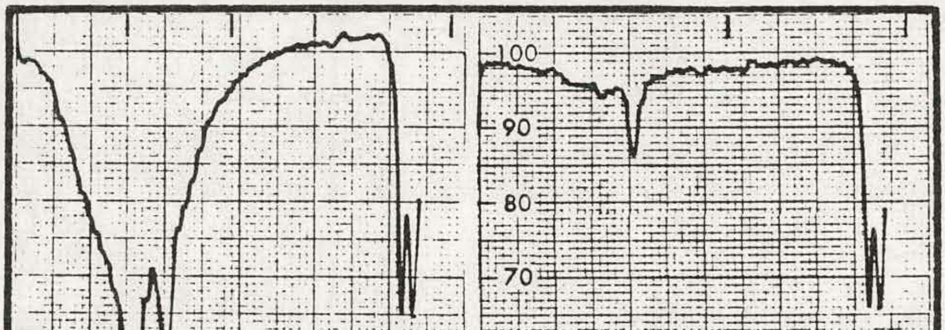

Fig. 7. The influence of water on the peak at 3600 [cm^{-1}] Ⓐ and that influence removed by Na_2SO_4 Ⓑ

consuming procedure, and another procedure is to be suggested whereby the complications at the wave number 3600 $[cm^{-1}]$ may be avoided.

If the hydrocarbons in a sample is extracted by applying aliquots (CCl_4) of a fixed magnitude to the sample, shaking the sample and draining off the aliquot, successive aliquots will show a decreasing concentration of hydrocarbons. It turns out that when the hydrocarbons originate from crude oil, a rapid decrease in the concentration of each subsequent aliquot is observed, a situation which has been investigated in [1]. If on the other hand the hydrocarbon originates from Corexit 9527 the concentration decreases much more slowly. This is exhibited in Fig. 8 where the concentration of Corexit in the water

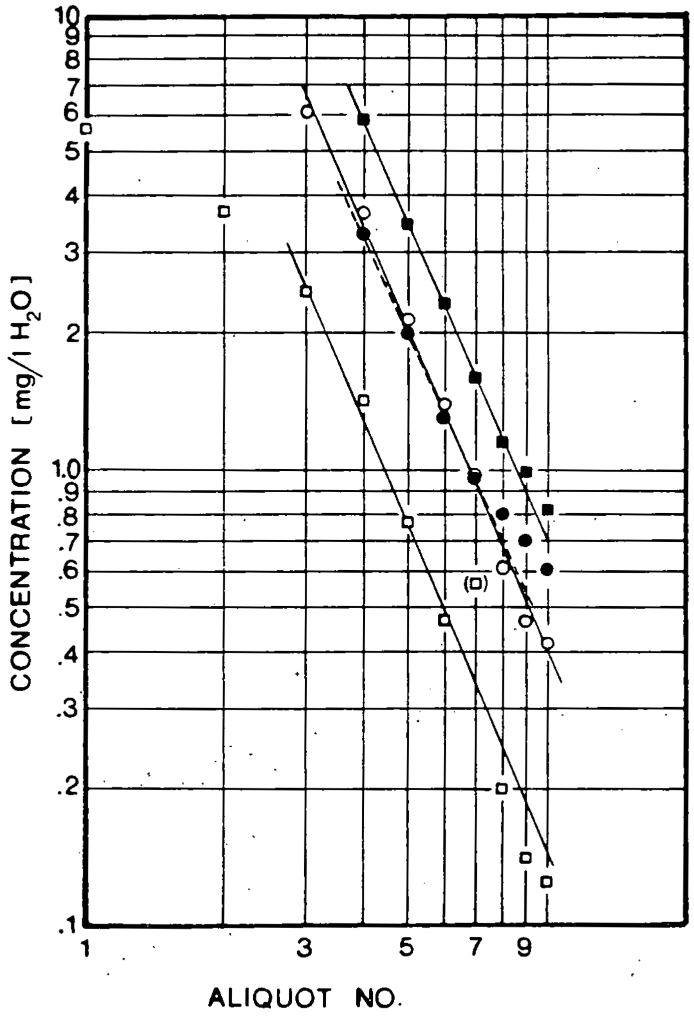

Fig. 8 Concentration $c_{C,i}$ as indicated by subsequent aliquots

sample as indicated by each aliquot is shown. The concentration $c_{C,i}$ indicated by aliquot no. i is found by means of the calibration curve in Fig. 3. For values less than 1 $[mg/l\ H_2O]$ the determination becomes somewhat uncertain. It is seen that the data points indicate a relationship given by the straight lines.

$$ln\ c_{C,i} = \lambda\ ln\ i + b \tag{9}$$

For the cases shown in Fig. 8 the data are given in Table III where m is the standard deviation obtained through linear regression applied to the data points.

Table III

Legend	No.	λ	b	m	$c_C[mg/lH_2O]$	Aliquots used to determine line
	I	-2.349	4.493	± 9%	49.7	all
	II	-2.200	4.235	± 2.0%	51.2	4.5.6.7
	III	-2.334	5.012	± 1.2%	72.8	4.5.6.7.8
	IV	-2.402	3.593	± 8.3%	25.0	3.4.5.6

To this one may add that the first aliquots do not follow the regular behavior indicated by eq. (9). Fig. 9 reveals in Case IV that the following relation then seems to apply:

$$ln\ c_{C,i} = \alpha i + \beta \tag{10}$$

where the respective values of α and β are given in Table IV.

Table IV

				Computed from eqs. (11, 12, 13)		
No	α	β	m	$e^{\alpha + \beta}$	k	c_C
I	- .4368	3.001	± 7.0%	12.99	.646	50.3
II	- .4604	3.020	± 3.6%	12.93	.631	48.0
III	- .4026	3.313	± 7.0%	18.36	.669	75.9
IV	- .4508	2.195	± 5.5%	5.72	.637	21.6

It reveals furthermore that eq. (10) can be applied with confidence also to the subsequent aliquots provided one does not go to too low concentrations.

The following additional information is important : The samples I and IV were prepared with Corexit alone, whereas samples II and III were prepared with a mixture of Corexit and Kuwait Crude in a ratio $r_{II} = 1.04$ and $r_{III} = 1.24$ respectively. Tables III and IV reveal through the values of λ and α that

1.) The concentrations $c_{C,i}$ of subsequent aliquots follows a "universal" law under the conditions used. This law is neither given by eq. (9) nor by eq. (10) but these equations are good approximations in two different regions.

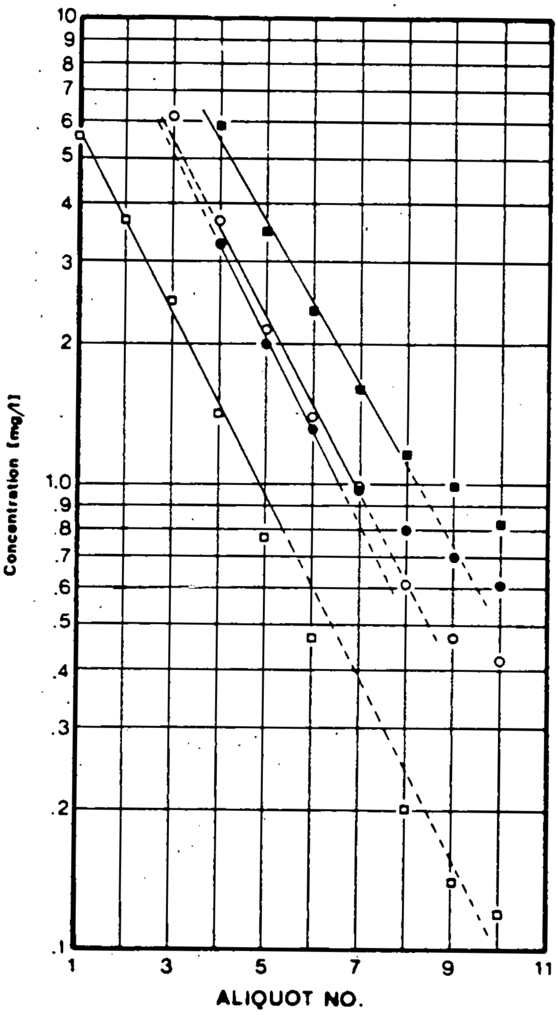

Fig. 9. Concentrations $c_{C,i}$ of subsequent aliquots

2.) The extraction of Corexit according to the "law" appears to be uninfluenced by the presence of oil in the sample.

This last observation gives rise to the following line of reasoning:

A.) It is assumed that the three first aliquots (in the cases used here) contains both oil and dispersant, but that the subsequent aliquots contain dispersant alone. This is due to the different way in which oil and Corexit apparently are extracted.

B.) The next aliquots (No. 4,5 and 6) ought then to follow the law of eq. (10).

C.) This law applies also to the first aliquots if the extraction takes place uninfluenced by the presense of oil.

D.) Since the curve according to which the extraction takes place is assumed to be "universal", it is possible to compute the original concentration of Corexit in the sample based on the information obtained from aliquots No. 4, 5 and 6.

Now, if eq. (10) can be applied, it means that:

$$c_{C,i} = e^{\alpha i+\beta} \tag{11}$$

$$c_{C,i+1} = e^{\alpha(i+1)+\beta}$$

or

$$c_{C,i+1} / c_{C,i} = e^{\alpha} = k \tag{12}$$

If this was true for all aliquots, one would find the total concentration of Corexit in the sample as

$$S = \sum_{1}^{\infty} c_{C,i} = \underline{e^{\alpha+\beta}\ (1+k+k^2+\ldots)}$$

$$= e^{\alpha+\beta}\ \frac{1}{1-k} \tag{13}$$

Since a different "law" applies for later aliquots eq. (13) will underestimate the total concentration. One may however assume that because of the "universality" of the decay, the deviation measured in percentage is a constant. If this constant is put equal to 0.73 one will, with the values of α and β determined in Table IV obtain the concentrations computed in the same table. This shows that the method seems to work.

One final comment may be advanced. When using the method enough aliquots must be applied to secure that the oil has been removed and that one has reached that part of the extraction procedure where subsequent aliquots lie on a line with $\alpha = -0.45$ when exhibited as done in Fig. 9. In the cases on which the present method was investigated the sample size was always 500 ml and the aliquot size 30 ml. This method is used in the evaluation of the drop size as well as the rain drop experiments.

Reference

[1] Leif N. Persen "The Entrainment of Oil from an Oil Slick into the Water Cloumn, Workshop, Princeton, May 1979.

Appendix C: The Evaporation Tests

THE EVAPORATION TESTS

The entrainment process is to be studied experimentally by properly chosen experiments. A major feature of such experiments is the determination of concentrations of oil in samples from the water column. It has, however, been noted that a certain percentage of the oil will evaporate and not be entrained in the water column over a longer period. This has led to the study of the evaporation process. Both Kuwait Crude and Corexit 9527 have been tested by letting an open surface of the two fluids be exposed to wind in a wind tunnel where the velocity field could be monitored. In addition to the tests with the two fluids alone, tests were made to investigate the mixtures of Kuwait Crude and Corexit 9527 in the ratios 20:1, 10:1, 7:1 and 5:1. Both for the case of Kuwait Crude alone, as well as for mixtures of Crude and Corexit 9527, the influence of an underlying waterbed was examined.

It should be realized that crude oil in general consists of components which evaporate differently. Thus, under given conditions only a portion of the crude oil will evaporate, whereas Corexit 9527 resembles water in the sense that it almost evaporates entirely under the same conditions. The results may thus not be expected to be comparable.

The physical quantities involved in the tests are the following:

m_e = mass of the evaporated portion of the fluid

m = total mass of the fluid used in the experiment

t = time

U_s = slip velocity in the air at the interphase (Fig. 1)

$du/dy\big|_{y=o}$ = velocity gradient in the air at the interphase (Fig. 1)

ρ = density of the oil

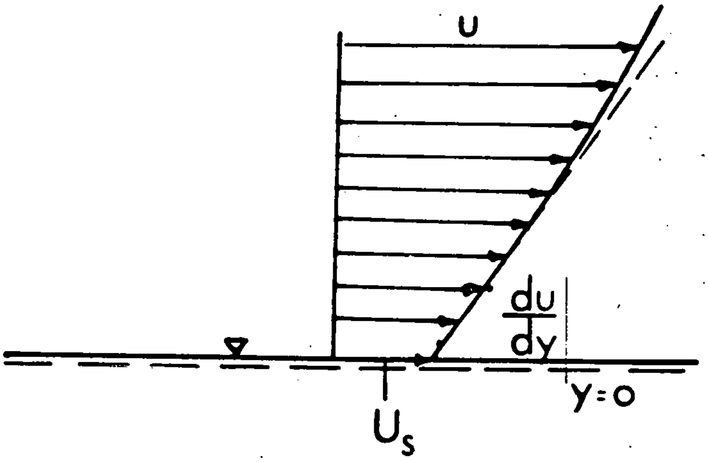

Figure 1. Velocity profile above the fluid

h = depth of the oil (oil slick thickness)

Buckingham's Π - theorem indicates the outcome of the experiment to be expressible in terms of the following variables:

$p = \frac{m_e}{m}$ = (percentage evaporation)

$\tau = \frac{U_s t}{h}$ = dimensionless time

$\Pi_1 = \frac{h}{U_s} \cdot \frac{du}{dy}\Big|_{y=o}$

$\Pi_2 = \frac{\rho h^3}{m}$

This means that the result of the experiments ought to be expressible as:

$$p = \frac{m_e}{m} = F\left(\frac{\rho h^3}{m},\ \frac{h}{U_s}\ \frac{du}{dy}\Big|_{y=o},\ \frac{U_3 t}{h}\right)$$

Table I shows the value of the parameters for six different tests performed with Kuwait Crude Oil. The results from these tests are shown in Fig. 2 where p is plotted as function of τ. They show that p is only slightly dependent on Π_1 and Π_2 which reflects the fact that the exposed surface as well as the depth of the fluid (oil slick thickness) was kept almost constant. In order to get an

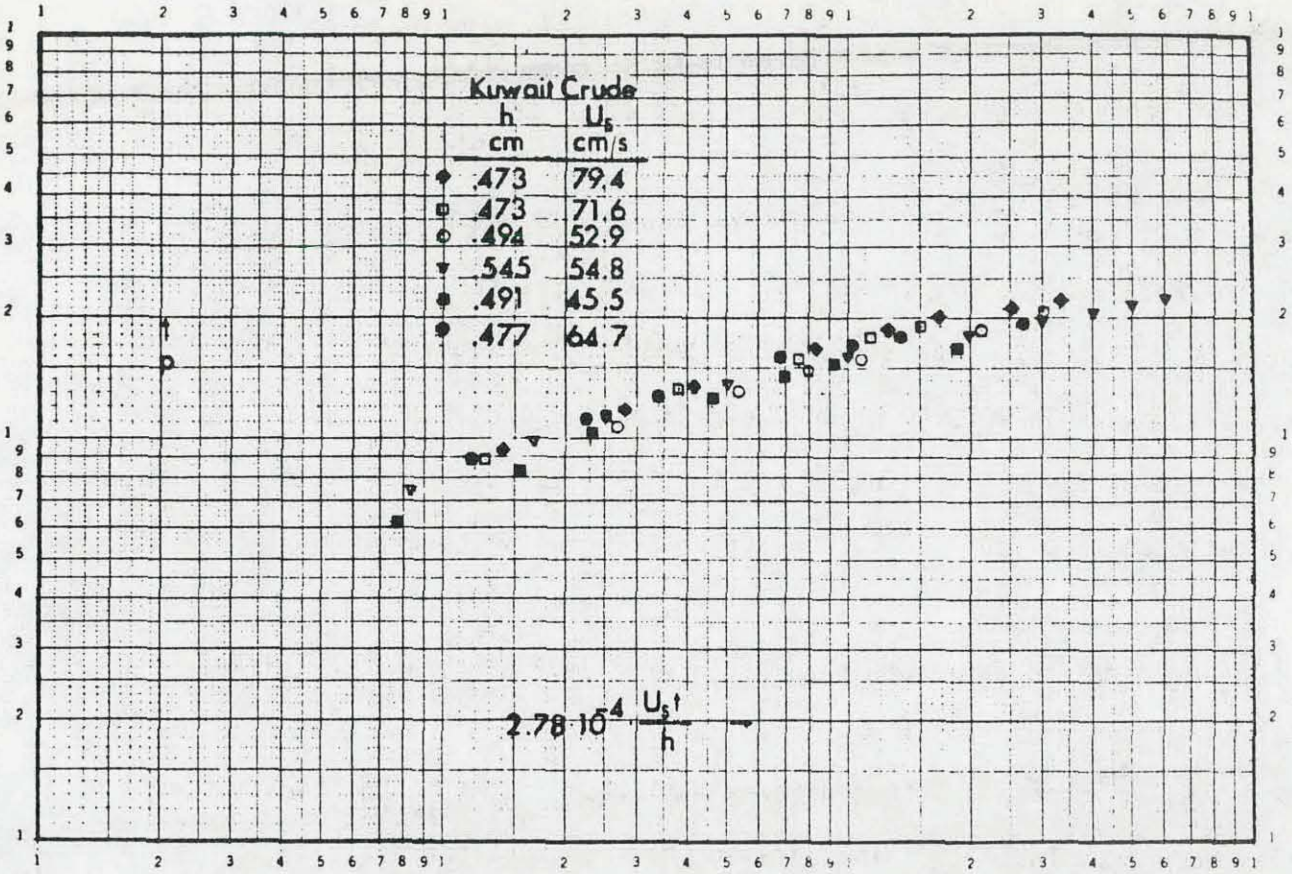

Figure 2. Evaporation data p versus $U_s t/h$

TABLE 1 (KUWAIT CRUDE OIL)

No.	Leg.	U_s [ft/s]	$du/dy\|_{y=o}$ [1/s]	h [cm]	U_s/h [1/s]	$\Pi_1 = \frac{h}{U_s}\frac{du}{dy}\Big\|_{y=o}$	$\Pi_2 \cdot 10^3 = \rho h^3/m \; 10^3$
1	○	1.7344	4.38	.494	107.01	.04093	.7211
2	■	1.4932	4.74	.491	92.69	.05114	.7124
3	●	2.1228	7.56	.477	135.65	.05573	.6723
4	□	2.3480	12.00	.473	151.30	.07931	.6611
5	▽	1.7982	8.76	.545	100.57	.08711	.8777
6	◆	2.6064	8.28	.473	167.96	.04930	.6611

indication of the asymptotic value of p , the following curve was fitted to the data:

$$p = \frac{A(\tau/\tau_o)^\kappa}{1 + (\tau/\tau_o)^\kappa}$$

where $\kappa = 0.75$ and $\tau_o = 26.78 \cdot 10^2$. The asymptotic value A = 26.00 is found from the data and the way in which the curve represents the data is exhibited in Fig. 3. This result should be considered in the light of an evaporation test performed in a ROTOVAP at 40°C over a period of 24 hours which led to a weight loss of 32.3%. In view of the fact that the present results were obtained at a temperature of 20 - 22°C, the agreement between the experimental results seems reasonable.

The evaporation data obtained for Corexit 9527 alone and for different mixtures of oil and Corexit are shown in Figs. 4 and 5. For Corexit alone, the data have been obtained with a greater variation in the fluid thickness as is easily seen from Table II. The data do, however, not correlate as well with only non-dimensionalizing the time and introducing τ as is seen from Fig. 4.

This may partly be due to the fact that different trays were used and certain cases where the surface area changed due to evaporation. For the mixtures, however, this did not happen, and the data correlate well again.

The importance of these tests does not lie so much in the actual results which, for Kuwait Crude, show that ∿ 75% of the total evaporation caused by

Table II (Corexit 9527)

No.	Leg.	U_s [ft/s]	$du/dy\|_{y=o}$ [1/s]	h [cm]	U_s/h [1/s]	$\Pi_1 = \frac{h}{U_s} \cdot \frac{du}{dy}\|_{y=o}$	$\Pi_2 \cdot 10^3 = \rho h^3/m\ 10^3$
8	□	2.4912	10.74	.561	135.35	.07936	.9300
9	●	1.8900	6.48	.768	75.01	.08639	1.7429
10	◆	2.4670	10.50	.378	198.93	.05278	.4222
11	■	1.5056	4.02	.513	89.46	.04494	.7776
12	◇	2.6016	10.62	.457	173.52	.06120	.6171
13	▼	.426	14.10	1.698	7.65	1.84388	3.1622
14	△	.144	15.30	1.731	2.54	6.03408	3.28631

wind under the circumstances investigated has taken place when

$$\frac{U_s t}{h} = 12.10^5$$

i.e., for circumstances investigated here approximately after two hours. It is far more important for the study of the entrainment process to realize that the composition of the entrained oil differs due to weathering.

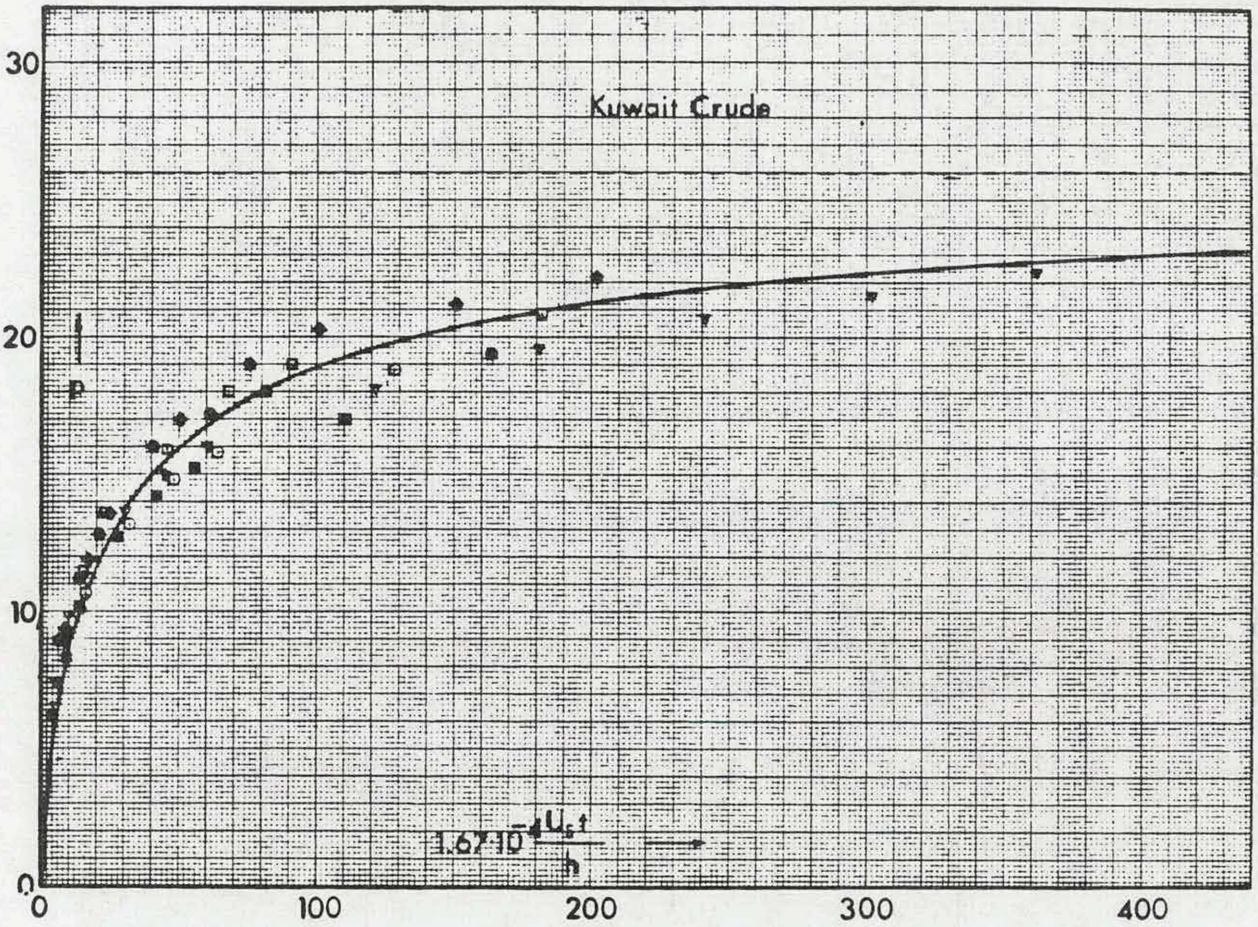

Figure 3. Evaporation data p for Kuwait Crude exhibiting the asymptotic value p = A = 26.0

Table III (Kuwait Crude: Corexit 9527)

No.	Leg.	U_s [ft/s]	$du/dy\|_{y=0}$ [1/s]	h [cm]	U_s/h [1/s]	$\Pi_1 = \frac{h}{U_s}\frac{du}{dy}\|_{y=0}$	$\Pi_2 \cdot 10^3 = \rho h^3/m\ 10^3$	Mix:
15	◆	2.3496	11.52	.438	163.51	.07046	.56688	20:1
16	◇	2.3184	11.58	.440	160.60	.07210	.57207	7:1

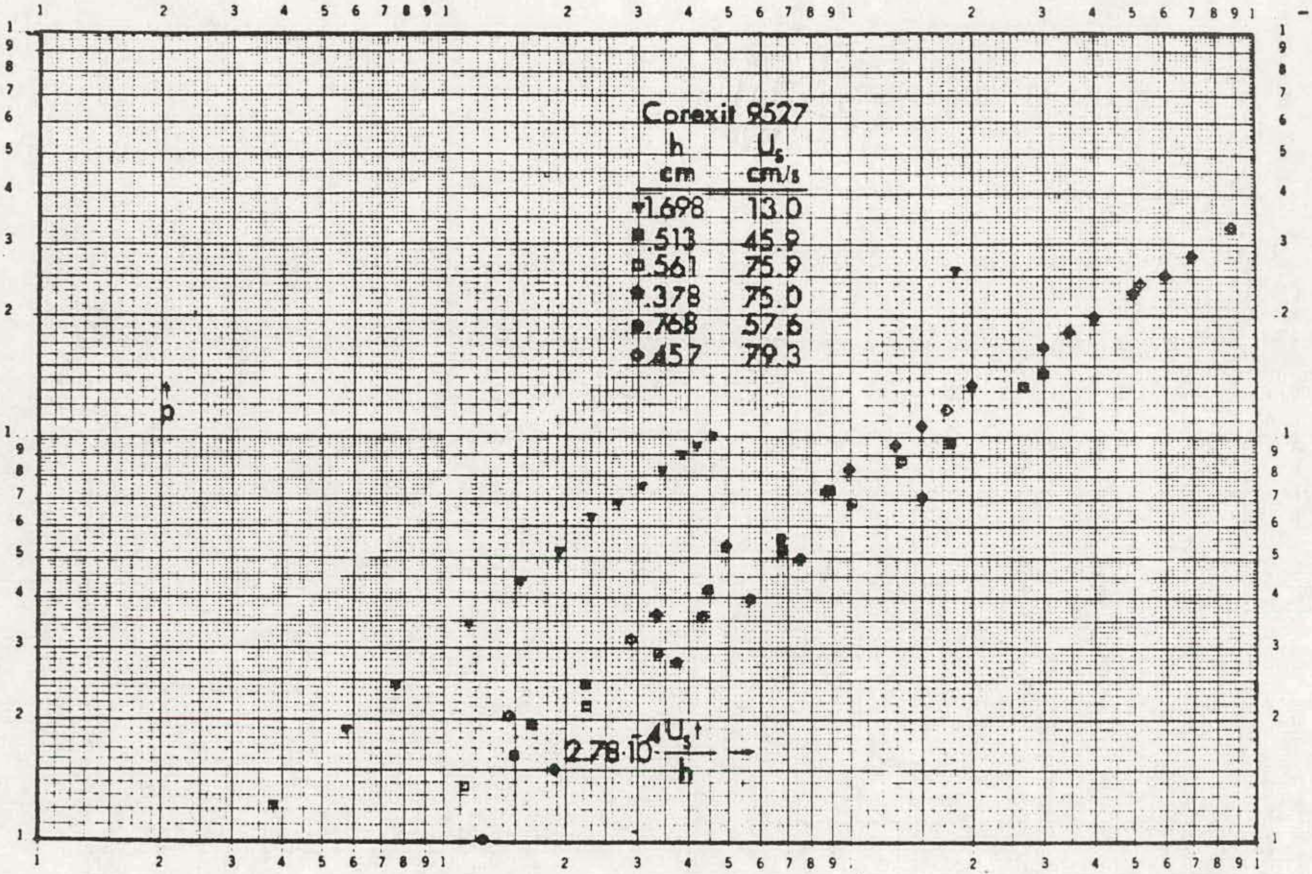

Figure 4. Evaporation data p versus τ for Corexit 9527

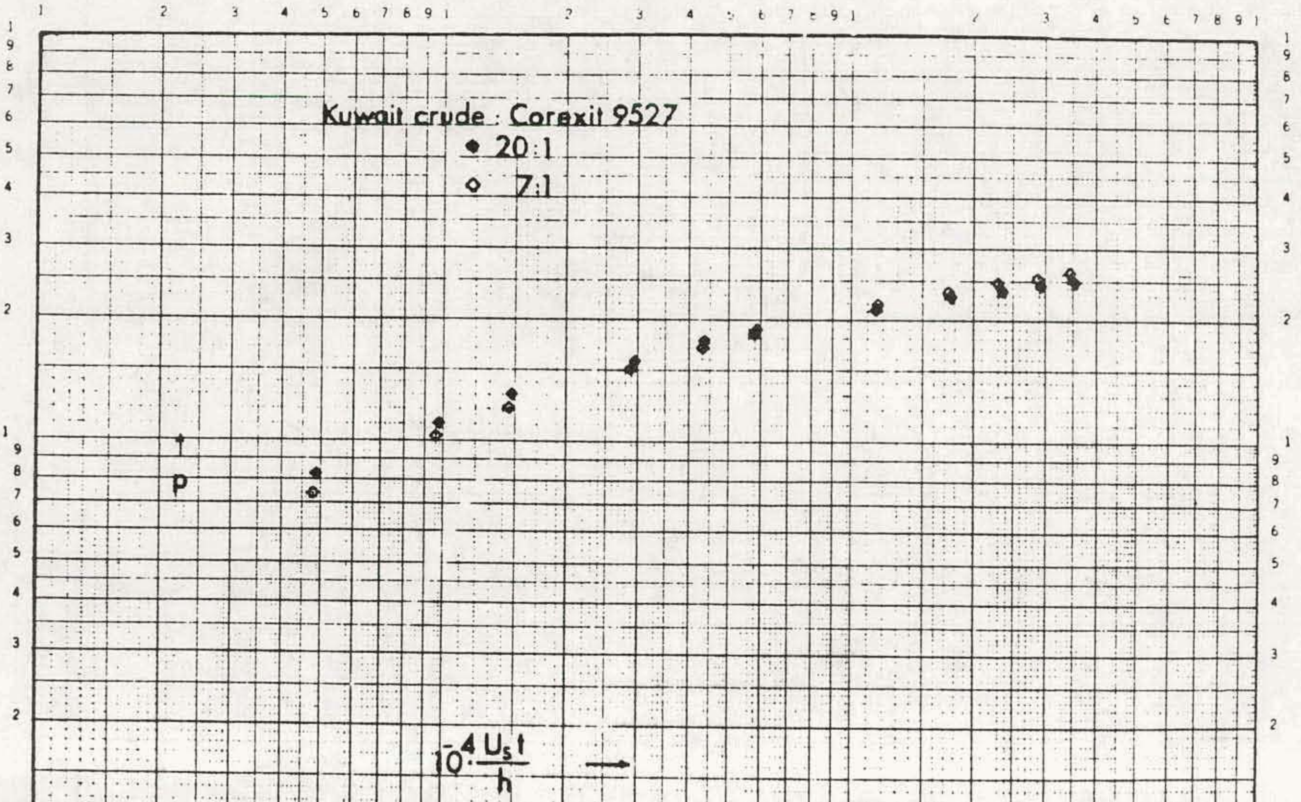

Figure 5. Evaporation data p versus τ for mixtures of Kuwait Crude and Corexit 9527

12.3 Section 5 Computer Manual
URI Oil Spill Model

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CHAPTER I INTRODUCTION

This manual is a guide to Version 2 of the URI Oilspill Model. The model, although it treats most of the known processes involved in the fate of spilled oil, has been designed primarily to study cleanup and treatment alternatives for a given spill condition. This requires that input be easily entered and output easily obtained in the shortest amount of time. The model has also been designed to allow for the rapid implementation of new modules reflecting advances in the state-of-the art.

The computer code is currently implemented on an Itel Advanced System/5 which is functionally compatible with an IBM System 370. It is written in Fortran IV and is run as a batch job. The main program, as presently configured, requires about 465 kilobytes of memory to run and a typical job using 2000 marker particles, 30 spillets and a time step of one day, consumes about 16 CPU minutes for a 72 day simulation.

In the next section of this chapter, an overview of the various steps required for a complete simulation are briefly described.

Chapter II is devoted to the input programs used to format environmental data for input to the preview and full scale simulation. The function of the preview run is discussed in Chapter III while the general operation of the complete simulation is outlined in Chapter IV. Chapter V provides a brief summary of the output programs used to plot the results. The details of the various programs as well as how to set up a complete simulation is covered in the appendices. In particular, Appendix I covers input to the preview and complete simulation model; Appendix II, the output available from these models; Appendix III a description of all variables contained in common in the simulation model; Appendix IV, a detailed description of the operation of each subroutine of the model; Appendix V a similar description for the input programs; Appendix VI a detailed description of the output programs; Appendix VII a listing of all programs; Appendix VIII output from a sample run; and Appendix IX a summary of oil properties required for input.

OVERVIEW

The simulation of an oil spill is divided into four steps. Formation at input, data, spill preview, main simulation and output. The flow chart showing this process is presented in Figure 1.

As indicated in Figure 1, the user may elect to prepare all input data with or without the use of the input programs. These programs manipulate only the most complicated input data, the environmental variables (bathymetry, wind, current, etc., see Chapter II), one of the five major input groups. The remaining four groups are discussed in greater detail in Appendix I. There are two characteristics of the environmental data which render them more complicated than the other input data. First, they read into the main program on grids defined by:

1. The grid origin in longitude and latitude.
2. The spacing of grid elements.
3. The number of elements in x and y.
4. The angle the grid makes with lines of constant latitude.

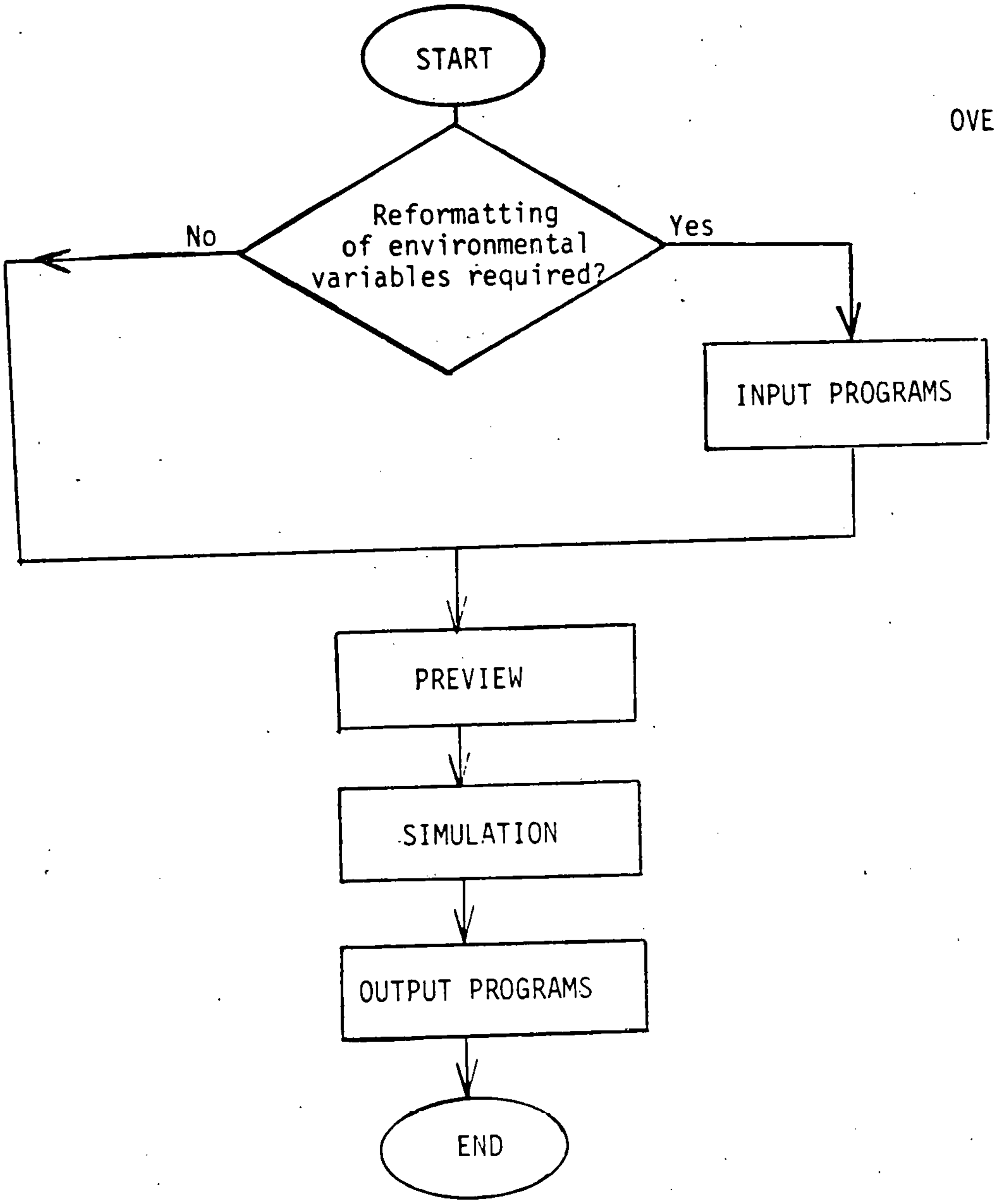


Figure 1. OVERVIEW

Second, the spacing of grid elements may be in meters or degrees longitude and latitude. These alternate grid spacings permit the model to operate on one of two size scales but also increases the complexity of defining the values of the variables and the grids. In the small scale mode, horizontal distance calculations are performed in meters while in the large scale mode, the calculations are performed in degrees. This allows environmental data to be obtained from satellites, where the data locations cover a spatially large grid requiring spherical coordinates such as longitude and latitude, or from smaller scale data collection programs such as might be located nearshore with recording instruments located only a few kilometers apart.

The input programs may be used to format the environmental variables to input the simulation model and/or to check the environmental data sets. Even if the user prepares the environmental data sets, the use of the input program that verifies the format is suggested. A small error in the location or format of an environmental grid may result in a costly but useless run.

In order to understand the second step in the simulation process, the preview run, it is important to first understand the difference in the concentration in the model of oil on the surface of the water compared to that of oil entrained into the water column. The surface oil is treated as a collection of "spillets." These are circular puddles of oil which spread, drift, evaporate, etc., independently of all other "spillets." If they overlap by more than predefined fraction, they are combined into one larger "spillet." The parameters describing this larger "spillet" are determined either by the sum of the corresponding parameters of the small "spillets" (such as the total volume of oil) or by the weighted sum of those parameters (such as the center of the "spillet"). In the present configuration, up to one hundred "spillets" are allowed at any one time. Oil is added to a spillet either from a source or by adding spillets together when they overlap. Table 1 gives a description of the variables used to define a "spillet."

The subsurface oil is treated as a collection of droplets each of which represents a large number of droplets with similar properties. The droplets in the model are, therefore, part of a statistical representation of the actual dispersion. Each droplet is described by a set of parameters such as the droplet radius, entrained mass associated with the droplet, its location, etc. These parameters are listed in Table 2. Up to two hundred categories of droplets are currently allowed. There may be many droplets in each category, but the total number of droplets is limited by memory requirements (to 2000 at present) and by execution time. A neutrally buoyant droplet may be used to represent the dissolved portion of the spilled oil.

Those subroutines that deal with the surface oil are formally separated from those dealing with the subsurface oil everywhere except in the determination of the volume of entrained oil, as the number of entrained marker particles. The preview run executes only the surface routines and keeps a running tally on the mass balance. It is used primarily to determine the mass to be associated with each subsurface particle. Such a determination is extremely difficult without this intermediate step because the total entrained mass depends on the wind

TABLE 1

"SPILLET VARIABLES"

-- Area of spillet treated thus far (meters^2).

-- Density of oil currently in spillet (gm/cc).

-- Fraction of each of up to eight classes.

-- Radius of Spillet (meters).

-- Interfacial tension of oil prior to treatment (Dynes/cm).

-- Interfacial tension of oil after chemical treatment (Dynes/cm).

-- Kinematic viscosity of the oil (Centistokes).

-- Mass of oil remaining in Spillet (metric tons).

-- Longitude and latitude at the center of the spillet.

TABLE 2

PARAMETERS OF DISPERSED OIL DROPLETS

-- Radius of the droplet (mm).

-- Density (gm/cc).

-- Fraction of each of up to eight classes of hydrocarbons.

-- Mass of entrained oil represented by the given droplet.

-- Longitude, latitude and depth in the water column (m) of the droplet.

speed as a function of time, the age of the oil, spill surface area, etc. If the number of particles is to be fixed, say at 2000, a good estimate of the total entrained mass is required to allocate the correct amount of mass to each entrained particle.

In addition to providing the user with an appropriate estimate of the mass associated with each entrained particle, the preview run is also useful in providing a preview of the surface behavior of the spill. Memory requirements may be less than for the full simulation and the time of execution is greatly reduced.

The main program integrates the subsurface portion of the simulation into the model.

The surface processes included are drifting, spreading and deposition. The oil enters the water column by dissolution and entrainment. The algorithm for the subsurface diffusion and advection makes use of the particle-in-cell method and is described in detail in Pavish (1977) and Spaulding (1976).

The output of the main program includes spillet size and location, subsurface concentrations, particle positions and a mass balance. In the final step of the simulation, this output is presented in graphical form by the various plotting routes. Specifically, mass balance, areal extent of the oil and a vertical view of the spill area are plotted.

CHAPTER II ENVIRONMENTAL GRIDS AND INPUT PROGRAMS

Input parameters required by the preview and the main simulation are logically divided into five main categories: environmental, oilspill, treatment, run control, and restart. Each of these categories has associated with it a well-defined format or set of formats. The user is required to determine and properly format variables in the first four groups. The restart data set is generated by the main simulation and intended to be transparent to the user; hence, only its function is described in this chapter.

The most complex set of input parameters is the environmental data set. In light of this, a pair of programs was written that will place environmental data into the proper format for input to the simulation model or check the environmental grids that may have been generated by the user. In this chapter, these programs are briefly described. Prior to this description, however, it is necessary to introduce the concepts associated with the environmental grids. This is done in the first section, the second section being reserved for the program description.

The other input parameters and formats are discussed in detail in Appendix I along with a list showing the order of entry of <u>all</u> input data.

A. Environmental Coordinate System

The environmental data are entered on a set of rectangular grids. The position of the (1,1) element is used to locate the grid with respect to longitude and latitude. The spacing between values is constant but not necessarily the same in both directions. The angle of the grid with respect to lines of constant latitude is a variable, defined by an input parameter and measured counterclockwise to the X axis. The model coordinate system is right handed with, for the zero rotation case, positive x eastward, and positive y northward. A grid may consist of from one element, in which case the variable defined is assumed to be spatially homogeneous over the entire ocean, or as many as 30 x 15 elements. The environmental data can be defined by either one or two grids. For example, wind velocity has x and y components and, therefore, needs two grids. Table 3 outlines the environmental grid variables and units.

The user has the option of spacing the environmental grids either in a spherical coordinate system or in a rectangular coordinate system. Spherical coordinates are used when the spatial scale of the problem is large, i.e. during the course of the simulation, the spill is expected to drift and spread over a distance covering several degrees latitude or longitude. This is referred to as the "large scale mode." Rectangular coordinates are used when the scale of the problem is small, less than a degree or so of latitude. This is referred to as the "small scale mode." The parameter ISCAL is used to specify the scale mode and applies to all environmental grids for a given simulation.

The units of the spacing between grid elements are dependent on the scale mode chosen. Environmental grids in the large scale mode may not be rotated. The spacing for the large scale mode must be in degrees of longitude and latitude for the x and y directions respectively, the units for the tidal currents must be degrees/sec for the large scale mode

TABLE 3 ENVIRONMENTAL GRID DEFINITION

GRID	TITLE	VARIABLE 1 Units	VARIABLE 2 Units	FORMAT	COMMON BLOCK	COMMENTS
Bathymetry	Bathymetry	Depth Meters	- -	Real	DPTH	Must not be moved during a run
Computational Cell	Comp Cell	- -	- -	Integer	COMP	Describes operational Area- Must not be moved during a run
Temperature	Temperature	Temp. Degrees C		Real	TMPC	
Wind Velocity	Wind Vel	U m/sec.	V m/sec.	Real	WIND	
Sea State	Sea State	Height meters	Period Seconds	Real	SEAS	
Current	Utid Current	U m/sec. or deg/sec.		Real	TIDE	If large scale mode - use degrees/sec.
Current	Vtid Current	V m/sec or deg/sec.		Real	TIDE	Same

because of the linear interpolation techniques which are used in the subsurface portion of the model. The units of the spacing for the small scale mode is meters.

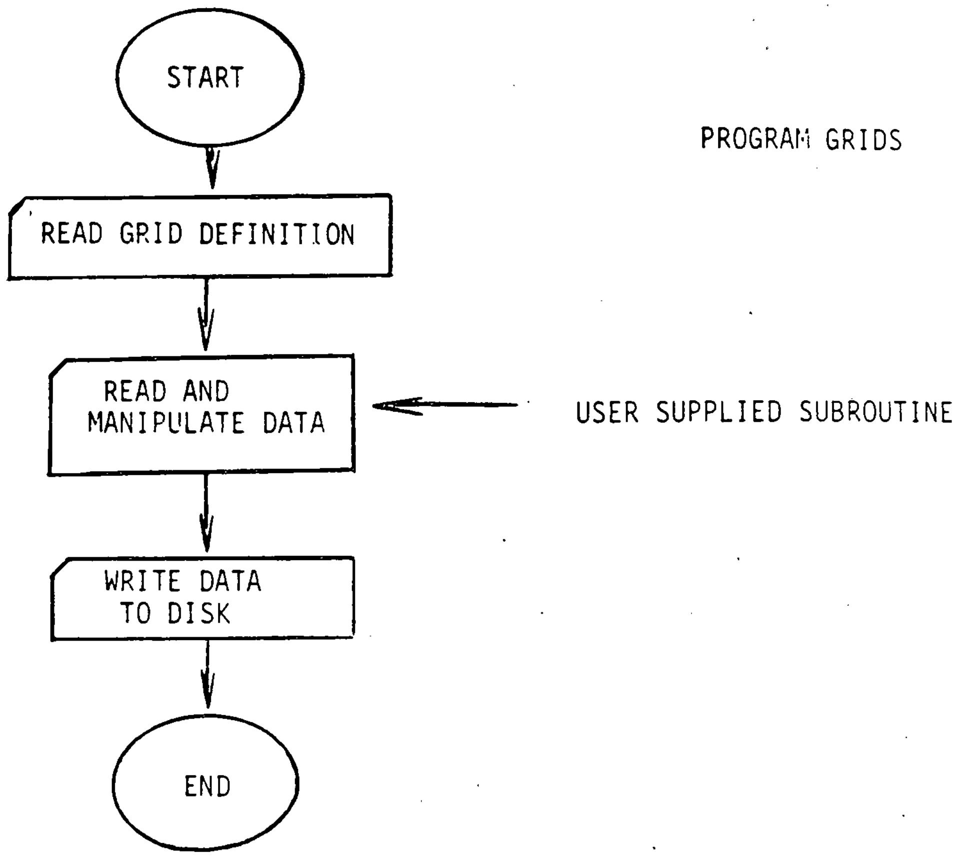
All of the grids are self-explanatory with the exception of the computation cell grid. This grid assigns an integer value to each element which when taken together, describe the area of interest (see Table 4) in both the horizontal and vertical directions. The program assumes the water surface cell reflects the particle downward and the bottom cell deposits the particle.

The uses must change 2 lines in the subroutine BOUNV (see Appendix IV) if another value is preferred.

The gridding system is a semispace-staggered system in that the computational cells are defined in the center of a cell while the remaining grids are defined at cell corners. There are no values at any of the zero locations (i.e., (0,0), (0,1)...) for any of the grids. The depth grid and computational cell grid are not to be moved or changed during a run because the program uses these grids as references. All other environmental grids may be moved or changed in any time step.

B. Input Programs for Environmental Data Grids

As is apparent from the description above, there is a great deal of flexibility in the nature of the environmental grids, the input format required of these variables by the input subroutine ARAYIN in both the preview and main simulation models is, however, quite precise. For this reason, a pair of programs (GRIDS and READATA) have been written to aid in the preparation of environmental data and to check the data sets once prepared prior to submitting a lengthy simulation. As indicated in Figure 1, this step is not mandatory but rather included as an aid in data preparation for the user. It should be stressed that these programs operate <u>only</u> on environmental variables. It is also important to note that although a user may elect not to use the formatting program, GRIDS, s/he is still advised to use the program, READATA, which reads and displays the "correctly formatted" variables, i.e., to check the data sets no matter how they are prepared. An error on the input environmental data sets may result in a significant loss of time and money. Flow charts for both programs are shown in Figure 2. The first program, GRIDS, places the environmental data into the power format for use by the main program. It first reads the grid definition variables such as angle and grid spacing. The program then calls a subroutine supplied by the user. This routine must read the environmental data and then perform any necessary interpolations or conversions to put it into a rectangular grid which will be used by the main program. The program then uses the subroutine ARAYOT which is basically a copy of the subroutine ARAYIN in the main program which reads the data, the only change being that this subroutine writes instead of reads the data. GRIDS may also be used to print the data if desired. It requires 200 kilobytes of memory and takes approximately 1.5 equivalent CPU minutes to write 135 environmental grids. These storage and run values will vary as a function of the amount of manipulation required.



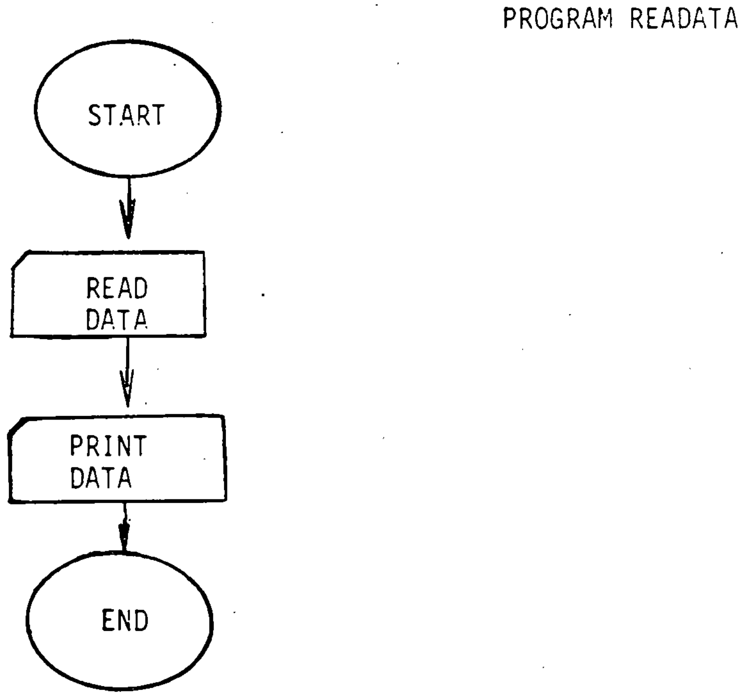


Figure 2. Flow charts for GRID and READATA

The second program, READATA, reads environmental grids as formatted for input to the simulation program exactly as the main program will read them and then prints out these arays. This program needs only 128 kilobytes of memory and takes approximately ten seconds of execution time to read and write 75 steps.

TABLE 4
COMPUTATIONAL CELL DEFINITION

VALUE	DEFINITION	COMMENTS
0	Land cell; More than half the cell is land	Important for Shoreline Interaction Processes
1	A water cell; Surrounded on all sides by other water cells	
2	Open Boundary cell; At least one side is at the edge of the grid	Important for interpolation when oil tracks near the boundary
101	Adjacent Water Cell; At least one side is connected to an open boundary cell on a land cell	Same as above
3	Reflection cell; Reflects droplets away from bottom or surface in vertical direction	
4	Bottom Depositional Cell; absorbs any oil which moves to within 1/2 grid spacing of bottom	

CHAPTER III PREVIEW RUN

In early applications of the model, it was found that prior to a full scale simulation, it was often useful to perform a quick simulation, skipping the detailed modeling of the subsurface portion of the spill. These runs were performed for one of two reasons:

1. The distribution of the subsurface portion of the spill was of little or no interest for the case under study.

2. Such a run was useful in determining the mass, XMSPAR, to be assigned to the marker particles, in the full scale simulation. As indicated in Chapter I, the total volume of oil entrained depends on a number of parameters that are continuously changing during a simulation; hence, this is a very difficult parameter to predict prior to the simulation. To make full use of the resolution offered by the subsurface portion of the model, the user generally wants to use as many marker particles as allowed, 2000 as presently configured. To do this, the correct mass per particle, XMSPAR, to achieve full utilization, must be determined prior to the simulation. If the mass per particle is too large, then less than the permissible number of marker particles will be released. If XMSPAR is too small, the entrainment of oil into the water column will terminate prematurely because there will be no particle locations available in the model to allow for the entrainment of new particles.

Because of the apparent need for such runs and the substantial savings in execution time that resulted from skipping the sophisticated subsurface portions of the model, the Preview run was introduced. The Preview run is invoked by setting the run control parameter, NRUN, to 1. The preview flow chart is shown in Figure 3 and a comparison with the flow chart for the full scale simulation shown in Figure 4 indicates that the only difference between the two runs is omission of the subsurface portion of the spill in the preview.

The output of a preview run may be used as input to the plotting programs exactly as the output from a full scale simulation, with the single exception that the subsurface distribution of the spill not be specified. The surface distribution is correct, identical with that resulting from a full scale simulation. The mass balance is correct except that droplets are not removed from the water column, so that the fraction of droplets that are deposited on the bottom or that escape through an open boundary, i.e., that leave the water column are not currently specified.

For a more detailed description of algorithms used in the surface related portion of the spill, the reader is referred to the discussion of the full simulation in Chapter 4.

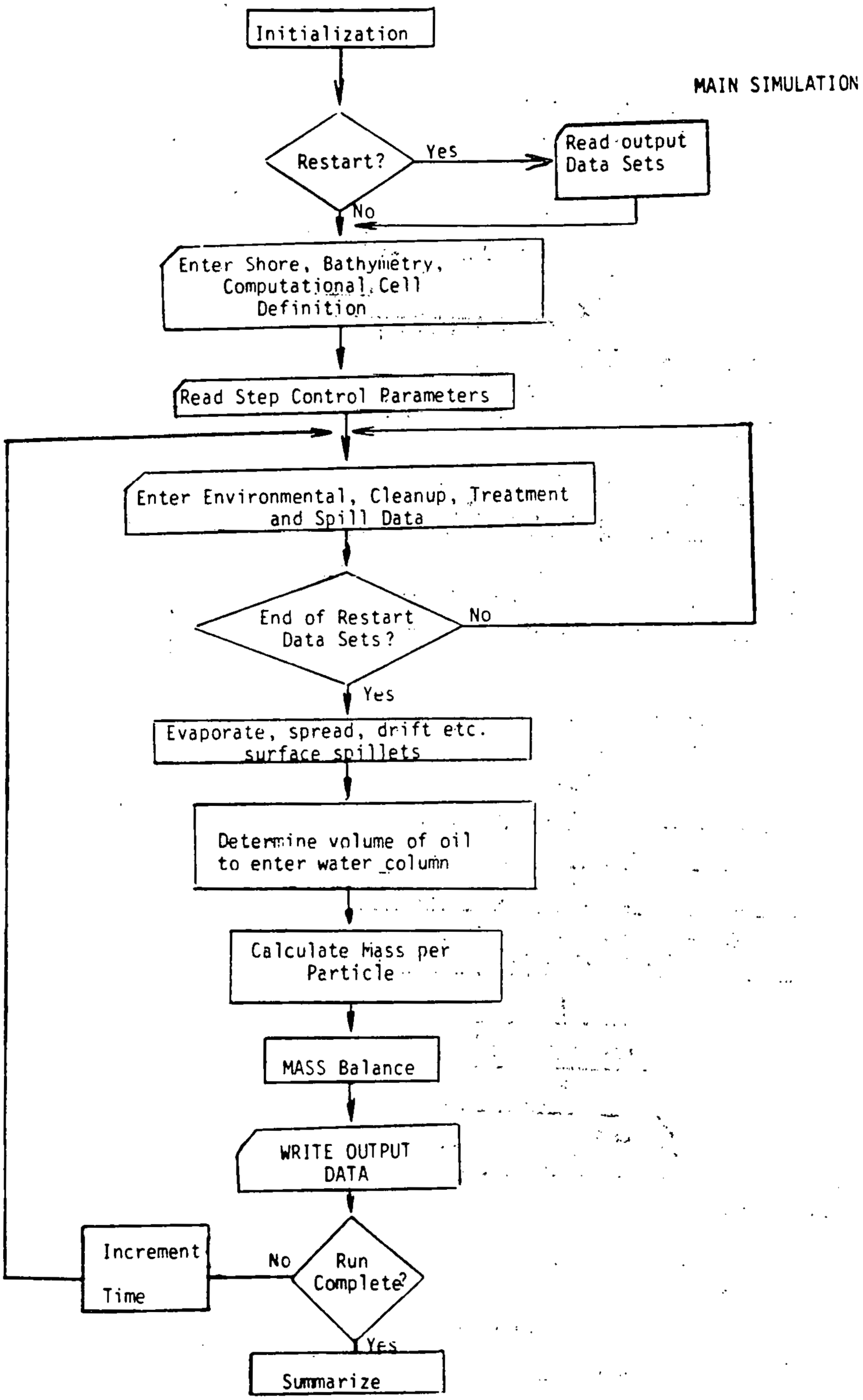


Figure 3. Flow Chart for the Preview Run

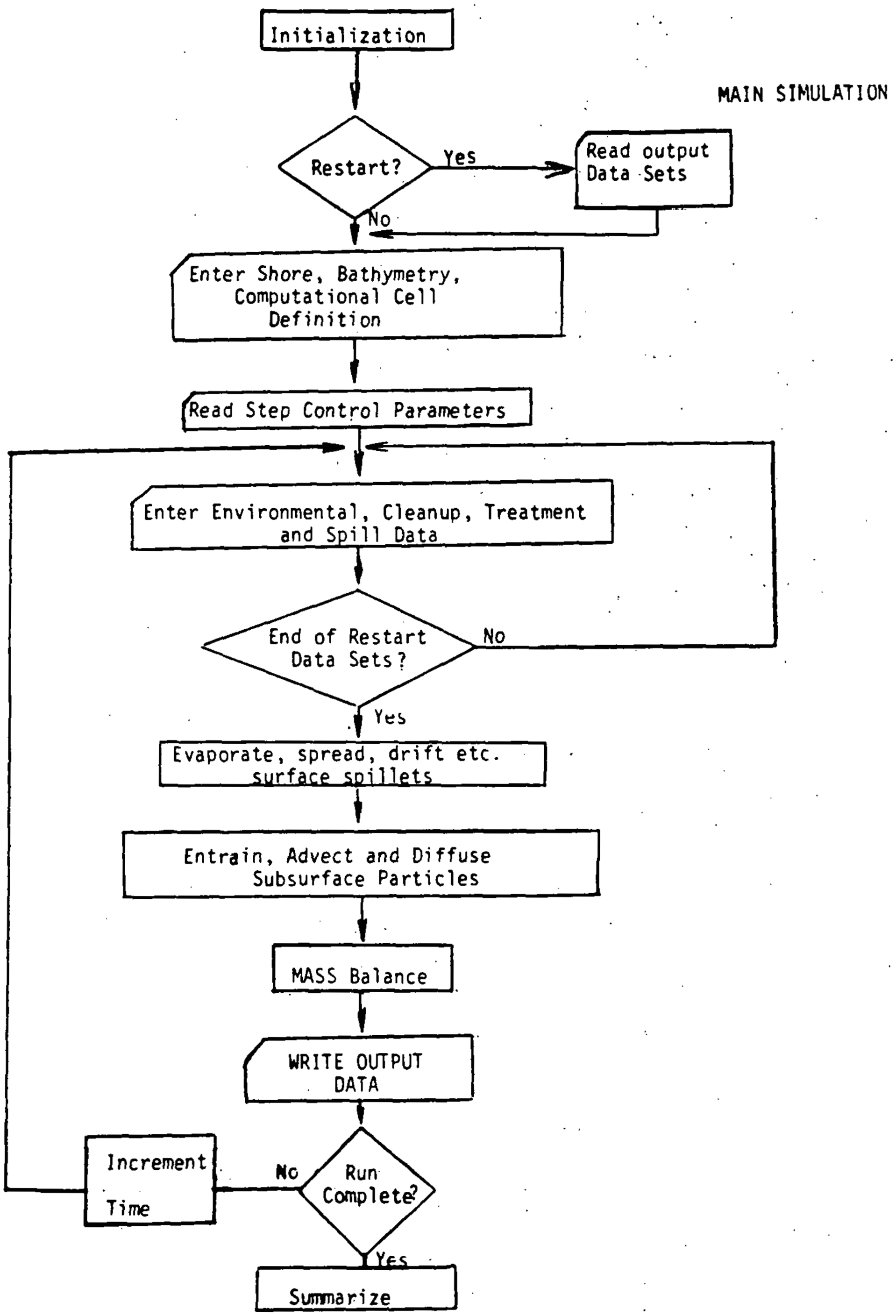


Figure 4. Flow Chart for Main Simulation

CHAPTER IV. MAIN SIMULATION

A. Introduction

This section is concerned with the description of the oil spill simulation model. The theoretical background is briefly discussed, followed by a description of program functions.

The objective of the model is to perform an environmental assessment of the treatment, with chemical dispersants, of spilled oil. This model, therefore, is directed primarily at the operational category of models dealing with cleanup and treatment alternatives. The model emphasizes the subsurface transport of spilled oil in much greater detail than those previously constructed because the major result of chemical treatment is to disperse the spilled oil into the water column. The flow chart for the model is shown in Figure 4. Most processes are handled in individual subroutines so that new algorithms can be easily incorporated. A more detailed description of the program, its subroutines and variables, are included in the Appendices III and IV.

B. Initialization

The first function performed in a simulation is to initialize. This consists of zeroing a number of counter and variables, such as mass balance, in addition to entering all fixed run control input which to a large extend will define the course of the simulation. The distinction "fixed" used above designates run control parameters that are entered once and remain unchanged for the rest of the simulation. They comprise two groups of variables, those entered in the main program which control the overall simulation (number of time steps, device numbers from which environmental data is to be read, etc.) as well as the parameterization of all surface related phenomena and those which determine the parameterization of the subsurface phenomena. All input parameters, associated formats and the order in which they are input are described in detail in Appendix I.

If this run is to continue a simulation begun in a previous run, the next step is to read the restart data set. The parameter NSTRT is used to specify a restart, being 1 if it is a continuation and 0 if the run is to begin from scratch. NSTRT equal to 1 requires that a previous run output all of the restart variables to disk. The restart data set contains the variables which define the spill at an instant in time with such as the spillet size and location, droplet properties and location, mass balance and any ongoing cleanup or treatment efforts at that step. It also retains the print parameters which control the output data stream, how much output and where it is to be written. For a restarted run, the program will also read all of the stored output data sets up to the restart step. This permits the use of the original output data sets.

The program then reads the bathymetry and computational cell grids as well as the shoreline data points. Because the droplet positions are defined with respect to the bathymetric grid, this grid cannot be changed in the middle of a run. This is why these grids are read prior to the commencement of the iteration in time.

The iteration in time now begins. The first function performed at each time step is to read in the step control parameters. These parameters indicate whether or not new environmental, spill or cleanup response data are to be input in this time step. Any of the environmental or spill control data sets except the definition of computational cells, the bathymetry and the shoreline, wind, temperature, sea state, tidal velocity, mechanical cleanup efforts, chemical treatment efforts and newly spilled oil may be read in at any time step. Cleanup and treatment efforts can overlap in time and space and grids can change orientation and spacing from one time step to the next. This allows for easy insertion of different resolution data such as from two satellites with different spatial resolutions or different orbital inclinations.

If this is a restarted run, and the previous run ended on an error, the program enters at this point a loop which reads all of the control parameters, environmental grids and cleanup/treatment efforts up to the point where the previous run stopped. Normal termination at a run also results in the appropriate data being written to the restart data set. The user must specify if the restarted run is to use the previous output data sets or use a new group of data sets. This is done by the use of the parameter NSTFN. This parameter indicates whether to use the previous data sets (NSTFN=1) or to use new data sets (NSTFN=0). The user must, however, in this case supply new input and output data sets.

C. Surface Processes

The program then executes the algorithms dealing with the surface related processes (see Figure 5). Each process is dealt with by a different subroutine and all are called from one subroutine. This subroutine loops over all spillets performing all surface related computation on one before moving on to the next. If a spillet moves to the edge of the study area, it is taken out of the loop so that no further processes will affect it. The first surface processes dealt with are those related to cleanup or chemical treatment efforts on the spillet. The variables used for this, such as efficiency, dispersant rate, etc., have been obtained through input and are described in Appendix I. These efforts are executed in the subroutines TREAT and CLNUP (see Appendix IV for a description).

The spillet is then located within each of the environmental grids. This is done for two reasons. First, it determines if the spillet is within the grid. If the spillet is outside of one grid, it is considered to be out of the study area and it is removed from the loop. If the grid is a single point, it covers the entire two dimensional plane and the spillet will never leave this grid. Second, the environmental variables are averaged over the spillet. This is done by averaging the values at all of the grid locations that the spillet covers. Some values such as depth are not used currently but the average wind velocity is used for evaporation, entrainment and drifting and the average current is used for drifting. See subroutine LOC8 in Appendix III for a detailed description of the location procedure.

The natural entrainment of mass and the creation of marker particles, is performed next. The amount of naturally entrained oil is determined from the Audunson et al. (1979) formulation. An exponential decay is added to Audunson's model to simulate the decrease in the amount of oil

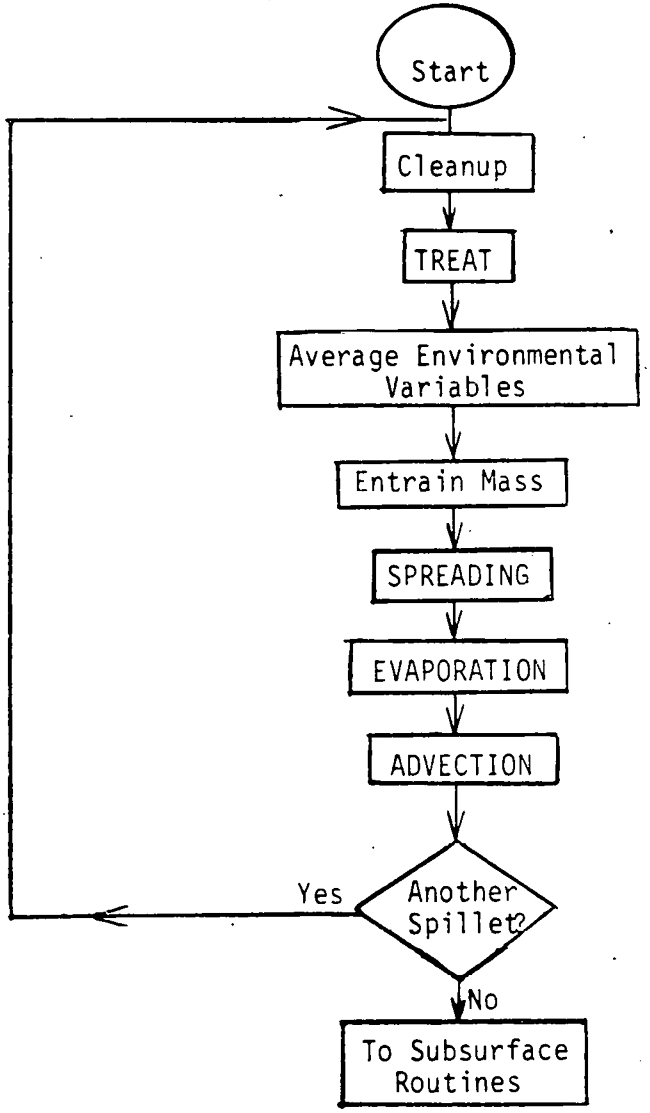


Figure 5. Flow Chart for Surface Portion of Simulation

entrained due to weathering. See subroutine ENTMAS, in Appendix IV, for a detailed discussion of this calculation. The amount of mass naturally entrained is combined with the mass dispersed into the water column during chemical treatment and the number of particles created is determined by dividing the entrained mass by XMSPAR, the mass per particle, a user supplied parameter (see Appendix I). The particles are then distributed in an ad hoc manner (described in the Appendix IV) by subroutines ENTRN and INJECT. Grossly they are distributed at random beneath the spillet.

The next process addressed is spreading. This is done using the simple three regime mechanism proposed by FAY (1969). There is a slight modification to the Fay procedure in that the effective release time for a given spillet is a variable that can change during the evaluation of the spillet. This is described in the Appendix IV for subroutine SPREAD and is necessitated by the requirement that oil may be added to or removed from a spillet or its interfacial tension may be changed with time.

Oil is then evaporated from the spillet using the method developed by Wang, Yang and Hwang (1976). (See Appendix III subroutine EVAPOR 8). The Wang, et. al. formulation requires that the oil be divided into eight components, the fraction by weight of each component being supplied by the user. These fractions are given for several crude oils, a No. 2 fuel and Bunker C oil in Appendix IX.

Following the evaporation, the surface slicks are advected. This is done using the tidal currents plus (vectorially) 3.5 percent of the wind speed (see Subroutine SURDFT).

D. Subsurface Process

The subsurface processes (which are again called from one subroutine) are now performed (See Figure 6). The important feature of the subsurface portion of the model is the mixed Eulerian-Lagrangian coordinate system. The Eulerian coordinate system is the one on which the tidal currents, the bathymetry and the computational cells are defined. The Lagrangian coordinate system is the one on which the oil droplet concentration is defined and is parallel to and contained within the Eulerian bathymetry system. This system expands and translates so as to always include all particles. Variables defined on the Eulerian system are interpolated to the Lagrangian system. The Lagrangian system also allows for a coordinate transformation on z, the vertical variable, such that the water column at every horizontal node is divided into the same number of equally spaced layers. This means that as the water becomes shallower, the vertical grid spacing becomes smaller, thus keeping the same relative vertical resolution.

Prior to diffusing and advecting the marker particles in the water column, the Lagrangian system must be established. This is done by locating the extremes in x and y of the particle positions and then adding a buffer to these extremes. This defines the edges of the Lagrangian grid. The grid spacing is determined by dividing the distance between the edges of the grid by the number of grid elements (see subroutine GRIDEX). This process is repeated each time step so that the droplets

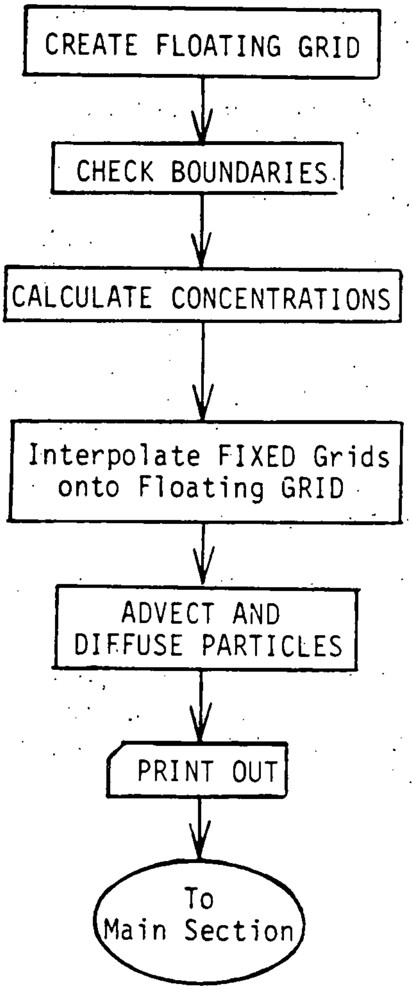


Figure 6. Flow Chart for Subsurface Portion of Simulation

never leave this grid. The program then checks the location of the droplets with respect to the computational cell grid (see subroutine BOUNV) and performs any necessary operations (e.g. deposits droplets on bottom or on shore). The concentrations are calculated at each of the floating grid locations (see subroutine CONC). Because the number of particles entrained in the first few time steps may be very small (say 100) and the concentration distribution calculated under such circumstances might be statistically unstable, this subroutine (CONC) is only called if a minimum number of particles (set by input parameter NCRIT) is exceeded. The next step is to interpolate the fixed grids values of tidal height, depth and currents onto the floating grid (see subroutine VELCT). Then, the diffusion velocities at each Lagrangian grid location are calculated and added to the advective terms. The particles are moved according to these velocities (see subroutine DISPV). The last step in the subsurface section is to output all requested subsurface information (see subroutine PRINT and output parameters KPRTU, KPRTC, KPRTP, NPRU, NPRC and NPRP in Appendix I). The output may go to paper and/or disk data sets, the latter being used as input to the plotting program. The step intervals for such output is controlled by a group of parameters input at the beginning of the run. The data output in PRINT are the concentration grid, the particle position array and the advective plus diffusive velocity Lagrangian grid. If the concentration was not calculated previously (i.e., if the number of particles is less than NCRIT), a new Lagrangian grid is created, the boundaries are checked and the concentration is calculated for printout. This terminates the subsurface portion of the simulation for the current time step.

E. Spill Overlap, Mass Balance and Restart Output

The next function of the main program is to add any spillets which overlap by a certain percentage (Input parameter COMB) and also write the mass balance to paper and/or disk. The final step is to save the restart variables if this step is an even multiple of NSUMM, the output interval for the restart data set.

CHAPTER V REFORMATTING AND PLOTTING PROGRAMS

A series of programs capable of reformatting and plotting the results of a simulated spill have been written to accompany the oil spill model. The relationship between each of the programs in the output and the data output from the model is shown in Figure 7. There are three possible plotted outputs of data resulting from a simulation.

i. Mass balance versus time (program PLOTMASS)

ii. The areal extent of the subsurface oil exceeding a given concentration and the areal extent of the surface slick greater than a given thickness, both as a function of time (program PLOTAREA)

iii. The spatial distribution of both subsurface and surface oil at a given instant in time (program PLOTMAP).

As indicated in Figure 7, the data output to disk by the simulation model is in the correct format for direct input to the mass balance plotting program. Both of the other plots, on the other hand, require at least one intermediate program to work the model output data into an appropriate form for input to the plotting routines. In particular, although the concentration distribution is output along with the other output parameters, it may be desirable to recalculate the concentration distribution on a grid different than the Lagrangian grid of the model. This is done by the program PARTICLE for those times in which sub-surface particle positions were output to disk. Prior to input into either PLOTAREA, PLOTMAP or CHECDATA, the concentration grid data, as well as the spillet data, must be passed through the reformatting program DATAOUT. This step is executed after recalculation of the concentration grid (if performed) as indicated in Figure 7.

Once the data has been reformatted, it may be verified by the program CHECDATA or plotted by PLOTAREA or PLOTMAP.

Each of the programs outlined in Figure 7 are briefly described below. All plotting programs make use of a CALCOMP Plotter with standard Calcomp subroutine calls. The detailed descriptions of these programs are included in Appendix VI.

A. PLOTMASS

The flow chart for the program PLOTMASS is included in Figure 8. There are two sets of input to this program; mass data output by the simulation model and plot control parameters defined by the user. These are input as shown in Figure 8. As indicated in the Figure, the user may plot the output of several different simulations in one run of PLOTMASS, or s/he may plot several different mass balance plots for the same simulated spill. The plot control parameters specify, among other things, the various mass quantities (atmosphere, surface, etc.) to be plotted. Finally, the program allows the data from two separate simulations to be plotted on the same graph for comparison.

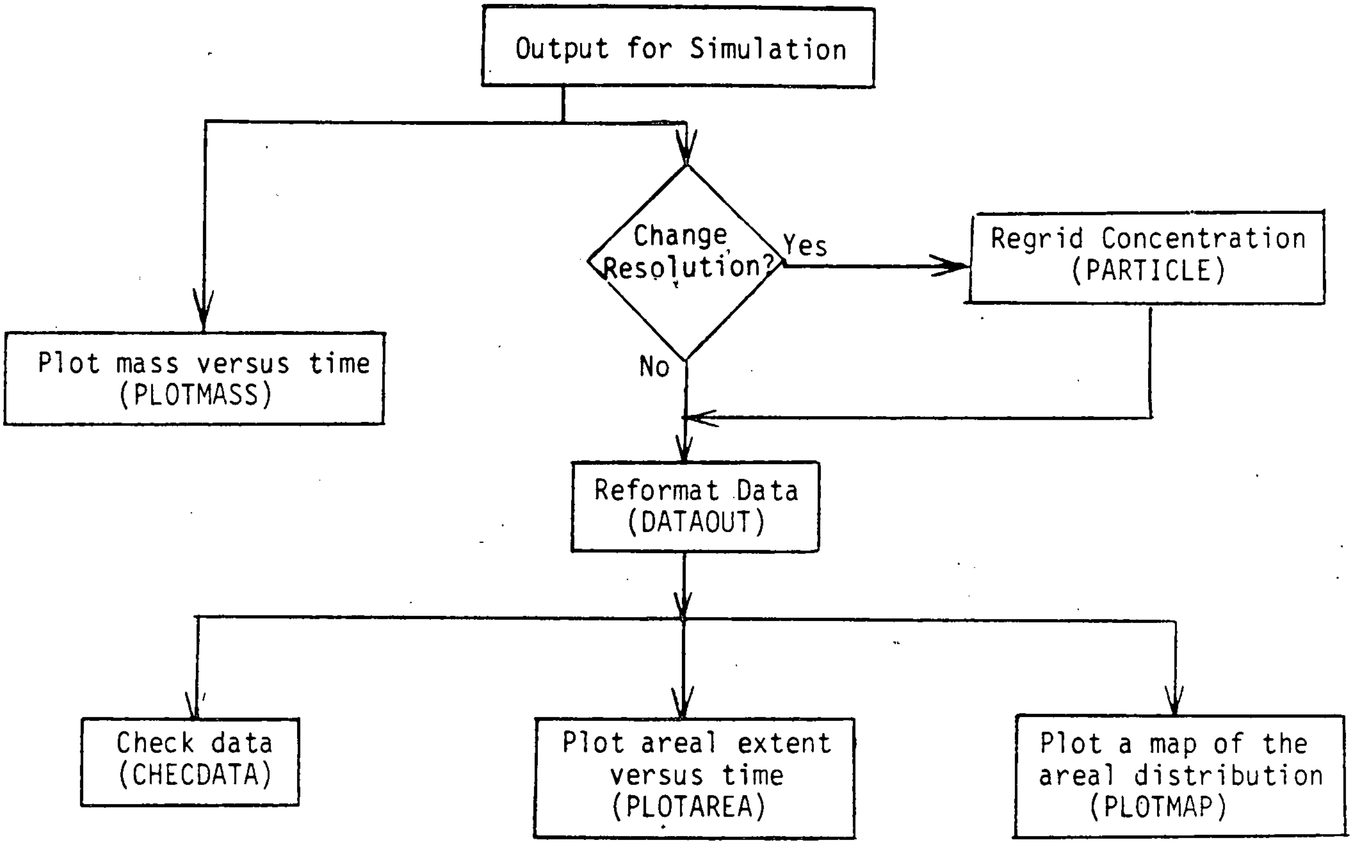


Figure 7. Overview of Output Program Sequence

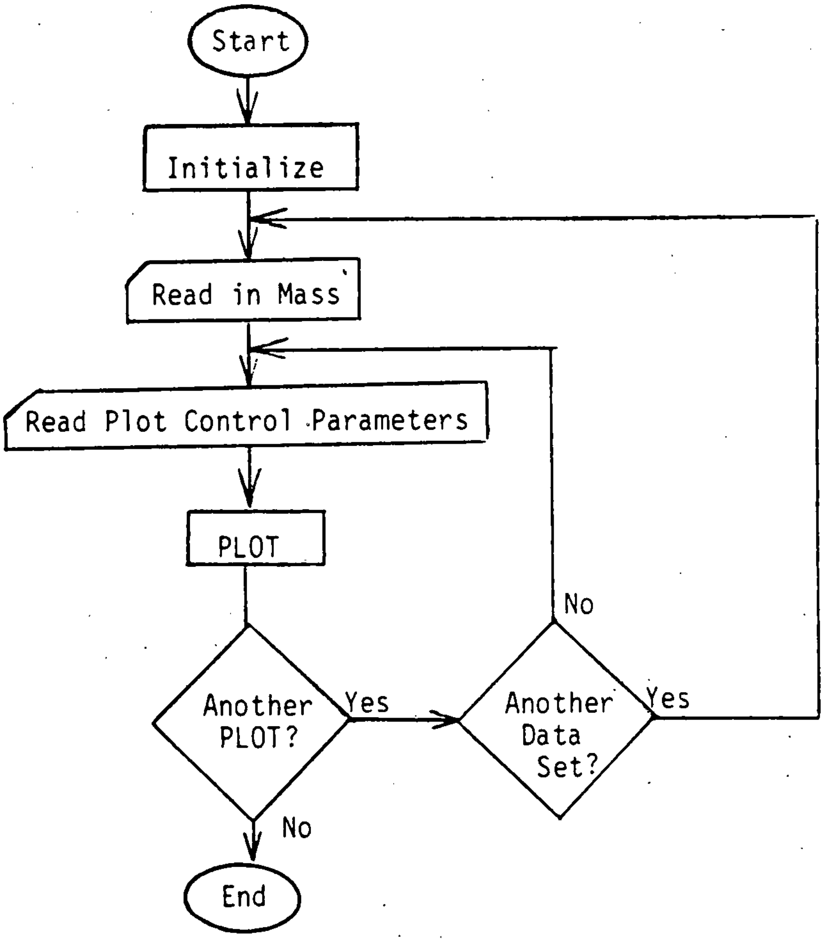


Figure 8. Flow Chart for Program PLOTMASS

B. PARTICLE

As indicated above, this program is used to calculate the concentration distribution on a grid different from the Lagrangian grid set up by the model. It requires, as input, the particle positions output by the simulation model, as well as those parameters required to define the new grid. The user supplies the latter. The flow chart for the program PARTICLE, is shown in Figure 9. The routines in this program that perform the required calculations have been extracted directly from the main program, hence, perform the calculations in exactly the same fashion.

C. DATAOUT

This program serves four functions. First, it compresses the data output by the oil spill model. Second, it integrates the surface and subsurface data sets into one data set for input to the plotting programs. Third, it performs cuts on both the surface distribution, by thickness, and on the subsurface distribution, by concentration. Fourth, it reads particle position data, (if requested) to be used by the program CHECDATA in verifying the output of the simulation. The overall operation of this program is outlined in the flow chart shown in Figure 10.

D. CHECDATA

This program simply reads the output of DATAOUT and prints it in an easy to read fashion for quick verification. The execution of this program is <u>not</u> required to plot the data.

E. PLOTAREA

The program PLOTAREA, see Figure 11 for its flow chart, is used to plot the areal extent of the surface and subsurface distribution. It reads the data output by DATAOUT from which the areal quantities are calculated. In the calculation for the area covered by the spillets, no attempt is made to account for the overlap of spillets, hence, the areal extent of surface oil will be overestimated if there is overlap. The user may elect to plot for one simulation only the surface and/or the subsurface. Or, s/he may elect to plot the output of two different simulations on the same plot for comparison.

F. PLOTMAP

The program, PLOTMAP, shown in the flow chart of Figure 12, allows the user to plot a map of the spill, showing both the surface and subsurface distribution of oil. Using the surface/subsurface data set output by DATAOUT. In addition, this program requires a set of control parameters that define the plots to be performed. There is a third optional input data set and that is the shoreline. The user may elect to plot the surface and/or the subsurface on a single plot at a given instant in time or s/he may elect to plot on a single plot these quantities at a number of different times. The user may also specify the times at which such plots are to be performed, as long as surface and/or sub-surface data was output by the main simulation at these times. The real use of this parameter is in limiting the plotting output in the case where, say maps for the 10, 20 and 30 day of a 30 day spill are desired, but the model

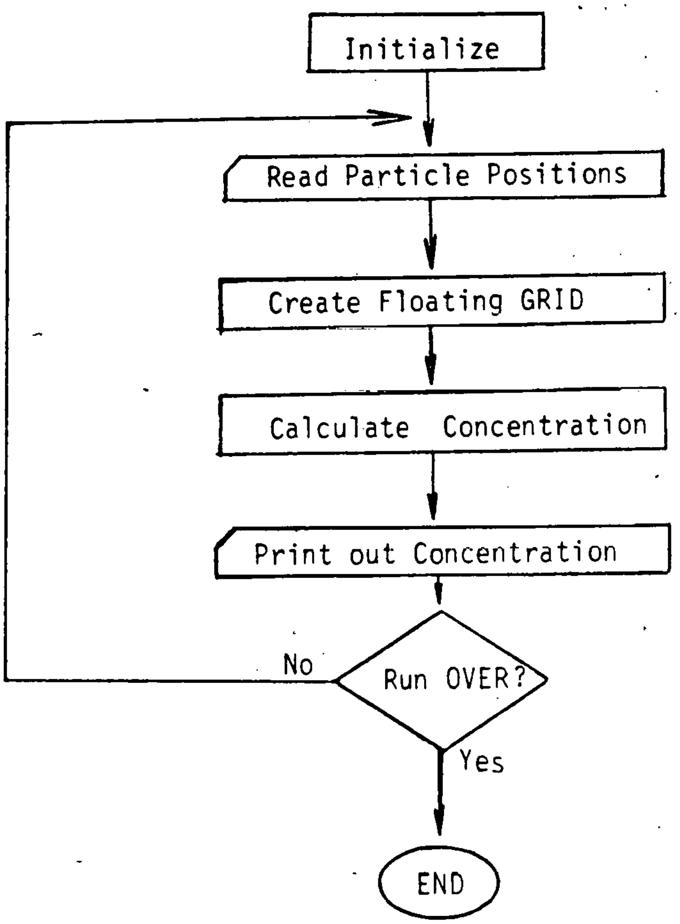
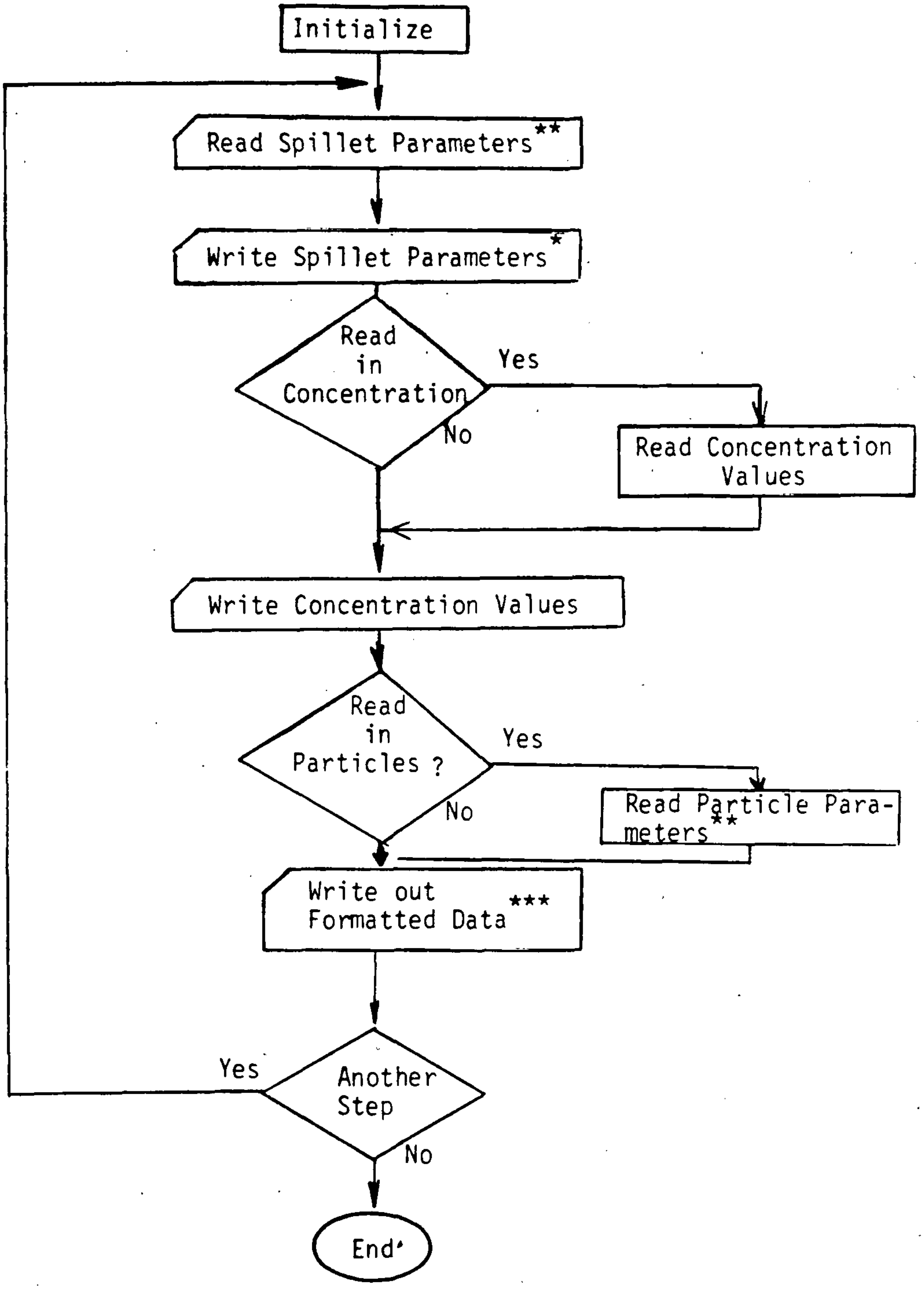


Figure 9. Flow Chart for Program PARTICLE



NOTES: * write out for plotting data set if needed
** print out as read in
*** printout in formatted manner

Figure 10. Flow Chart for Program DATAOUT

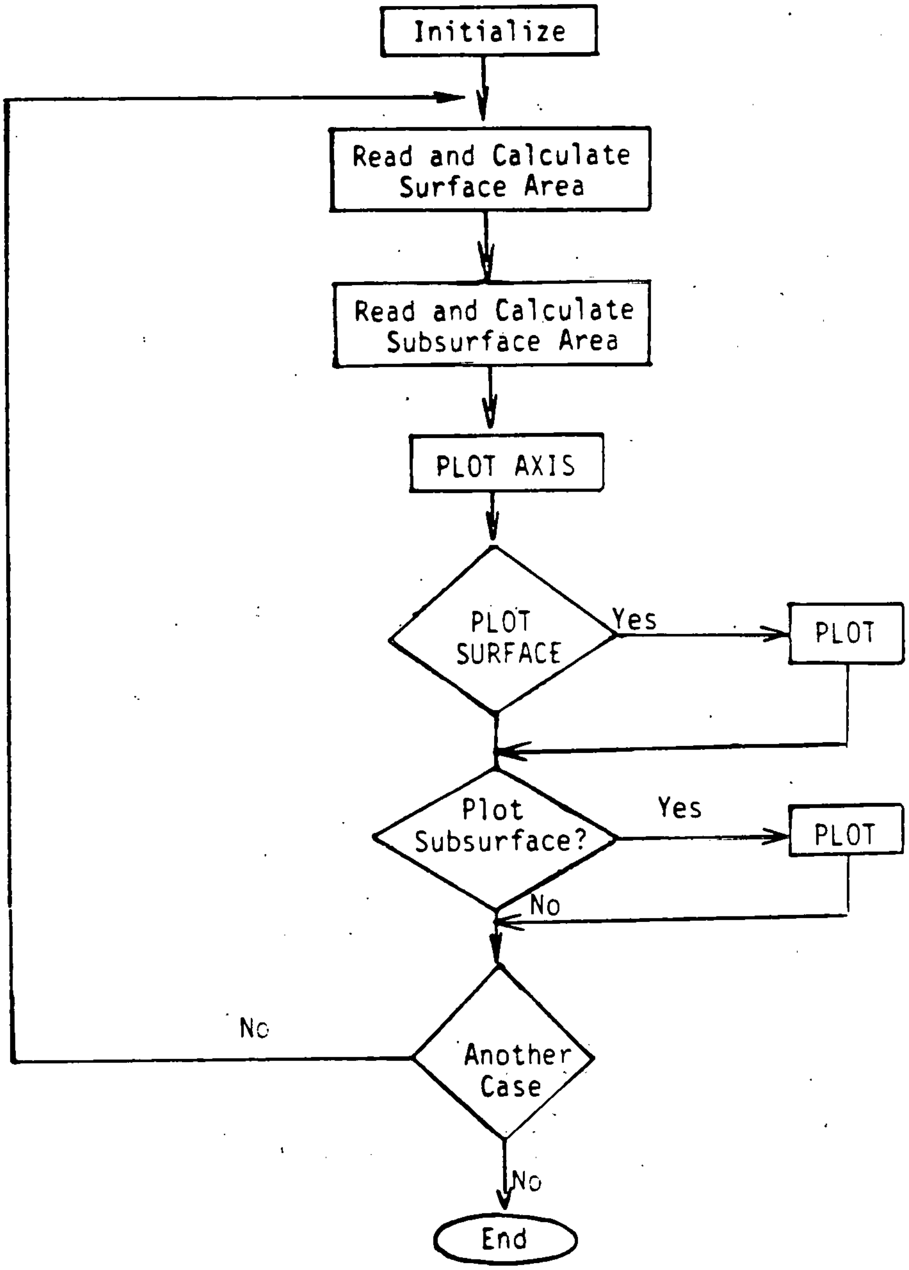


Figure 11. Flow Chart for Program PLOTAREA

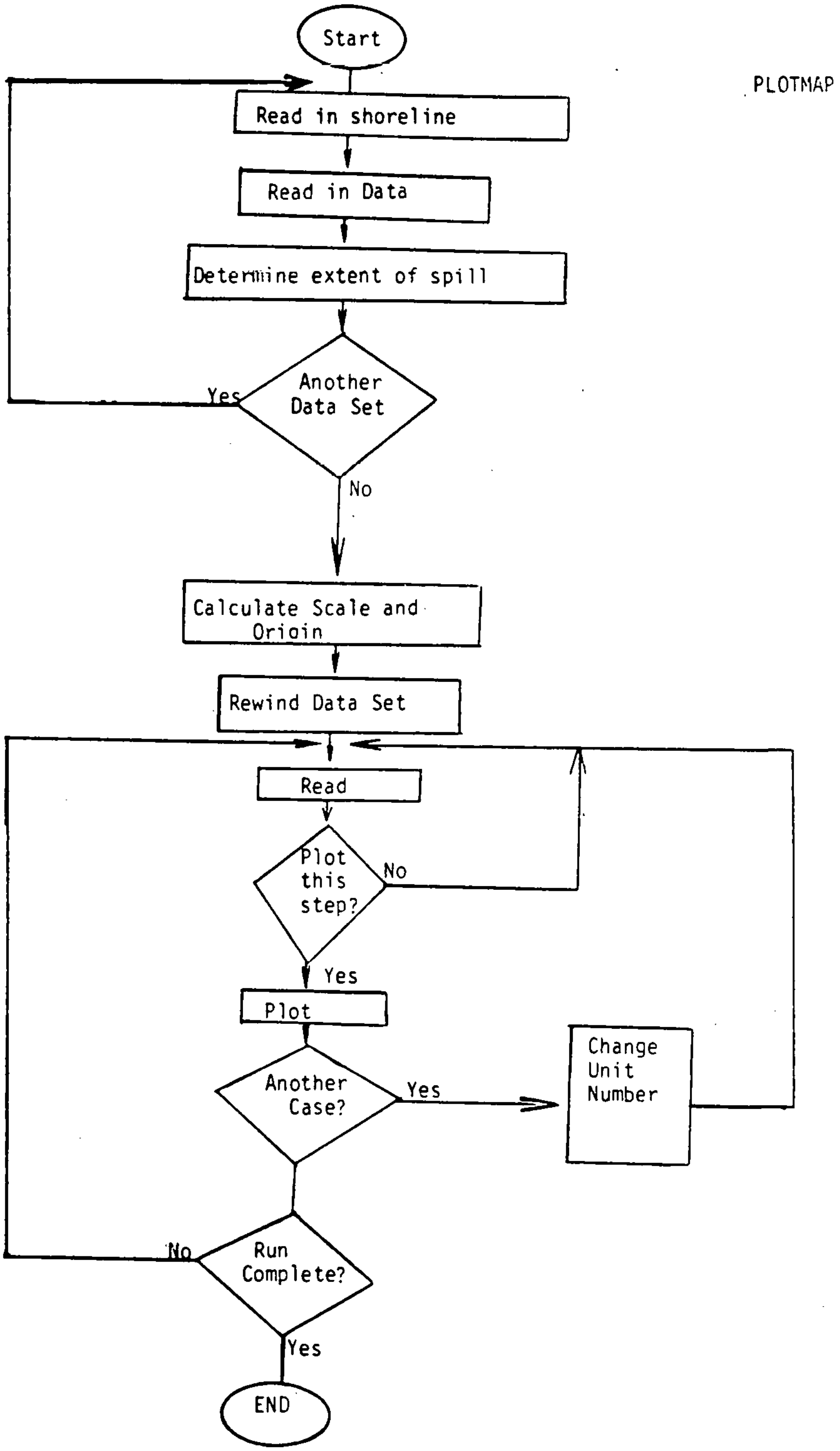


Figure 12. Flow Chart for Program PLOTMAP

outputs sufficient data to generate maps every day. Again, the user must remember that only the spillets exceeding the thickness defined in DATAOUT and the region in which the concentration exceeds the level also defined in DATAOUT, will be plotted. To obtain maps of lower concentration values, DATAOUT must be rerun. As in the case of PLOTAREA and PLOTMASS, two simulation runs may be compared on one map.

APPENDIX I: Input Parameters and Formats for the Preview Run and the Main Simulation

A. Environmental Variables

Input Data Format

In Chapter II GRIDS, a program that will format environmental data for input to the main programs is described. For the user who elects not to use this program, the format structure of the environmental data is described here. First, the grid name and definition is input. Specifically, the variables NAM, VAR1, UNITS1, VAR2, and UNITS2 are read unformatted or with the format (13A4). See Table I-1 for a description of each variable. The name of the grid entered in NAM must be exactly as given in Table 3 (Chapter 2) and must be left justified. The next logical input record contains IMAX, JMAX, ANGLE, XL, YL, XS, YS, UNITS3, again either unformatted or with format:

(2I5, 3F10.6, 2F10.4, 2A4)

Finally the grid itself is read in. Again the option is either unformatted or formatted. In the unformatted case, the entire grid is read in as one logical record, the implied do loop on X (east to west) then on Y (south to north). If the grid contains two parameters, e.g., u and v, two logical records are required, one for each parameter. Some grids are real and some integer. (See Table 3, Chapter 2, for a definition of which are real and which are integer, as well as which are two parameters and which are only one). For the case in which the grid is real and is to be formatted, the format is:

(10F6.2)

Each row begins a new logical record and is read from left to right (west to east) starting at the lowest y or southernmost row of the grid and moving up. For two parameter arrays, first the entire array for one parameter is read and then the second parameter is read with exactly the same format.

For integer variables, the fashion in which the data is read is the same, only the format differs.

(15I4) replaces (10F6.2)

Table I-2 presents the read statements as they appear in ARAYIN.

B. Oilspill Variables

1. General Description

As discussed in Chapter I, spilled oil is represented in the simulation either as spillets, circular puddles of oil on the surface, or droplets, representative droplets of oil in the water column. In its present configuration, only spillets may be defined by the user. Droplets are either defined by the program or read in under the restart capability, but the user does not have easy access to this means of entering data.

TABLE I-1

Variable	Format	Description
NAM (3)	34A	Name of input grid used for printout. These must be exactly as written in Table III, Chapter I under Title.
VAR1(2)	2A4	Name of the first variable of the grid; used for printout.
UNITS1(3)	3A4	Dimensions of the first variable used for printout. (meter, degrees per/sec., etc.)
VAR2(2)	2A4	Name of second variable of the grid.
UNITS2(3)	3A4	Dimensions of the second variable.
IMAX	I5	Number of elements in the x direction.
JMAX	I5	Number of elements in the y direction.
ANGLE	F10.6	Angle measured from lines of constant latitude to the positive x-axis of the grid in the counter-clockwise direction (degrees).
XL,YL	F10.6,F10.6	Location of the (1,1) element of the grid (Longitude and Latitude).
XS,YS	F10.4,F10.4	Spacing between grid lines in x and y directions, respectively (meters or degrees, see input variable ISCAL).
UNITS3(2)	2A4	Dimensions of XS and YS.
ARRAY1	see Table IV	Values at grid nodes for first grid if real.
ARRAY2	see Table IV	Values at grid nodes to second variable if two grids describe one environmental variable.
MARAY1	see Table IV	Values at grid nodes for first grid if integer.
MARAY2	see Table IV	Values at grid nodes for second grid if required.

TABLE I-2 INPUT IN SUBROUTINE ARAYIN

Formatted

```
line number

 12                 Read (ND,100) NAM, VAR1, UNITS1, VAR2, UNITS2
 13      100        FORMAT (13A4)
 14                 READ (ND,105) IMAX, JMAX, ANGLE, XL, YL, XS, YS, UNITS3
 15      105        FORMAT.(215, 3F10.6, 2F10.4, 2A4)
```

Unformatted

```
line number
 18                 READ (ND) NAM, VAR1, UNITS1, VAR2, UNITS2
 19                 READ (ND) IMAX, JMAX, ANGLE, LX, YL, XS, YS, UNITS3

 60-83   C          HERE TO READ UNFORMATTED REAL VARIABLES.
         C
          40        CONTINUE
                    READ (ND) ( (ARRAY1 (I,J), I=1, IMAX), J=1, JMAX)
                    IF(NO.EQ.1) GO TO 80
                    READ (ND) ( (ARRAY2 (I,J), I=1, IMAX), J=1, JMAX)
                    GO TO 80
         C
         C          HERE TO READ UNFORMATTED INTEGER VARIABLES.
         C
          50        CONTINUE
                    READ (ND) ( (MARAY1 (I,J), I=1, IMAX), J=1, JMAX)
                    IF (NO.EQ.1) GO TO 90
                    READ (ND) ( (MARAY2 (I,J), I=1, IMAX), J=1, JMAX)
                    GO TO 90
         C
         C          HERE TO READ FORMATTED REAL VARIABLES.
         C
          60        CONTINUE
                    DO 62 J=1, JMAX
                      READ (ND,110) (ARRAY1 (I,J), I=1, IMAX)
         110          FORMAT (10F6.2)
          62        CONTINUE
                    IF (NO.EQ.1) GO TO 80
                    DO 64 J=1, JMAX
                      READ (ND,110) (ARRAY2 (I-J), I=1, IMAX)
          64        CONTINUE
                    GO TO 80
         C
         C          HERE TO READ FORMATTED INTEGER VARIABLES
         C
          70        CONTINUE
                    DO 72 J=1, JMAX
                      READ (ND,120) (MARAY1 (I,J), I=1, IMAX)
         120          FORMAT (15I4)
          72        CONTINUE

                    IF (NO.EQ.1) GO TO 90
                    DO 74 J=1, JMAX
                      READ (ND,120) (MARAY2 (I,J), I=1, IMAX)
         74         CONTINUE
```

A spillet is described by positional parameters, physical parameters, and chemical parameters (See Table I-3). The user is required to specify all parameters describing a spillet for the time when it is first to appear.

It is not necessary that the spillet be fresh in the sense that the oil has just escaped from a well, tanker, or pipeline. If the user would like to simulate a spill starting several weeks after the initial catastrophe, it sufficies that s/he enter spillets representing the locational, physical, and chemical variables as they are at that time. The model takes over from that point.

2. Input Data Format

Oil Spill parameters are entered in two logical records. The first record reads:

BSPIL, DSPIL, RSPIL, SSPIL, TSPIL, USPIL, WSPIL, XSPIL and YSPIL

with the format

(6F8.3, E8.2, 2F8.3)

The units assumed by the program are shown in the list of spillet variable in Table I-3.

Following this the composition of the spillet is input from one logical record containing between one and eight numbers each representing the fraction of a given hydrocarbon class.

The format of this record is:

(8F5.2)

The number of hydrocarbon classes is defined by the user through the parameter MSPIL discussed in the run control section. This variable is specified once per run, i.e., all spillets are required to have the same number of hydrocarbon classes. The program, as currently configured, uses all eight classes. The fraction of each of the eight classes for four different types of oil, as well as a chemical description of each class, is given in Appendix IX. The user must exercise great caution if s/he decides to use a different set of hydrocarbon classes from the eight outlined in Appendix IX. In particular, the coefficient defining vapor pressure for each class included as data in the evaporation subroutine will have to be changed if the classes are restructured.

The format statements as they actually appear in the subroutine that reads in spillet parameters are shown in Table I-4.

C. Treatment Variables

1. General Description

TABLE I-3
SPILLET PARAMETERS

Variable name	Description
BSPIL	Beginning time of spillet (hours).
DSPIL	Density of oil (gm/cc).
RSPIL	Radius of spillet (meters).
SSPIL	Interfacial tension of oil (dynes/cm).
TSPIL	Density of oil at time equal zero (gm/cc).
USPIL	Kinematic viscosity of oil (centistokes).
WSPIL	Weight of oil in spillet (metric tons).
XSPIL	Longitude of center of spillet.
YSPIL	Latitude of center of spillet.
GSPIL	Mass fraction of each class of oil.

TABLE I-4

FORMAT OF SPILLET PARAMETER INPUT

```
      READ (ND,100) BSPIL(I), DPSIL(I), RSPIL(I), SSPIL(I), TSPIL(I),
   1                USPIL(I), WSPIL(I), XSPIL(I), YSPIL(I)
100   FORMAT (6F8.3, E8.2, 2F8.3)
      READ (ND,101) (GSPIL (I,J), J=1, MSPIL)
      FORMAT (8F5.2)
```

TABLE I-5
PHYSICAL CLEANUP PARAMETERS

Variable name	Description
BCLN	Beginning time of effort (hours).
DCLN	Duration of this effort (hours).
ECLN	Efficiency of effort.
RCLN	Radius of effort (meters).
VCLN	Volume rate of cleanup effort (metric tons/hour).
XCLN	Longitude of center of cleanup effort.
YCLN	Latitude of center of cleanup effort.

TABLE I-6
CHEMICAL TREATMENT PARAMETERS

Variable	Description
BCHEM	Beginning of this effort (hours).
DCHEM	Duration of this effort (hours).
PCHEM	Fraction of oil entrained.
RCHEM	Radius of this effort (hours).
SCHEM	Interfacial tension of treated oil (dynes/cm).
TCHEM	Toxicity of dispersant.
VCHEM	Volume rate of dispersant used (liters/hour).
WCHEM	Dispersant used per square meter (liters/meter^2).
XCHEM	Longitude of center of effort.

Available in this model are two response alternatives to the simulated spill. One alternative is the chemical dispersion of the spill and the other is the mechanical cleanup of the oil. Both methods may be used simultaneously and for each method there may be up to ten efforts in progress at once. The algorithm employed to implement a spill response effort is discussed in a later chapter. A response to the spill is not required for a simulation.

2. Input Data Format

All seven mechanical clean-up variables are read in one logical record in alphabetical order with the format:

(7F10.3)

The variables are listed in Table I-5 along with the units assumed by the program.

In the case of chemical treatment, there are ten variables. These are again read in alphabetical order, this time however, in two logical records. The format used for chemical treatment variables is:

(5F10.3)

These variables, along with the appropriate units, are listed in Table I-6.

The read statements and associated format for both the mechanical cleanup and chemical treatment variables are shown in Table I-7.

TABLE I-7 FORMAT STATEMENTS FOR RESPONSE VARIABLES

a. Mechanical Cleanup

```
     READ (ND,100) BCLN (I), DCLN (I), ECLN (I), RCLN (I),

    1               VCLN (I), XCLN (I), YCLN (I)
100  FORMAT (7F10.3)
```

b. Chemical Treatment

```
     READ (ND,100)BCHEM (I), DCHEM (I), PCHEM (I), RCHEM (I), SCHEM (I),

    1   TCHEM (I), VCHEM (I), WCHEM (I), XCHEM (I), YCHEM (I)

100  FORMAT 5F103
```

D. Run Control Variables

1. General Description

Run control variables include all parameters that control the evolution of a spill simulation but which, other than their association with the model, have little physical significance. All run control variables except the step control parameters are read in only once. A set of step control parameters is read in for each step. These parameters direct the model to read (or not to read) environmental variables, spillet variables, and response variables for the given time step. In the first step, a grid must be read in for each environmental variable. In addition, at least one spillet must be entered. All run control variables have been separated into three groups: general run control, subsurface control, and step control. These variables are listed in Table I-8 to I-10.

2. Data Input Formats

All run control variables except shoreline points and step control parameters are read in a similar format by one of the two subroutines READI and READF. READI is used to enter fixed point (integer) variables while READF is used for floating point (real) variables. They each require a logical record for each new variable entered. In addition, they require the name of the variable as used in the program. If an incorrect name is specified or the cards are out of order, a message is printed and the run terminated. In addition, integer variables must lie within a given range or the program will again print a message and the run will be terminated. These precautions are included to guard against an error associated with the input cards being out of order, a card forgotten or an integer variable entered one or more columns to the left of the desired location. The format for integer variables is:

```
(I15, 5X, A8)
```

where the A8 portion is to include the variable name left justified precisely as indicated in Tables I-8 and I-9. The format used for floating point (real) variables is:

```
(F15.5, 5X, A8)
```

where again A8 is the variable name.

Shoreline points are read in unformatted. Two logical records are required; one for x, longitude, and one for y, latitude. If NSHOR, the number of shoreline points, is zero, this read will be skipped.

All eight step control parameters are entered in one logical record in the following order:

NP, NV, NT, NK, NS, LSPIL, LCLN, LCHEM

These variables will be zero if no action is to be taken, one if the associated environmental grid is to be read in and equal to the number of

TABLE I-8 General Run Control Variables

Variable	Subroutine used	Range	Explanation
NSTRT	READI	0-1	0 - this run is not a restart 1 - this is a restart, the restart data set will be read.
NSTFN	READI	0-1	0 - this restart run uses new output data sets. 1 - this run uses previous output data set.
NSUMM	READI	0-100	Interval number of steps for writing out restart variables in the subroutine SUMMUP.
NRUN	READI	0-1	0 - total spill simulation. 1 - this activates the Preview run only (see Chapter III).
IDAY	READI	1-365	Day of year on which the spill begins.
NENV	READI	0-100	Print control parameter for formatted output of step control parameters in main program 0 - no printout 0 - prints out at this step interval.
DT	READF		Size of time step in hours.
TIMMAX	READF		Length of simulation (hours).
ISCAL	READI	1-2	1 - select small scale mode 2 - select large scale mode (see Chapter II).
NPRTA	READI	-1,0,1	Environmental grid printout control parameter (see Subroutine ARAYIN). -1 - no printout 0 - limited printout 1 - full printout
NPRTC	READI	0-1	Print control for cleanup and treatment efforts. 1 - printout all current cleanup and treatment efforts 0 - printout only newly started efforts.
NR	READI	1-20	Input file for step control parameters.
NCD	READI	1-20	Unit from which computational cell grid is to be read.

NCU	READI	1-4	Computational cell grid format control parameter. 2 - unformatted integer 4 - formatted integer
NDD	READI	1-20	Unit number from which the bathmetric grid is to be read.
NDU	READI	1-4	Bathmetric grid format control 1 - unformatted real 3 - formatted real
NED	READI	1-20	Unit number from which the tidal elevation grid is to be read.
NEU	READI	1-4	Tidal elevation grid format control (See NDU).
NKD	READI	1-20	Unit number from which the temperature grid is to be read.
NKU	READI	1-4	Temperature grid format control (see NDU).
NSD	READI	1-20	Unit from which sea state grid is to be read.
NSU	READI	1-4	Sea state grid format control (see NDU).
NTDU	READI	1-20	Unit from which the U components (x-direction) of current are to be read.
NTDV	READI	1-20	Unit from which the V components (y-direction) of current are to be read.
NTUU	READI	1-4	Format control for x current grid. (See NDU).
NTUV	READI	1-4	Format control for y current grid.
NWD	READI	1-20	Unit number from which the wind grid is to be read.
NWU	READI	1-4	Wind grid format control (see NDU).
NCHD	READI	1-20	Unit number from which the chemical treatment data is to be read in.
NCLD	READI	1-20	Unit number from which the physical cleanup data is to be read.
NSHD	READI	1-20	Unit number from which the shoreline points are to be read.
NSPD	READI	1-20	Unit number from which new spillet information is to be read.
NMAX	READI	1-2100	Maximum number of droplets allowed. This parameter is used to dynamically allocate

			space for x,y,z and NORDR in the subsurface subroutines. These variables are currently dimensioned of 2100 in the main program.
NTCLASS	READI	1-200	Maximum number of particle classes allowed. The dimensions will allow 200 different types of particles.
NUMCL	READI	1-200	Maximum number of particles per class.
XMSPAR	READF		Amount of oil to be represented by each droplet metric (tons).
MAXSPL	READI	1-99	Maximum number of spillets allowed. Dimension statements currently limit this to 100.
COMB	READF		Percentage of overlap needed in order to combine two spillets (see Subroutine ADD).
MSPIL	READI	1-9	Number of components of oil. Due to the evaporation model, this is how set at 8.
NSPPRD	READI	-1-100	Spillet print control parameter for disk data sets. This gives the interval (in steps) of how often to write out spillet information. (see Subroutine SPILIN).
NSPPRP	READI	-1-100	Spillet printout control parameter. -1 - no printout 0 - printout only on first step 0 - printout interval
NSHOR	READI	0-1500	Number of shoreline points.

TABLE I-9 SUBSURFACE CONTROL VARIABLES

Variables	Subroutine used	Range of Values	Explanation
POWX	READF		Power of length factor in scale dependent diffusion equation in x-direction (see Subroutine DIFF).
POWY	READF		Power of length factor in scale dependent diffusion equation in y-direction (see Subroutine DIFF).
EXX	READF		Coefficients used in scale dependent diffusion equation for the x direction.
EYY	READF		Coefficient used in the scale dependent diffusion equation for the y direction.
NTRANS	READI	0-1	Parameter for vertical transformation. 0 - uses depths as read in. 1 - normalizes all vertical distances by the depth.
DXX, DYY, DZZ	READI		Constant diffusion coefficients in the x, for Lagrangian Coordinate System.
DYY			Same y
DZZ			Same z
NSUB	READI	0-1	Control parameter for analytical diffusion. 0 - do not use 1 - use analytical sub-grid diffusion until standard deviation of cloud is comparable to grid mesh.
NDIFF	READI	0-1	Control parameter for using scale dependent diffusion. 0 - use constant coefficients 1 - calculate scale dependent diffusion equations (see Subroutine DIFF).
NCRIT	READI	0-1000	Minimum number of particles needed to calculate concentration for use in diffusion.
NEXTR	READI	0-1	Control parameter for Lagrangian grid. 0 - use fixed grid 1 - use Lagrangian grid

DEPC	READF		Vertical origin of initial particle distribution (meters)
POMIN	READF		Gives the minimum spacing in meters in the x and y-directions if only two particles are present. If the particles are too close together, the Lagrangian grid cannot be created around them without having an error.
AFRAC	READF		Determines the fraction of particles within RO (RO is radius of spillet divided by RIFRAC, see Subroutine ENTRN and INJECT).
RIFRAC	READF		Radius up to which particle density is uniform (see Subroutines ENTRN and INJECT).
HENT	READF		Length of time of entrainment for use in calculating the maximum radius of the initial particle distribution (see Subroutine ENTRN).
DDIAMT	READF		Diameter of droplets (mm).
DVELZT	READF		Vertical velocity of droplet (m/sec). Zero if neutrally buoyant.
NPTSUB	READI	-1 -1	Controls printout of subsurface information concerning Lagrangian grid (Subroutine GRIDEX) and scale dependent diffusion (Subroutine DIFF). -1 - no printout 0 - print only on first step >0 - printout at this step interval.
NPRTMS	READI	0-100	Print control parameter for mass balance. This is given in an interval number of steps and controls paper and disk printout.
KPRTV	READI	0-100	Print control parameter for formatted paper output of Lagrangian grid velocity values, concentration values and particle parameters respectively. This is given in an interval number of steps.

NPRD	READI	0-1	Control parameter for indicating that some disk data set output is requested. 0 - no output 1 - if any printout of concentration or particle parameters is desired.
NPRU,NPRC,NPRP	READI	0-100	Interval control in number of steps for printout of velocity, concentration or particle disk data sets.
NUSP	READI	1-20	Spillet output unit number.
NUPS	READI	1-20	Restart data output number.
NUCN	READI	1-20	Concentration unit number.
NUPT	READI	1-20	Particle parameter unit number.
NULV	READI	1-20	Velocities Lagrangian unit number.
NUMS	READI	1-20	Mass unit number.
NUDP	READI	1-20	Deposited particle unit number.
NULT	READI	1-20	Lost particle unit numbers.

spillets, cleanup efforts, or treatment efforts to be read in. The format used is:

(8I5)

NOTE: One logical record with these eight parameters is read in for each time step of the model. The variables and their definition are shown in Table I-10.

E. Restart Variables

Restart variables are all the parameters required to restart a simulation which may have been terminated for one of three reasons: (1) program or system error that resulted in an abnormal termination of a job, (2) the user, after having run a simulation for some predetermined number of time steps, and having examined the resulting output decides to extend the run, or (3) the user wishes to run the model at several different time steps and spatial resolutions, e.g., high temporal and spatial resolution followed by coarser resolution. All the parameters required to restart the model are written to disk (or tape) every NSUMM time steps (NSUMM determined by the user). The model may be restarted only at the time step following the last time step for which restart data were written.

When a run is to be restarted, the run control variable NSTRT is set equal to 1. If the run is to restart an abnormally terminated one, all data sets used in the previous run must be included. The model will read these data sets to the point where the previous run terminated. If the user specifies NSTFN = 0, the program only reads the restart data set and uses new input and output data sets. In addition, a number of variables generated by the simulation and output to the restart data set are read.

F. Input Sequence for all Input Data

Because the user may elect to read some of the environmental variables, treatment data, or spillet data from Unit 5 (the card reader, normally used for run control parameters), it is essential that the order in which all input data (except RESTRT) be known. This order is indicated schematically in Table I-II.

TABLE I-10 STEP CONTROL VARIABLES

Variable name	Description
NP	Wind grid control parameter.
NV	Tidal currents grid control parameter.
NT	Tidal heights grid control parameter.
NK	Temperature grid control parameter.
NS	Sea state grid control parameter.
LSPIL	Number of new spillets this step.
LCLN	Number of new cleanup efforts this step.
LCHEM	Number of new treatment efforts this step.

Table I-11

INPUT LIST (in order of entrance, read down from left to right)

NSTRT
NSTFN
NSUMM
NRUN
IDAY
NENV
DT
TIMMAX
ISCAL
NPRTA
NPRTC
NR
NCD
NDU
NDD
NDU
NED
NEU
NKD
NKU
NSD
NSU
NTDU
NTDV
NTUU
NTUV
NWD
NWU
NCHD
NCLD
NSHD
NSPD
NMAX
NUCLAS
NUMCL
XMSPAR
MAXSPL
COMB
MSPIL
NSPPRD
NSPPRP
NUSP
NURS
NUCN
NUPT
NUVL
NUMS
NUDP
NULT
NSHOR
SHORELINE POINTS

POWX
POWY
EXX
EYY
NTRANS
DXX
DYY
DZZ
DX
DY
DZ
IMSUB
JMSUB
KMSUB
NSUB
NDIFF
NCRIT
NEXTR
DEPC
POMIN
AFRAC
RIFRAC
ROFRAC
HENT
DDAMT
DVELZT
NPTSUB
NPRTMS
KRPTU
KPRTC
KPRTP
NPRD
NPRV
NPRC
NPRP

READ THRU
RESTART SECTION

BATHMETRY GRID

COMPUTATION CELL GRID

The following are repeated each step if needed:

STEP CONTROL PARAMETERS

WIND VELOCITY GRID

TEMPERATURE GRID

SEA STATE GRID

X - DIRECTION TIDAL CURRENT GRID

Y - DIRECTION TIDAL CURRENT GRID

TIDAL LEVEL GRID

PHYSICAL CLEANUP EFFORTS

CHEMICAL TREATMENT EFFORTS

INITIAL SPILLET PROPERTIES

APPENDIX II: SIMULATION MODEL OUTPUT

The output from the simulation model takes one of two forms; paper copy to allow the user to monitor a simulation, or digitally stored data (either on disk or tape) to be used as input to the plotting programs (See Fig. II-1). Because the model is capable of generating enormous volumes of data in both cases, a number of printout parameters have been added to the model. In general, output to paper is treated by a different set of parameter than that to disk or tape allowing for the two different modes to be treated separately.

A. Printed output used to monitor a run (Generally UNIT 5)

First, all of the input parameters read by either READI of READF are written out as they are read. There is no choice in the output of these parameters. For the remaining input parameters, environmental grids, response alternatives, and spillet characteristics the user does have a choice of the amount of output.

Every timestep, the program reads in a set or parameters which control that step. This command list may be printed out if desired under the control of the parameter NENV. If NENV is zero, no printout is generated. For NENV greater than zero, the step control information is printed every NENV step.

The output of <u>all</u> environmental grids is controlled by one parameter NPRTA. Any environmental input data written out will start on a new page so the user must therefore take great care here when selecting environmental output for a long simulation. For example, a 30 day simulation with three hour timesteps and a new current grid and wind grid each timestep will require at least 480 pages to print out just these two data sets. To suppress environmental grid output set NPRTA=-1. Limited printout defining the grid location and orientation only is selected with NPRTA=0. The entire grid is printed out with NPRTA=1.

Mechanical cleanup and chemical treatment efforts may also be summarized on paper. The controlling parameter for this output is NPRTC: its value being 0 when only new efforts are to be printed out and 1 when all current efforts are to be printed out. If NPRTC equals 1, this information is printed out for every timestep for which there exists a response effort, new or ongoing.

The spillet printout control variable is NSPPRD and is used to define the interval at which the defining variables for each spillet are printed out. NSPPRD=-1 suppresses all output while NSPPRD=0 prints out only on the first timestep (at which time at least one spillet must be released). If NSPPRD is greater than zero, then spillet information is printed out for the first step, the last step, and at any other step number that is a multiple of NSPPRD: eg. NSPPRD=3 would result in all spillet information being printed on the 1st, 3rd, 6th, 9th, ..., last steps. Again, caution must be exercised when specifying this parameter as the output can become voluminous; eg. if the run has 39 spillets and runs for 30 days and the spillet data is printed out every timestep, approximately 2000 pages of output would be generated (12 lines/spillet *39 spillet, = 8 pages/timestep x 240 timesteps=1920 pages).

Summary Order of Output II-1

D - Disk Data Sets

P - Paper

(all controlled by parameters)

ALL OUTPUT CONCERNED WITH INPUT	P
FLOATING GRID DEFINITION	P
SCALE-DEPENDENT DIFFUSION	P
CURRENT VELOCITIES	P, D
FLOATING GRID DEFINITION	P
CONCENTRATION PARAMETERS	P, D
PARTICLE PROPERTIES	P, D
VELOCITY VALUES	P, D
MASS BALANCE	P, D
RESTART PARAMETERS	D

In addition to the input parameters described above, there are three other groups of data that may be output to the printer. The first such group consists of two separate pieces of information specifically, the subsurface grid definition variables and the subsurface diffusion parameters. The grid definition variables locate the Lagrangian grid and define the size of the associated grid elements. The subsurface diffusion variables consist not only of the values of the scale dependent diffusion, but also of the statistical characteristics of the cloud of entrained particles used to obtain the scale dependent diffusion. The printout of all of the variables in this group is controlled by one parameter, NPTSUB. As in the case of spillet data, NPTSUB equal to -1 suppresses such printout, NPTSUB equal to 0 prints out only on the first step and NPTSUB greater than 0 prints out on steps that are multiple of NPTSUB and on the first and last steps.

The second group of derived variables, the printout which the user may control, defines the mass balance; e.g., mass evaporated, mass on the surface, mass entrained, etc., the controlling parameters in this case is NPRTMS. Not only does this parameter control printout to paper, but also to disk/tape; i.e., whenever data is written to the printer it is also written to the mass balance disk data set. This is an important set of parameters and takes little space either on disk or paper, hence, should in general be output fairly often. NPRTMS is greater than or equal to zero, printing out nothing when equal to zero, and every NPRTMS step otherwise.

The last group of derived data output are the particle locations and the velocity vectors and concentration values on the Lagrangian. Each of these is controlled by its own parameters, KPRTP, KPRTU, KPRTC respectively. All of these variables operate in the same fashion printing out nothing when equal to zero and printing out every KPRT (i) steps otherwise.

Finally, the program will print to paper warning or error messages when appropriate. The user has no control over the printout of such data.

All of the print control parameters for output to Unit 5 are listed with their meaning in Figure II-2.

B. Disk/tape output data sets.

There are seven possible output data sets; data sets written to disk or tape that can be used by other programs either to plot the results or to restart the simulation model as described in Chapter IV. These are summarized in Table II-2 and described in some detail below.

1. Restart

As described earlier, this data set contains all of the run generated variables needed to restart a run. Of course, all input data sets are also required, i.e., environmental variables, etc. The controlling parameter for this output is NSUMM, the restart data being written every NSUMM timesteps in addition to the last timestep if the previous run terminated with no errors. All restart data is written to Unit # NURS in the subroutine SUMMUP. Because a large volume of data is generally

Figure II-2

Control Parameter	Meaning (for more detailed information, see Figure I-8)
NENV	Step control printout environmental header
NPRTA	Controls printout of enviromental header
NPRTC	Controls printout of cleanup efforts, treatment efforts and spillet information
NSPPRP	Step control for spillet data
NPTFLT	Step control for subsurface information
NPTSUB	(see Subroutine SUBSUR)
KPRTV	Print control for floating grid velocity values
KPRTC	Print control for concentration values
KPRTP	Print control for particle parameters
KPRTMS	Print control for mass balance output

TABLE II-2
DISK DATA SETS

Data Set	Subroutine	Unit Number	Control Parameter	Memory Space Needed
Restart	SUMMUP	NURS	NSUMM	932 bytes plus 84 bytes per spillet and 16 bytes per particle.
Spillet	SPILIN	NUSP	SNPPRD	72 bytes per spillet.
Concentration	PRINT	NUCN	NPRC	80 bytes plus 4 times (number of X grid elements plus number of Y grid elements) plus (the number of X grid elements times the number of Y grid elements).
Particles	PRINT	NUPT	NRPD	80 bytes plus 4 times (the number of Y grid elements plus the number of Y grid elements (plus 56 times the number of classes plus 18 times the number of particles.
Mass	MASSC	NUMS	NPRTMS	36 bytes per step.
Lost Particles	BOUNV	NULT		32 bytes per particle.
Deposited Particles	BOUNV	NUDP		32 bytes per particle.
Velocity Components	PRINT	NUVL	NRDV	88 bytes times maximum number of X or Y grid elements.

output for every NSUMM timesteps, the decision was made to overwrite the previous restart data so that restart data exists only for the most recent multiple of NSUMM steps or if the previous run terminated successfully for the last step. This means that a run may only be restarted for the last timestep that restart data was written.

The space requirements for a restart data set depend both on the number of particles and the number of spillets, the appropriate equation being

Space in bytes = 932 + 84* (Number of spillets) + 16* (Number of particles)

The longest logical record is 88 bytes and the output data is unformatted (binary). The DD statement for the restart data set on an IBM 370 system with 39 spillets and 2000 particles is:

```
FT01F001 DD DSNAME = RESTART.DATA,
            DISP = (NEW, CATLG),
            UNIT = SYSDA,
            DCB = (RECFM = VBS,LRECL = 88, BLKSIZE = 4404),
            SPACE = (TRK, (40,10), RLSE)
```

Note: i. To save memory, it helps to single buffer all of the output data sets, i.e., set BUFNO=1 in the DCB parameter.

ii. 4 bytes have been added to the longest logical record because the data set is unformatted and 4 bytes have been added to each block for the same reason.

2. Spillets

All spillet information is output every NSPPRP step to unit # NUSP by the subroutine SPILIN. This output is suppressed for NSPPRP=0. Because a time history of each spillet is desired for input to the plotting program, every NSPPRP step is appended to the data already written i.e., the space requirements of this data set grow with the length of the run and with an increased frequency of output. If a run is restarted, these data sets are read to the appropriate step and subsequent output is added to the end.

The data defining each spillet at a given timestep is output as one logical record 72 bytes in length. The DD statement for a 30 day run with spillet data output once per day and a total of 39 spillets is:

```
FT F001 DD DSNAME = SPILLET. DATA,
           DISP = (NEW, CATLG),
           UNIT = SYSDA,
           DCB = (RECFM = VBS, LRECL = 76, BLKSIZE = 7604),
           SPACE = (7604,(12,1),RLSE)
```

Note: Again, the data is output in binary, and DISP= OLD for a restarted run.

3. Concentration

The concentration grid is output in the subsurface subroutine PRINT and is controlled by the step parameter NPRC. It is written to unit # NUCN.

Each grid is output as three logical records; one locating the x grid nodes in the fixed depth grid, the second locating the y grid nodes, and the third giving the concentration at each node. The longest logical record is therefore a function of the number of x, y and z grid elements. For a 15*15*3 (x*y*z) grid, one concentration grid output per day for a 30 day run; the DD statement would take the form:

```
FT F001 DD DSNAME = CONC.DATA,
        DISP = (NEW, CATLG),
        UNIT = SYSDA,
        DCB = (RECFM = VBS,LRECL = 2704, BLKSIZE = 8116),
        SPACE = (8116,(10.1),RLSE)
```

Note: Again, the data is output in binary, and DISP = OLD for a restarted run.

4. Particles

The position of all particles currently in the water column will be output to unit # every NPRP steps by the subroutine PRINT. Because the particle positions are referenced to the lagrangian grid, the location of these grid elements is also output. Finally, the particle class information must be output. The total space requirements per time step are:

Space in bytes = 80+4*(# of x grid nodes + # of y grid nodes) + 56* (# of particle classes) + 18* (# of particles)

For a 15*15 (x*y) grid, with all particle information output once per day a 30 day run, 200 particle classes and 2000 particles, the DD statement would take the form:

```
FT F001 DD DSNAME = PART.DATA,
        DISP = (NEW, CATLG),
        UNIT = SYSDA,
        DCB = (RECFM = VBS,LRECL = 68,BLKSIZE = 1296),
        SPACE = (TRK, (100,50), RLSE)
```

Note: This data set can consume a large volume on the disk.

5. Mass Balance

The mass of oil in the various environmental categories dealt with in the model, water surface, water column, shore, etc., is output in the subroutine MASSC to unit #NUMS every NPRTMS timesteps. As in all previous cases, if the step control parameter is zero, no output is generated. A single logical record 36 bytes long is output every NPRTMS steps. For a 30 day simulation with two outputs per day, the DD statement would assume the form:

```
FT F001 DD DSNAME = MASS.DATA,
        DISP = (NEW,CATLG),
        UNIT = SYSDA,
        DCB = (RECFM = VBS,LRECL = 40,BLKSIZE = 404),
        SPACE = (404,(3,1),RLSE)
```

6. Lost Particles

Every time a marker particle passes out of the study area, all of its parameters as well as its location is written to unit #NULT. This is done in the subroutine BOUNV and is not under the control of the user. If this output is not desired, a dummy data set is required:

```
FT F001 DD DUMMY
```

If the output is desired, each particle lost to an open boundary will use 32 bytes hence the DD statement will take the form:

```
FT F001 DD DSNAME = LOST.DATA,
        DISP = (NEW,CATLG),
        UNIT = SYSDA,
        DCB = (RECFM = VBS,LRECL = 36,BLKSIZE = 364),
        SPACE = (364,(30,10),RLSE)
```

Note: In this case, the exact volume on disk required is not known because the number of particles lost is not known. Some upper limit must be estimated.

7. Deposited Particles

Because the user may desire a plot of the distribution of oil on the sea floor following a simulated spill, the characteristics and locations of each deposited particle are output to disk, unit #NUDP. All comments relevant to deposited particles are identical to those for lost particles and therefore are not repeated here.

8. Velocity Components

The floating grid velocity components are written to unit #NUVL in subroutine PRINT. The DD statement for a 15*15 grid will be:

```
FT F001 DD DSNAME = VEL.COMP,
        DISP = (NEW,CATLOG),
        UNIT = SYSDA,
        DCB = (RECFM = VBS,LRECL = 88,BLKSIZE = 1588),
        SPACE = (TRK,(90,10),RLSE)
```

This writes all 3 components so that much output is generated.

APPENDIX III: Variables in Common in the Main Simulation Program

In this Appendix, the variables in all of the common statements in the main simulation model are described. The descriptions are arranged in alphabetical order by common name. In addition to a description of the variable, the associated units are also defined.

(1) /CHEM/ - defines chemical treatment
LCHEM - number of new treatment efforts during this step.
NCHEM - total number of current treatment efforts.
NCHD - unit from which the treatment data shall be read.
BCHEM(ICHEM+)- 10*- time this treatment effort begins (hours).
DCHEM(ICHEM) - 10 - duration of treatment effort (hours).
RCHEM(ICHEM) - 10 - radius of treated area (meters).
SCHEM(ICHEM) - 10 - interfacial tension of treated oil (dynes/cm).
TCHEM(ICHEM) - 10 - unused.
VCHEM(ICHEM) - 10 - volume of dispersant used (liters/hour).
WCHEM(ICHEM) - 10 - dispersant used per square meter (liters/meter**2).
XCHEM(ICHEM) - 10 - center of treated area (Longitude).
YCHEM(ICHEM) - 10 - center of treated area (Latitude).
PCHEM(ICHEM) - 10 - percentage of oil entrained if treated area is larger than spillet area.

(2) /CLEN/ - defines the physical cleanup effort.
LCLN - number of new cleanup efforts during this step.
NCLN - total number of current cleanup efforts.
NCLD - unit from which the cleanup data shall be read.
BCLN(ICLN) - 10 - time this cleanup effort begins (hours).
DCLN(ICLN) - 10 - duration of this cleanup effort (hours).
ECLN(ICLN) - 10 - efficiency of this cleanup effort (%).
RCLN(ICLN) - 10 - radius of this cleanup effort (meters).
VCLN(ICLN) - 10 - oil recovery rate (tons/hour).
XCLN(ICLN) - 10 - center of this effort (Longitude).
YCLN(ICLN) - 10 - center of this effort (Latitude).

(3) /CNTL/ -control parameters
IMSUB, JMSUB, KMSUB - number of grid elements in the X, Y, and Z directions for Langrangian Coordinate System (See description of subroutine GRIDEX for a better explanation).

NPRTA - printout control parameter for the environmental data (used in Subroutine ARAYIN).

---

*This numerical value indicates the size of the array as currently configured.

+ICHEM indicates that this parameter applies for each of the ICHEM treatment efforts of the NCHEM current efforts.

-1 no printout
0 limited printout
1 full printout
NPRTC - printout control for cleanup and treatment efforts.
-1 printout all current cleanup and treatment efforts for every timestep.
0 printout only when new efforts are started.
DT - timestep size (hours).
TIME - in seconds.
TIMMAX - time since start of spill at which run is to end.
ISCAL - 1 program does necessary distance calculations in meters.
2 program does necessary distance calculations in degrees of Longitude or Latitude.
NSAV(99) - spillets which have been removed in Subroutine ADD and added to the end of the spillet list.

(4) /COMP/ - defines the computational cell as explained in Chapter II.
MAXCX, MAXCY - number of grid elements in X and Y.
AC - angle between the X axis and lines of constant Latitude (degrees).
MCOMP(MAXCX,MAXCY) -30,15 - computational cell definition.
XCL,YCL - Longitude and Latitude of the (1,1) grid position.
XCS,YCS - grid spacing in X and Y (meters or degrees).

(5) /DENS/ - Den (8) - densities of the eight fractions of oil. These are initialized in the main program and listed in the section which describes the evaporation subroutine; EVPOR8. Sample values are given in Appendix IX.

(6) /DEPOS/ NLOST - number of subsurface particles lost through a computational boundary.
NDEP - number of subsurface particles deposited on bottom.

(7) /DIFU/ NCRIT - minimum number of particles needed before diffusion velocities are calculated. The time at which NCRIT is exceeded depends upon how fast the particles are being entrained.
NDIFF - control parameter for calculating scale dependent diffusion coefficients.
0 use constant coefficients which are input.
1 call subroutine DIFF which calculates scale dependent diffusion coefficients.
DXX,DYY,DZZ - diffusion coefficients in X,Y, and Z directions respectively (meters^2/sec).
EXX,EYY - coefficient used in scale dependent diffusion equation.
POWX,POWY - power of length factor used in scale dependent diffusion equation.

(8) /DPTH/ - fixed depth grid. The subsurface particles positions are tracked with respect to the origin of this grid.
MAXDX,MAXDY - number of grid elements in the X and Y directions.
AD - angle between X axis and lines of constant Latitude (degrees).
HGHT(MAXEX, MAXEY) - 30,15- depth of water at mean low tide (meters).
XDL,YDL - Longitude and Latitude of the (1,1) grid position.
XDS,YDS - grid spacing in the X and Y directions (meters or degrees).

(9) /ELVN/ - - tidal heights grid. Used in performing the Z coordinate transformation for the subsurface diffusion/advection calculation.
MAXEX,MAXEY - number of grid elements in the X and Y directions.
AE - angle between X axis and line of constant Latitude (degrees).
HGHT(MAXEX,MAXEY) -30,15- elevation of sea level due to tide (meters).
XEL,YEL - Longitude and Latitude of the (1,1) grid position.
XES,YES - grid spacing in the X and Y directions (meters or degrees).

(10) /FLOT/ - velocity at floating grid nodes.
UFLT,VFLT,WFLT(IMSUB,JMSUB,KMSUB) (15,15,10) - advective current plus diffusion velocities at each of the floating Lagrangian Coordinate System grid nodes. (m/sec. or degrees/sec.)

(11) /INJC/- passes definitions of the initial particle positions during entrainment and treatment. This is explained in detail in Subroutine ENTRN.
DEPC - verticle origin of initial particle distribution (meters).
AFRAC - determines the fraction of particles within RO (RO = RSPIL/RIFRAC).
RIFRAC - determines radius over which particle density is uniform (meters).
ROFRAC - factor which determines rate at which particle distribution falls off.
DDIAMT - diameter of entrained droplet (mm).
DDVELZT - z velocity of droplet, zero if neutrally buoyant.
HENT - length of time of entrainment for use in calculation of RMAX in Subroutine ENTRN (hours).

(12) /MASS/- defines location of all mass for mass balance (all in metric tons).
XMATM - mass in atmosphere.
XMBIO - mass biologically consumed.
XMBOT - mass deposited on bottom.
XMCLN - mass physically cleaned up.

XMDMP - total amount of mass dumped up to that step.
XMLOS - mass lost through boundaries.
XMSHP - mass deposited on shore.
XMSUR - mass left on surface.
XMSUS - mass in water column.

(13) /MAXVEL/ - passes maximum velocity for the courant number which is: maximum velocity*timestep/grid spacing.
UAMAX,VAMAX,WAMAX - advection courant numbers (meters/second).
UDMAX,VDMAX,WDMAX - diffusion courant numbers (meters/second).

(14) /OUTF/ output unit numbers.
NUSP - spillet information.
NURS - restart data.
NUCN - concentration data.
NUPT - particle parameters.
NUMS - mass balance.
NULT - lost particle parameters.
NUDP - deposited particle parameters.
NUVL - velocity values.

(15) /PRNT/ control parameters for subsurface printout.
KPRTV,KPRTC,KPRTP - print control parameters for paper printout of velocity values, concentrations and particle positions. This is an integer number which indicates how often (in number of steps) the user wants this information printed out. Value is zero if no printout is desired.
NPRD - control parameter to indicate that information is to be written out to disk.
-0 for no writeout.
1 if any of the three variables below are not equal to zero.
NPRV,NPRC,NPRD - control parameter for writing out to disk. This indicates the interval (in number of steps) between output to disk for velocity, concentration, and particle position.
NPTSUB - controls printout of some subsurface information.
-1 no printout.
0 printout only the first timestep.
0 printout at that interval of steps.

(16) /PTYP/ - the particles are grouped into classes depending upon their properties. This common block passes these properties.
NCLASS - number of classes at this timestep.
NUMBD(ICLASS) -(200) - number of particles in ICLASS.
DDIAM(ICLASS) -(200) - diameter of particle.
DDENZ(ICLASS) -(200) - density of particle. This is the same density of the oil at the moment of entrainment. (grams/cubic centimeter).
DMASS(ICLASS) -(200) - amount of mass represented by each particle (metric tons).
DVELZ(ICLASS) -(200) - fall velocity of particle, usually is

zero for neutrally buoyant oil droplet (meter/second).

DCOMP(ICLASS,8) -(200,8) -composition of oil in the droplet. This is the composition of the oil at the moment of entrainment.

NTCLASS - maximum number of classes allowed. This is currently set at 200.

NUMCL - maximum number of particles in each class.

(17) /SEAS/ - defines Sea State grid.

MAXSX,MAXSY - number of grid elements in the X and Y direction.

AS - angle between X axis and lines of constant Latitude (degrees).

WAVHGT(MAXSX,MAXSY) -30,15 - average wave height (meters).

WAVPRD(MAXSX,MAXSY) -30,15 - average wave period (seconds).

XSL,YSL - Longitude and Latitude of (1,1) grid position.

XSS,YSS - grid spacing in X and Y direction (meters or degrees).

(18) /SHOR/ describes shoreline.

NSHOR - number of shoreline points.

XSHOR(ISHOR) -1500 - Longitude of shoreline points.

YSHOR(ISHOR) -1500 - Latitude of shoreline points.

(19) /SPIL/- passes spillet properties.

MSPIL - number of hydrocarbon fractions. This is currently set to eight.

NSPIL - number of spillets at this timestep.

ASPIL(ISPIL) -99 - treated area of spillet. This is negative when the total spillet has been treated (meters^2).

BSPIL(ISPIL) -99 - time that spillet appeared (seconds).

DSPIL(ISPIL) -99 - density of spillet (grams/cubic centimeter).

FSPIL(ISPIL) -99 - fraction by volume of treated spillet.

GSPIL(ISPIL,MSPIL) -(99,8) - fraction by mass of each hydrocarbon class for the spilled oil.

RSPIL(ISPIL) -99 - radius of spillet (meters).

SSPILT(ISPIL) -99 - interfacial tension of oil (dynes/centimeter).

SSPILT(ISPIL) -99 - interfacial tension of treated oil (dynes/centimeter).

TSPIL(ISPIL) -99 - not used

TSPILT(ISPIL) -99 - not used

USPIL(ISPIL) -99 - kinematic viscosity of the oil (centistokes).

WSPIL(ISPIL) -99 - mass of the oil in spillet (metric tons).

XSPIL(ISPIL) -99 - Longitude at center of a spillet.

YSPIL(ISPIL) -99 - Latitude at center of a spillet.

(20) /SUBS/- control parameters for subsurface section.

NTRANS - transforms the Z direction.

0 uses depths as given.

1 transforms Z so that all Z values are normalized by the depth.

NSUB - 0 particle diffusion with respect to Lagrangian grid.
1 use analytical diffusion until standard deviation of cloud is comparable to grid mesh.
NEXTR - control of Lagrangian grid.
0 use fixed grid.
1 use expanding and translating grid.
NMAX - maximum number of particles. Restricted by dimension of particle location variables.
NMAX - number of particles at current timestep.
DX,DY,DZ - grid spacings of Lagrangian grid (meters or degrees).
XOR1G,YOR1G - this is the distance between the origin of the fixed depth grid and the floating Lagrangian grid. These numbers are in fixed depth grid units. Therefore, to get the actual distance in meters or degrees, these numbers must be multiplied by the grid spacing of the depth grid (XDS,YDS).
ZOR1G - point of reference for vertical distances. For a constant depth, this is at the bottom.

(21) /TIDE/ - Advective current grid. There are two grids, one for X velocities and one for Y velocities. They have the same spacing, size, and orientation but may have different origins so that a numerical model using a space staggered grid may be used to generate the values.
MAXTX,MAXTY - number of grid elements in the X and Y direction.
AT - angle between X axis and lines of constant Latitude (degrees).
UT(MAXTS,MAXTY) -30,15 - velocities in the X direction (meters/second or degrees/second).
VT(MAXTX,MAXTY) -30,15 - velocities in the Y direction (meters/second or degrees/second).
XTLU,XTLV - Longitude of (1,1) grid position for UT and VT.
YTLV.XTLV - Latitude of (1,1) grid position for UT and VT.
XTS,YTS - grid spacing in X and Y directions for both tidal current grids (meters or degrees).

(22) /TMPC/ - temperature grid.
MAXKX,MAXKY - number of grid elements in the X and Y direction.
AK - angle between X axis and lines of constant Latitude (degrees).
TEMP(MAXKX,MAXKY) -30,15 - temperature (degrees centigrade).
XKL,YKL - Longitude and Latitude of (1,1) grid position.
XKS,YKS - grid spacing in X and Y direction (meters or degrees).

(23) /WIND/ - wind grid
MAXWX,MAXMY - number of grid elements in the X and Y directions.
AW - angle between X axis and lines of constant Latitude (degrees).
UW(MAXWX,MAXWY) -30,15 - wind speed in X direction (meters/

second).

VX(MAXWX) -30,15 - wind speed in Y direction (meters/second).

XWL,YWL - Longitude and Latitude of (1,1) grid position.

XWS,YWS - grid spacing in X and Y directions (meters or degrees.

APPENDIX IV: PROGRAM SUBROUTINE AND ALGORITHM DESCRIPTIONS FOR THE SIMULATION MODEL

This Appendix is devoted to the detailed description of the main program and each of the subroutines of the simulation model. The main program is discussed first, and then followed by the subroutines in alphabetical order. Following the description of each subroutine is a list, including a description of the subroutine's most important arguments which are not in common or read in. Those variables in common or read in have been discussed in Appendices II and III.

1. Main Section

The main section of the program acts as the controller for a simulation. All of the major subroutine calls originate from this section. Initialization for all but the subsurface variables is performed by this section and it controls all input by either reading the variables directly or by calling the subroutines which then do the reading. (See Figure IV-1). Following the standard initiation at the run control parameters, there may be a second level of initialization controlled by the parameter NSTRT. This initialization occurs if NSTRT equals one, i.e., if this run is to be a continuation of a previous one. If NSTRT equals zero,this section is skipped.

The restart section will read all previous output data sets to their end and then it will read the restart data set which locates all spillets and determines the mass and subsurface parameters at the last step for which restart data was written. The previous environmental, spillet, cleanup and treatment efforts are read in under control of the parameter INR which counts the steps up to the restart step. The same input data sets used for the restart are the ones used for the previous run which did not finish. The same output data sets will be used as well. If the user desires to use new input and output data sets for the restarted run, the input variable NSTFN must be set equal to zero. Care should be taken when using new data sets to be sure the new unit numbers and/or data set names should be correct in the input data set.

The next major section of the program consists of the iteration over time. This is the actual simulation of the spill. This begins with the input of the step control parameters. The formatted printout of the commands issued by the step control parameters is determined by the input variable NENV, which indicates the step interval for output. Following this step, the program reads the appropriate environmental variables, spillets and cleanup activities and then performs the indicated cleanup operations. The main surface subroutine (SURFUS) and main subsurface routine (SUBSUR) are then accessed. Prior to calling the subsurface routines, the program converts all verticle measurements to the transformed system if required (no transformation for NTRANS = 0, transformation for NTRANS = 1).

In the next section, the mass balance is calculated and any spillets that overlap by a predefined fraction (COMB) are combined regardless of the step number. The last function performed for a time sep is to write to disk the restart data if the step number is a multiple of NSUMM or if this is the last time step of the run. If this is not the last time step, the entire simulation procedure is repeated from the entry of the step control parameters.

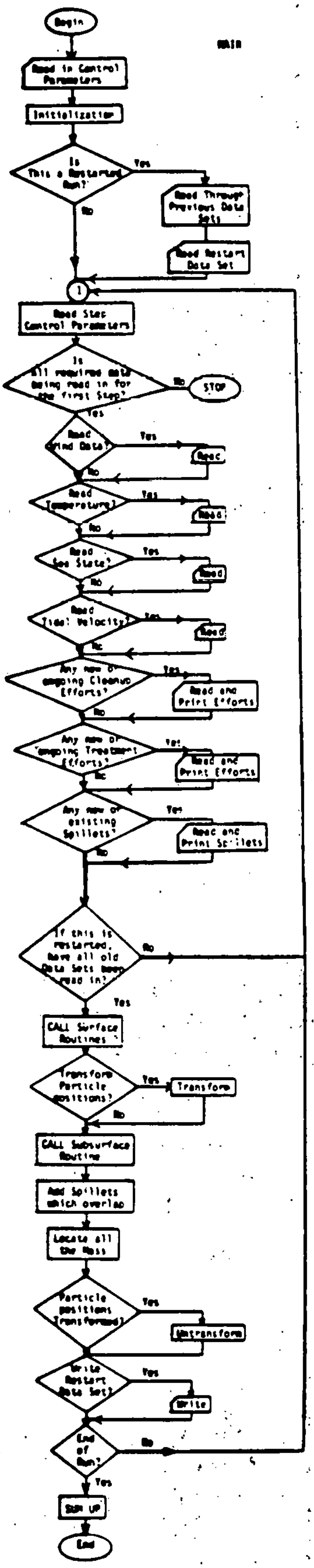


Figure IV - 1. Flowchart for subroutine MAIN.

SUBROUTINES CALLED: ADD, ARAYIN, BOTOFT, CHEMIN, CLNIN, CNVRTZ, CONSUM INITSS, MASSC, READF, READI, RESRFS, SHORE, SPILIN, SUBSUR, SUMMUP, SURFES.

Important Variables Not in Common Read In

INR - This is used for the restart section. It counts the number of times that the program reads through the environmental input parameters before it has come to the step at which the previous run terminated.

NSTEP - Step number. Time zero is step zero.

NORDR (ICLASS) - 2000 Integer *2 - Class to which that particle belongs.

X,Y,Z (I) - 2000 - Position of droplet with respect to origin of floating grid (meters or degrees).

Subroutine ADD

This subroutine combines two spillets and their properties if they overlap by more than some predetermined fraction. (See Figure IV-2). The sum of their radii is compared to the distance between the centers. If this difference is larger than a given percentage (defined by input the parameter COMB) of the smallest of the two radii, then they are combined. Spillet parameters of the two spillets are combined either by adding the two values or by calculating a weighted average of the two. For example, the mass is simply the sum of the two while the location is a weighted mean (by weight) of the location of the two centers. In Table IV-1, all spillet variables are listed along with the method of combination.

CALLED FROM: MAIN

SUBROUTINES CALLED: DIST

Important Variables not in Common or Read in:

DISTA - the sum of the radii.

DIS - distance between spillet centers.

NSAV(ISP) - 99 - number of the spillet which has been moved to the end of the list.

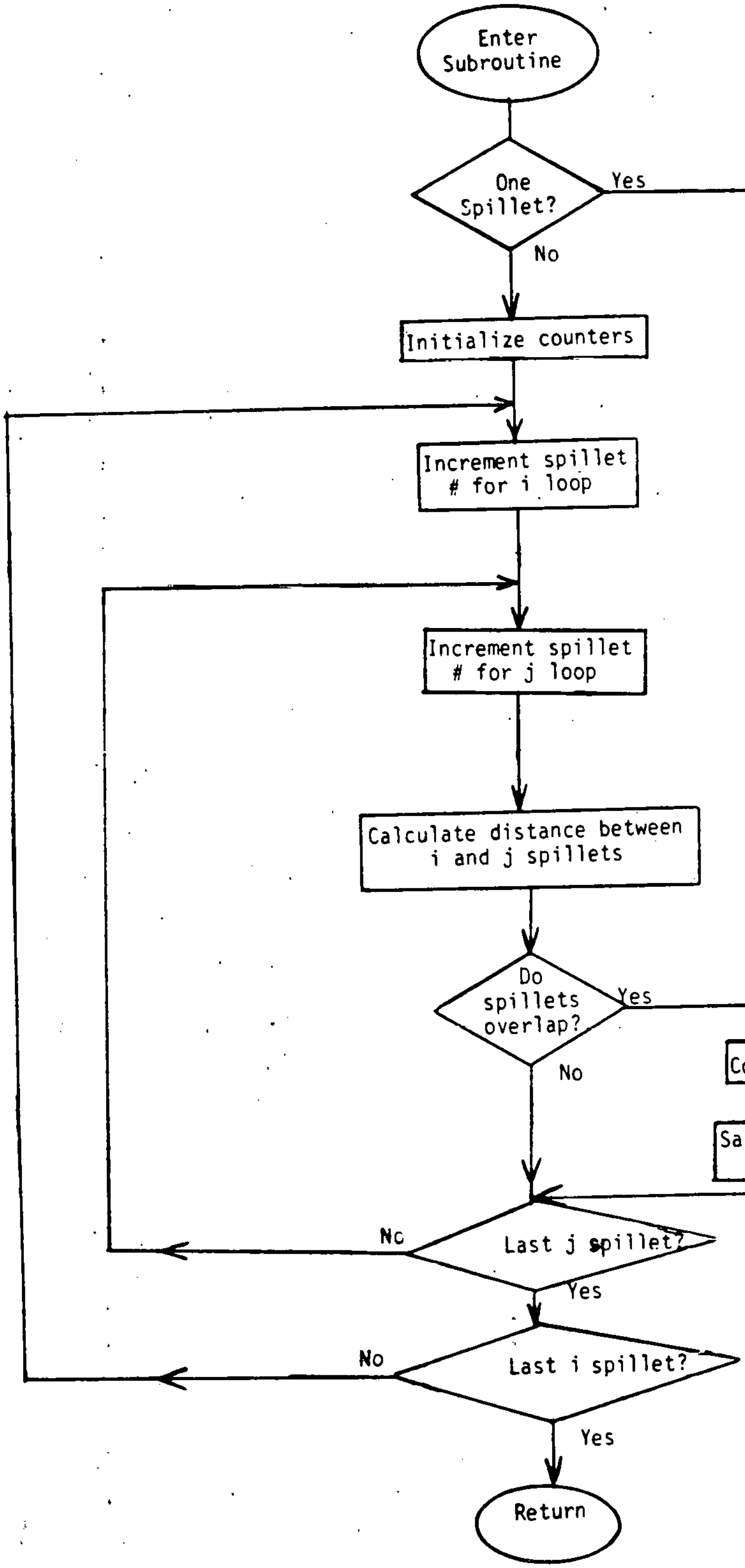


Figure IV - 2. Flowchart for subroutine ADD.

Table IV-1

Combination of Spillet Parameters in Subroutine ADD

Variable Name	Method of Combination	Variable Description
ASPIL	Sum	Spillet area treated
GSPIL	Weighted mean	Fraction by mass of each class of oil
RSPIL	Square root of sum of squares, i.e., sum areas	Spillet radius
SSPIL	Weighted mean	Interfacial tension of oil
TSPIL	Weighted mean	Density of oil at t=0
SSPILT	Weighted mean	Interfacial tension of Treated oil
TSPILT	Weighted mean	Not used
USPIL	Weighted mean	Kinematic viscosity of oil
USPIL	Sum	Mass of oil in spillet
XSPIL	Weighted mean	Longitude of spillet center
YSPIL	Weighted mean	Latitude of spillet center
FSPIL	Weighted mean	Fraction by mass of treated spillet

Subroutine ARAYIN

This subroutine has been designed to enter all environmental grids. It is flexible in that the orientation, size and location of each grid may be different but structured in that the defining parameters must follow one of a number of well-defined formats. The precise format statements, as well as the various formatting options are described in detail in Appendix I, along with associated variables. In this section, the operation of the subroutine is discussed in terms of the flow diagram, Figure IV-3.

Upon entering the subroutine, the grid definition parameters are read either formatted or unformatted, depending on the value of the format control parameter NU. The dimensions of the grid are then verified. If ISCAL equals 1, then the grid separation is in meters and must be larger than 5 or the program stops. If, on the other hand, ISCAL equals 2, the grid separation is in spherical coordinates and must be less than or equal to 5 or again the program stops. Finally, if the grid separation is in spherical coordinates, the grid cannot be rotated so the parameter ANGLE must equal zero. If it is not, the program stops. If all of the conditions are successfully met, the grid may be printed out if desired. This printout is controlled by NPRTA, (-1 no printout, 0 limited printout and 1 full printout).

The next step is to read in the environmental parameters. First the format type is determined, real formatted, real unformatted, integer formatted or integer unformatted and then the first variable is input for the entire grid. If there is a second variable, NO equal to 2, it is then input. The last step is to output the environmental data again under control of NPRTA.

CALLED FROM: MAIN

SUBROUTINES CALLED: NONE

Important Variables Not in Common or Read In See Table I-1

Subroutine AVGSIG

This subroutine calculates the average of the particle positions (X,Y,Z) over all particles then, under control of NCELCT, calculates the standard deviation. The standard deviation is defined by:

$$\sigma = \sqrt{\frac{\left[\sum_{i=i}^{N} x_i^2 - \left(\sum_{1=1}^{N} x_i\right)\right]^2 \Big/ N}{N - 1}}$$

CALLED FROM: DIFF, DISPV

SUBROUTINES CALLED: NONE

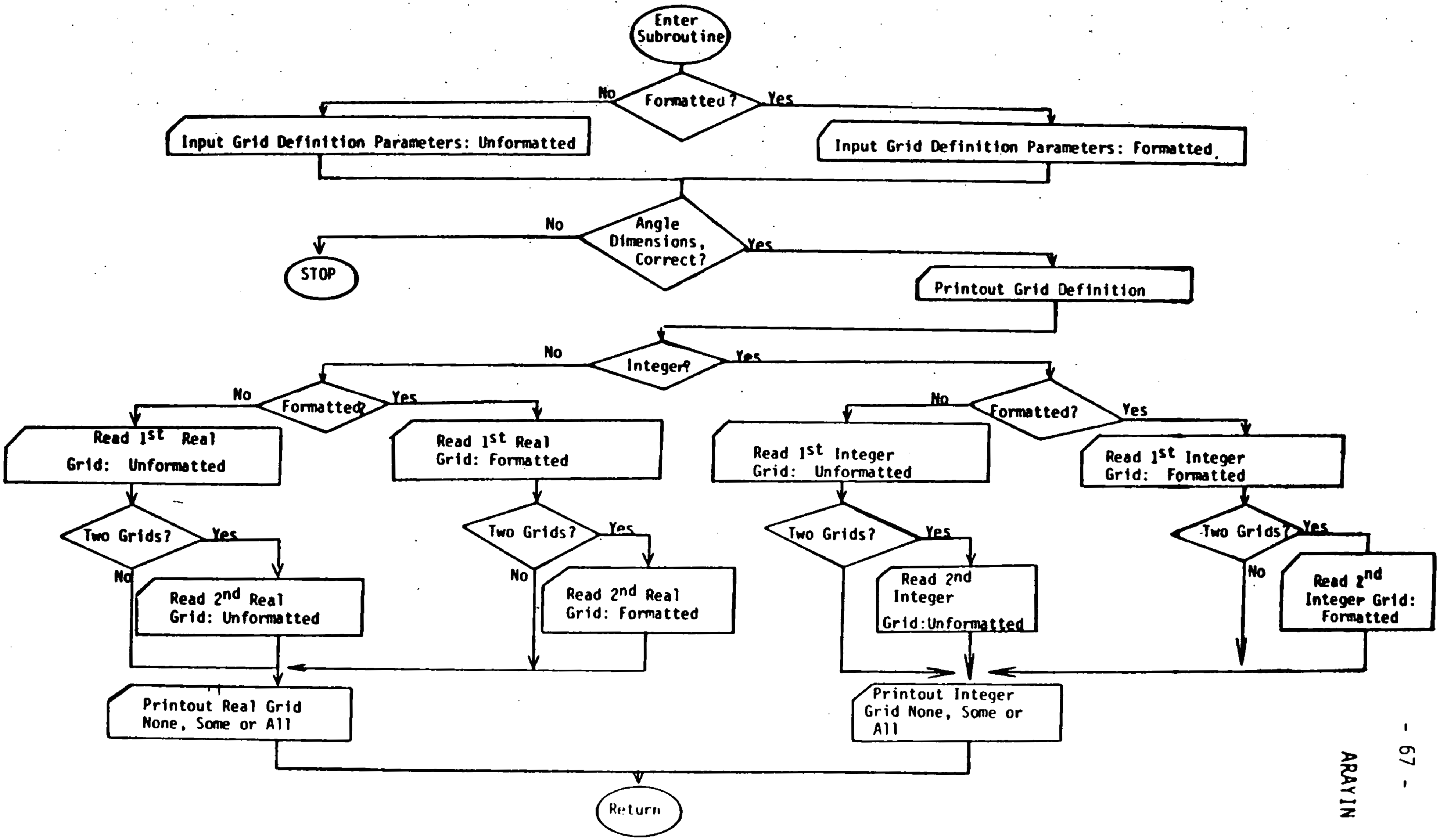


Figure IV.-3 Flow Chart for subroutine ARAYIN

Important Variables not in Common or Read in

XNUM - number of particles

XAVG,YAVG,ZAVG - average values for X,Y and Z positions.

SIGX,SIGY,SIGZ - standard deviations of X, Y and Z positions.

NCELCT - 0 calculate only the mean.
- 1 calculate the mean and standard deviation.

Subroutine BOUNV

This subroutine locates the position of the particles with respect to the computational cell grid and then, either displaces the particle, removes it from the particle list, or leaves it as it was, depending on the numerical value of the computational cell grid element in which it is located. See Figure IV-4, for a flow chart of BOUNV.

First, the routine determines where each of the floating grid nodes are with respect to the fixed computational grid. Each floating grid element is then assigned the boundary condition of the fixed computational grid in which it is located. The number associated with each condition is listed in Table IV-2. The particles are then located within the floating grid. If a particle is within one half of a grid distance of an open boundary or a bottom deposition cell, the particle is removed from the list. If the grid is a reflection cell, the program moves the particle to half of a grid space, plus a small distance (ER) away from the boundary. The user can change the value of ER within the program. A particle occupies a fictitious cell volume, equal to a floating grid cell, so the boundary calculations are determined by the overlap of this particle volume in the boundary cells. If the particle is deposited or lost, the last particle on the list is moved to its position in the order. At present, the land cells are generally defined as reflection cells as are the surface boundary cells. The user may, however, assign any configuration to these that s/he desires.

The location and properties of any droplet deposited or lost are written to a disk data set. The number of particles either lost or deposited are printed out by the MASSC subroutine.

CALLED FROM: SUBSUR, PRINT

SUBROUTINES CALLED: ROTAT

Important Variables not in Common or Read In

ER - When a particle is moved, it is moved this fraction of a grid cell beyond the middle of the cell.

M - I, J, K - The boundary conditions of the floating grid location calculated from the fixed computational cell grid. See Table IV-2 for the meaning of the various numerical values.

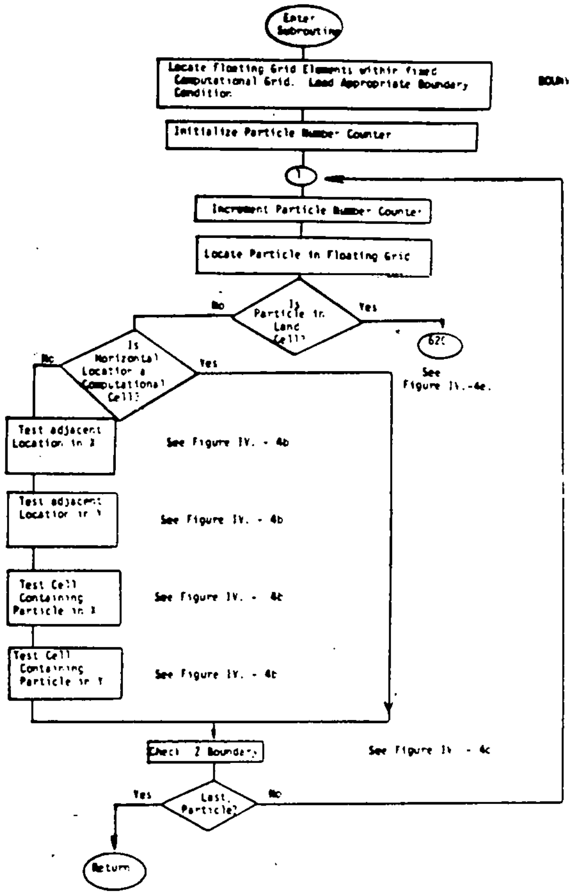


Figure IV. - 4a. Flow Chart for Subroutine BOUN

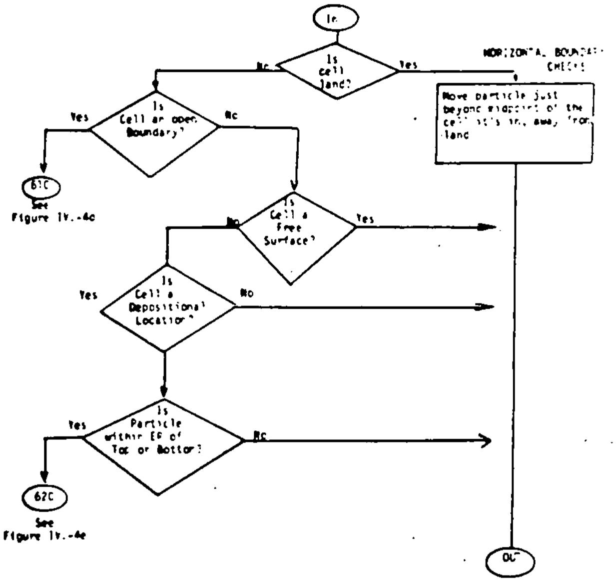


Figure IV.-4b. Flow Chart of Horizontal Boundary Checks

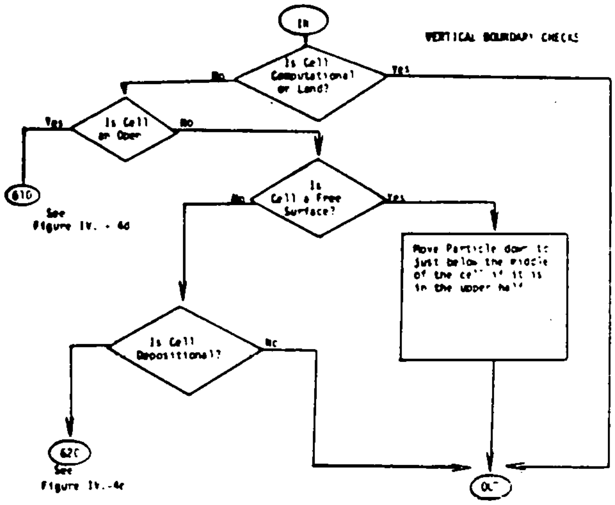


Figure IV. - 4c. Flow Chart of Vertical Boundary Checks

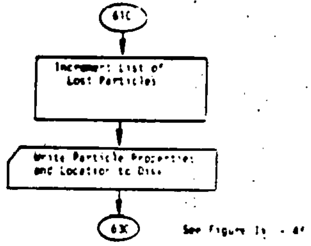


Figure IV. - 4d Flow Chart of Lost Particle Operation

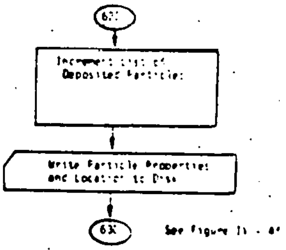


Figure IV.-4e Flow Chart of Deposited Particle Operation

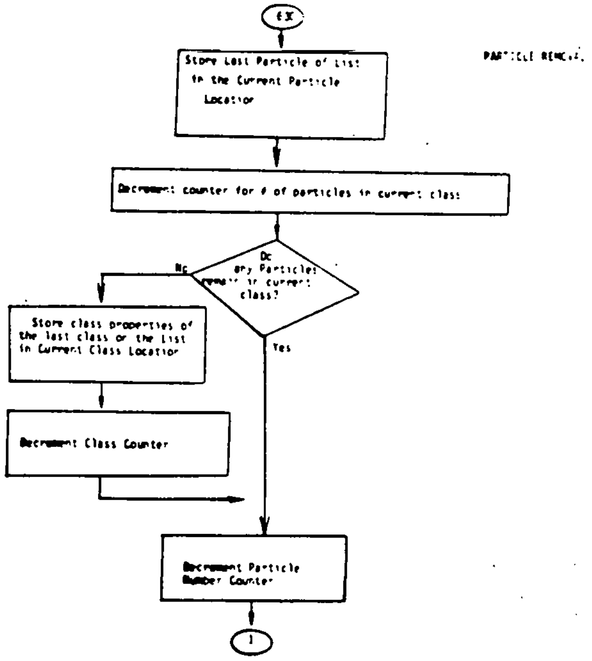


Figure IV.-4f. Flow Chart of Particle Removal.

Table IV-2

Model Boundary Conditions

DEFINITION	VALUE	ACTION TAKEN
Land Cell	0	Deposit particle, remove particle from list
Computational Cell	1	none
Open boundary	2	remove particle from list
Water cell with an adjacent cell that is not water	101	none
Free surface reflection cell	3	Displace particle down if in the lower half of the cell
Bottom Deposition Cell	4	Absorbs any oil which moves to within 1/2 grid spacing of bottom.

Subroutine CHEMIN

This subroutine reads in the data for new chemical treatment efforts and also lists all treatment efforts in progress. See Appendix I for a description of the input format and see Figure IV-5 for a flow chart of this subroutine.

The subroutine first prints a header. Then all efforts in progress are listed. Finally, new efforts are read in and their characteristics pointed out.

CALL FROM: MAIN

SUBROUTINES CALLED: NONE

Important Variables not in Common or Read In: None

Subroutine CLNIN

This subroutine serves two functions: It reads in the data that determines new mechanical cleanup efforts and it lists all mechanical cleanup efforts in progress. See Appendix I for a description of the input format and See Figure IV-6 for a flow chart of this subroutine.

First, the subroutine prints a header. Then all efforts in progress are listed. Finally, new effort(s) are read in and their characteristics printed out.

CALLED FROM: MAIN

SUBROUTINES CALLED: NONE

Important Variables not in Common or Read In: None

Subroutine CLNUP

This subroutine simulates the mechanical cleanup of spilled oil. See Figure IV-7. At any one time, there may be up to ten individual cleanup efforts in progress. Each effort is defined by its location, radius of influence, beginning time, duration, oil recovery rate and efficiency of cleanup effort. This last variable is to simulate the possible inability of the cleanup device to remove all of the oil in a spillet from the surface.

The subroutine is called once for each spillet every time step as long as there are continuing cleanup efforts. The first function performed is to remove any expired cleanup efforts from the list. This is done by subroutine REMOV. Following this, each of the cleanup efforts is examined in sequence to determine whether or not its range of influence includes the current spillet. If it does, a volume of oil is removed from that spillet equal to the smaller of:

1. The cleanup rate times the time step.

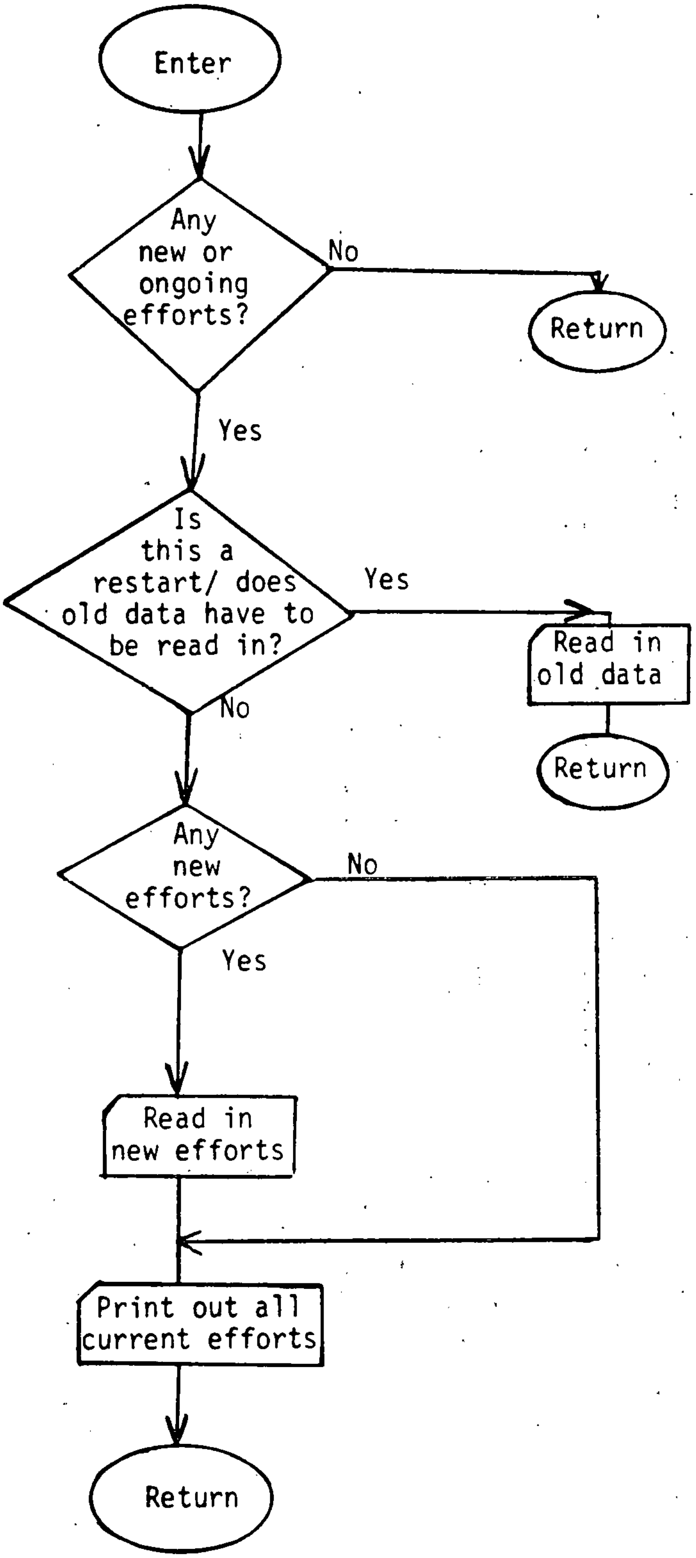


Figure IV - 5. Flow chart for subroutine CHEMIN.

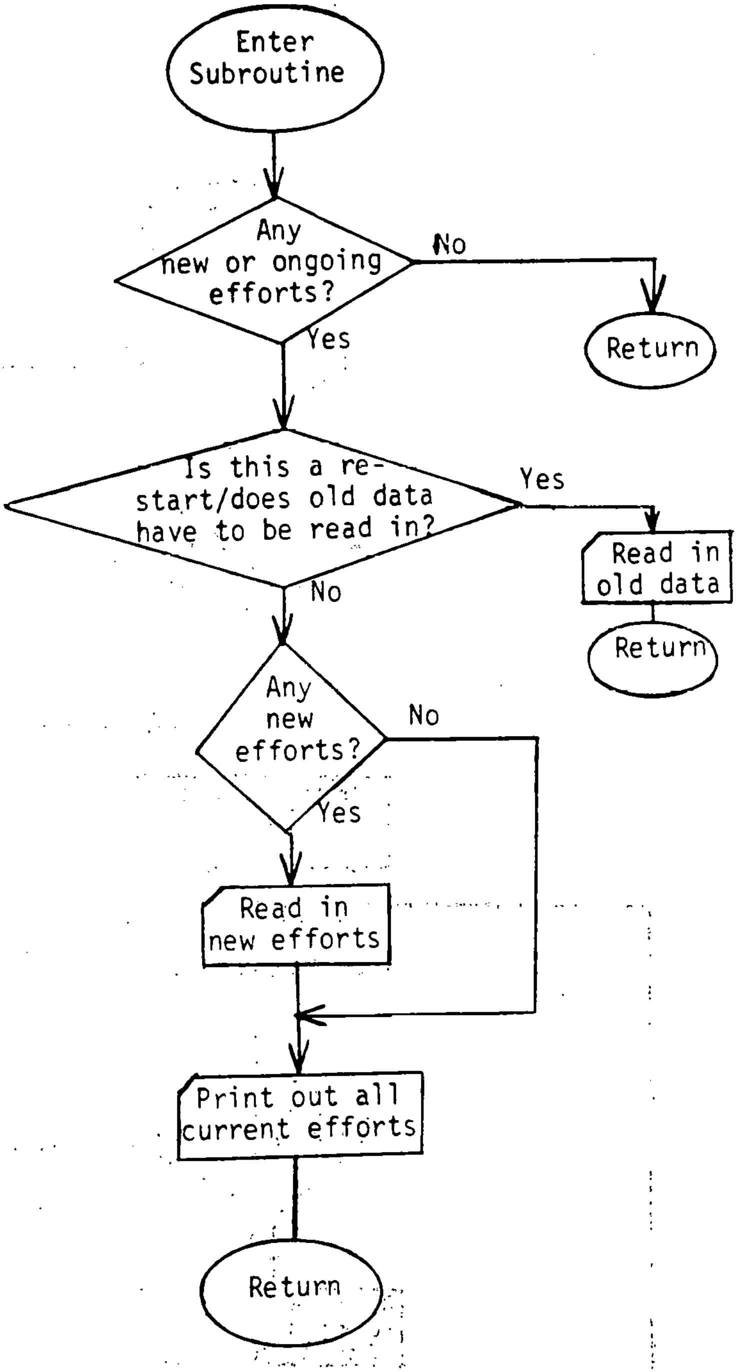


Figure IV.- 6. Flow chart for Subroutine CLNIN.

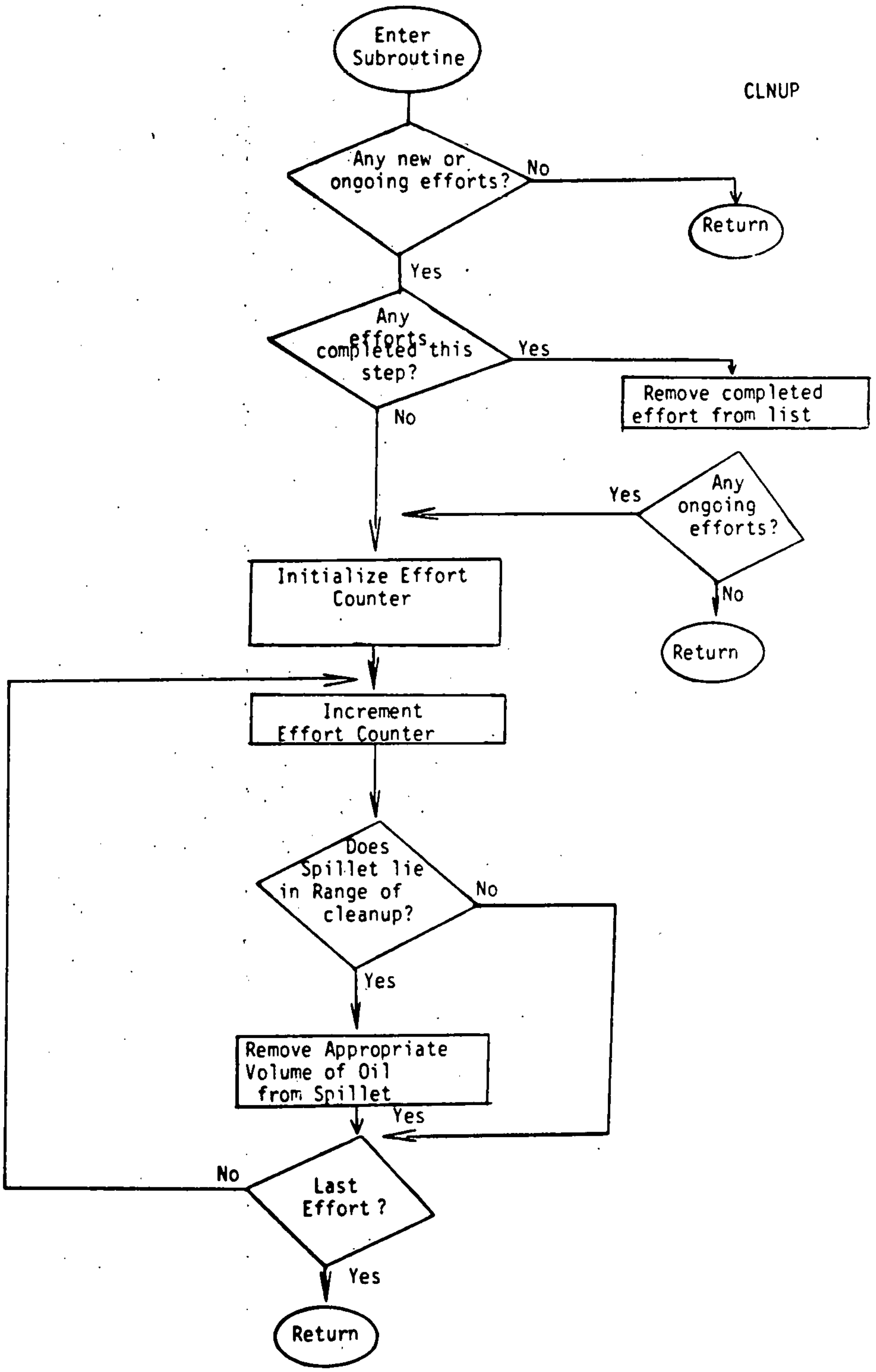


Figure IV. 7. Flow Chart for Subroutine CLNUP.

2. The total volume of the spillet times the efficiency factor.

Following any action by all current cleanup efforts, the mass balance of the spill is updated and control is returned to the main program.

It should be noted that the volume cleanup rate of a particular effort applies to each spillet the center of which falls in the area covered by that effort. This means that if three spillets fall within the range of a given cleanup effort, a maximum of three times the volume cleanup rate for that effort may be removed from the surface.

CALLED FROM: MAIN, SURFES

SUBROUTINES CALLED: REMOV, DIST

CLNUP VARIABLES

ISP - the number of spillet on which the cleanup efforts is operating.

SMCLN - Amount of oil removed from this spillet (metric tons).

RC - Radius of spillet, ISP (meters).

DIS - Distance between center of cleanup effort and center of spillet (meters).

AMNT - Maximum amount of oil which may be removed in this step (metric tons).

EFF - Efficiency expressed as a fraction.

Subroutine CNVRTZ

This subroutine, Figure IV-8, converts the particle positions in z, the vertical coordinate, to or from the transformed coordinate system. This transform is regulated by the parameter NTRANS (see input variables). If NTRANS = 1, this routine is called at the beginning and end of the run. The transformation consists of interpolating the water depth at the particle position form the depth grid, and then normalizing the z position by this depth. The result is that the relative resolution in z is independent of horizontal location (x,y).

CALLED FROM: MAIN

SUBROUTINE CALLED: VELC

Important Variables not in Common or Read In

MCNTRL = -1 convert from transformed system.

= 1 convert to transformed system.

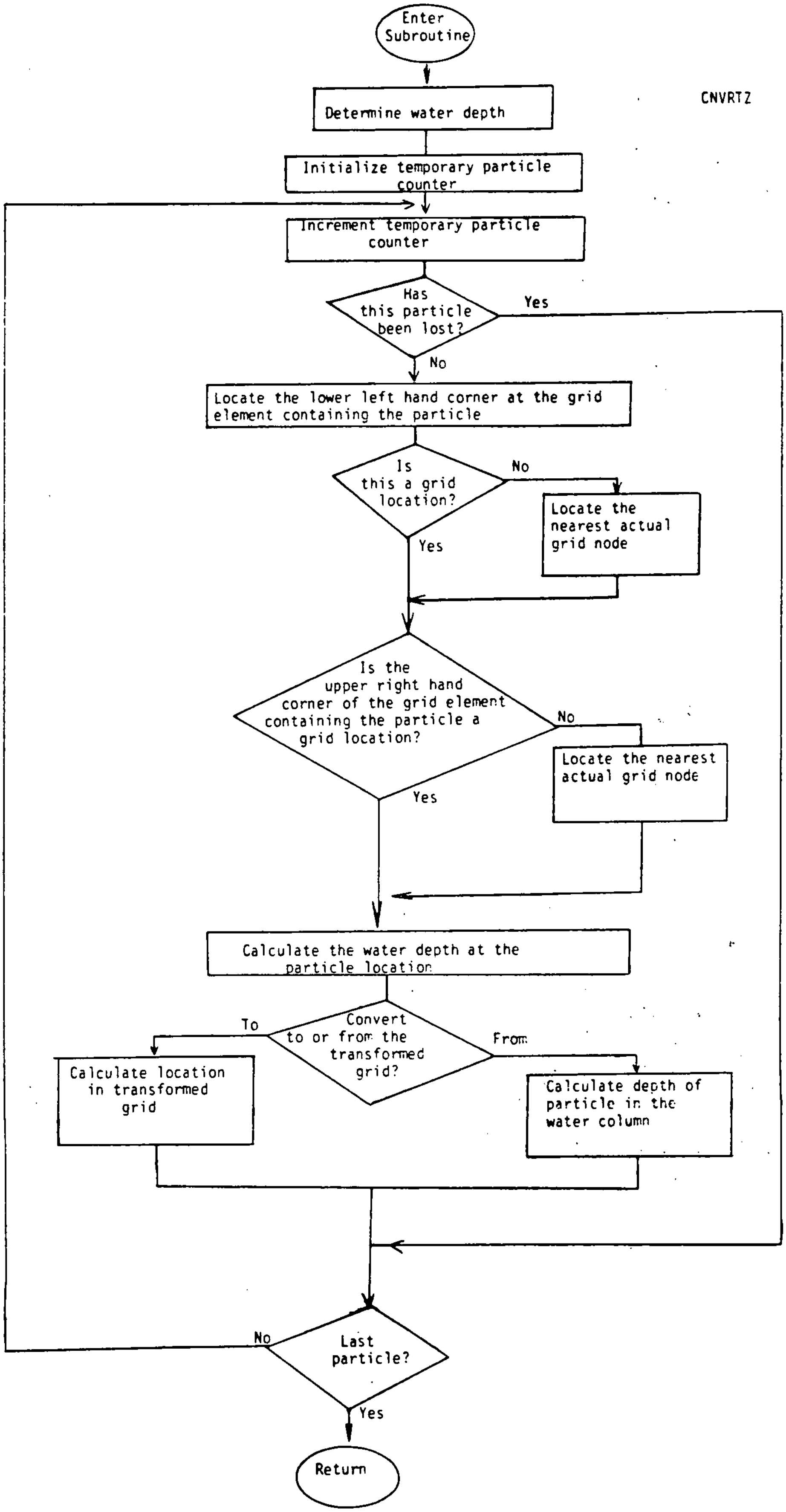


Figure IV. 8. Flow Chart for Subroutine CNVRTZ

Subroutine CONC

This subroutine (Figure IV-9) determines the hydrocarbon concentration in the water column resulting from entrainment. Each particle is assigned a fictitious volume equal to the volume of a floating grid element and centered on the particle location. The fraction of this volume in each floating grid element is then added to the volume of oil already in that element. The fictitious volume may overlap a maximum of eight surrounding cells. This process is performed for each particle. When all particles have been processed, the mass of oil in each floating grid element is divided by the volume of that element to determine the concentration.

CALLED FROM: SUBSUR, PRINT

SUBROUTINES CALLED: None

Important Local Variable: none

Subroutine COURAN

This subroutine, see Figure IV-10 for its flow chart, is used to determine when the courant condition has been violated. The courant condition specifies that a marker particle may not move more than one half of a model grid unit in one time step. If the condition is violated, the numerical results are uncertain and a message to that effect is printed out. The run will continue. In the early stages of a spill, the courant condition will often be violated. Because the floating grid dimensions are small, the surface spillet is small, but the time step is relatively long. It is thought that for the simulation of the model in its present form, this problem is not overly serious because it is the long term results that are of interest. The early stage instabilities have little effect on these results. If it is the near term results that are being examined, then the time scale must be considerably shortened compared to the values used in the examples of this manual.

Two sets of courant numbers have been defined, one for the advective velocity component and one for the diffusive velocity component. This is because the fixed grid on which the advective velocities are defined is generally much larger than the floating grid on which the diffusive velocities are defined. It is, therefore, conceivable that the courant condition is not violated even though a marker particle moves several floating grid units.

CALLED FROM: SUBSUR

SUBROUTINES CALLED: None

Important Local Variables:

CAU - courant number for advective velocity in x.

CAV - courant number for advective velocity in y.

CONC

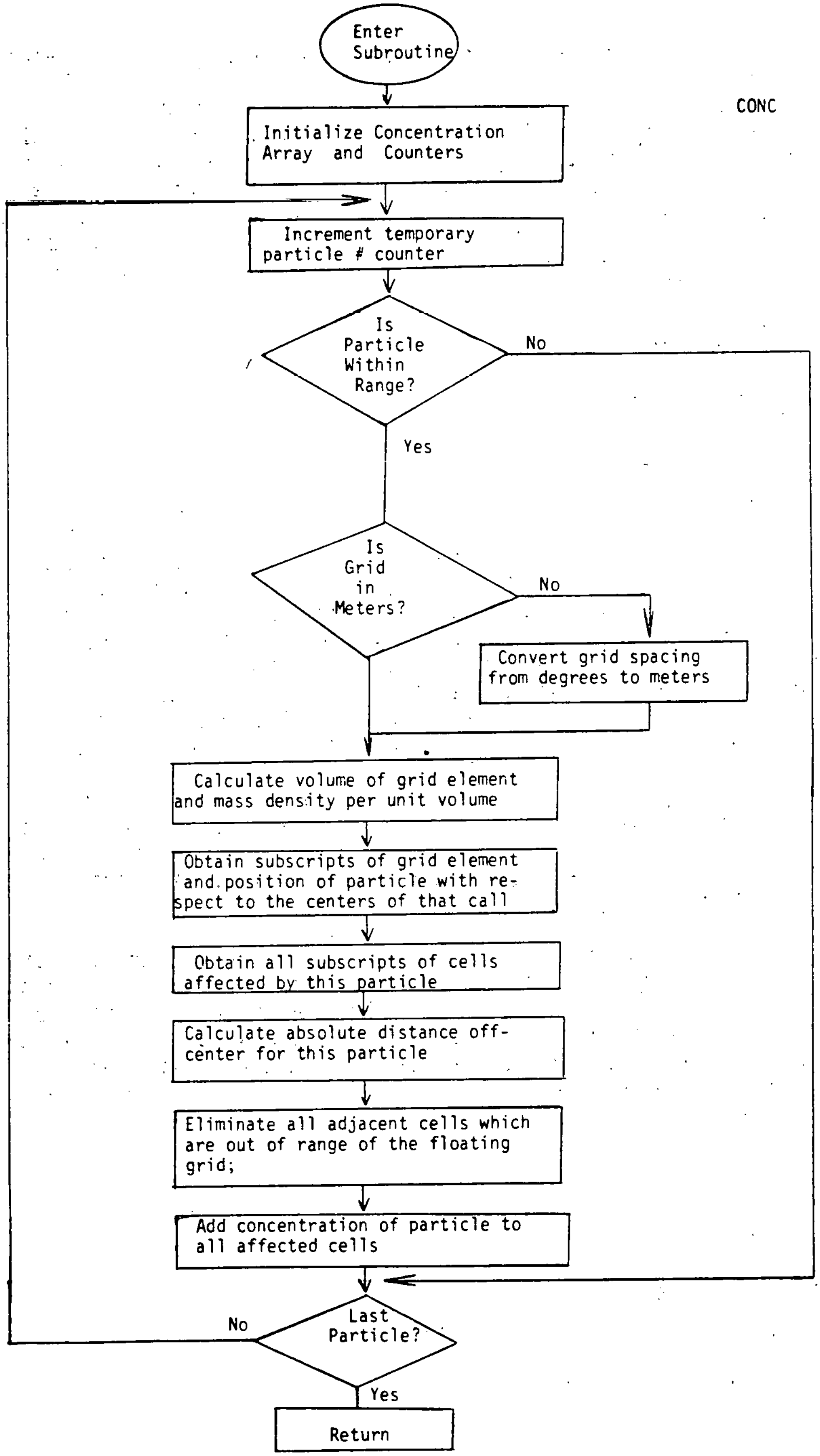


Figure IV.-9 Flowchart for Subroutine CONC.

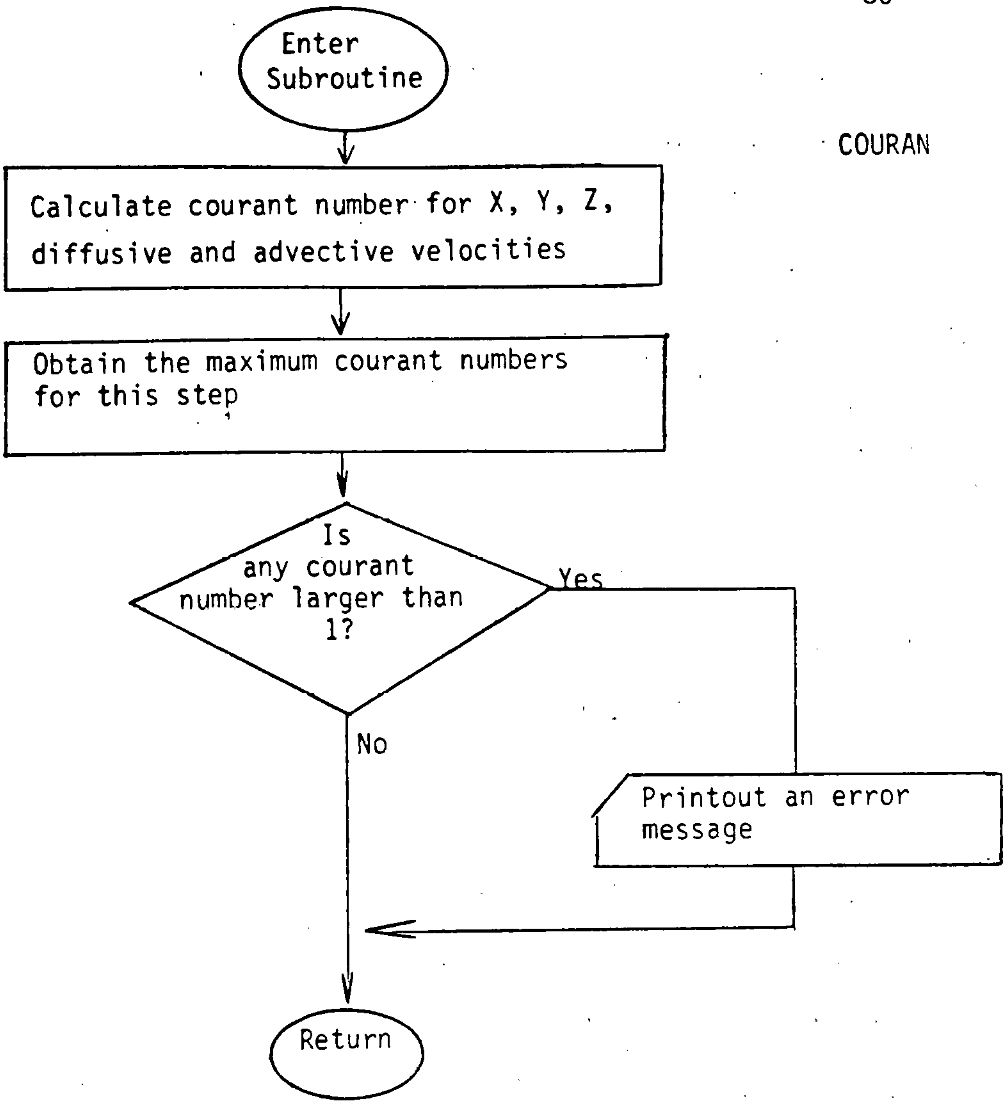


Figure IV.-10. Flow Chart for subroutine COURAN.

CAW - courant number for advective velocity in z.

CDU - courant number for diffusive velocity in x.

CDV - courant number for diffusive velocity in y.

CDW - courant number for diffusive velocity in z.

Subroutine DIFF

This subroutine (Figure IV-11) calculates the diffusion coefficient if the scale dependent diffusion model has been selected (see input parameter NDIFF). It uses subroutine AVGSIG to calculate the standard deviations of the particle positions and then the 4/3 law to determine the coefficient. If the large scale mode is used, the diffusion coefficient is calculated for the average latitude of the droplet cloud. The X component of the diffusive coefficient is given by:

$DXX = EXX*SL^{POWX}$

where SL = 3.0*2.0*SIGX*SIGY

SIGX, SIGY are the standard deviations of the particles.

DXX - diffusion coefficient (m^2/sec).

EXX - constant. (now set to .05)

POWX - constant. (now set to 4/3)

The y and z components are determined in a similar fashion. The values for the scale-dependent diffusion coefficients can come from Pavish and Spaulding (1977). The value for POWX and POWY is recommended as .99838 (assuming the length scale is in meters). The coefficient (EXX) is .0018. This is a composite line from many sources of data including Okubo, Yudelson, Kohand, and Chano.

CALLED FROM: SUBSUR, VELCT

SUBROUTINE CALLED: AVGSIG

Important Local Variables: as above

Subroutine DISPV

This routine (figure IV-12) displaces each particle according to the advective and diffusive velocities calculated for the timestep being simulated. The velocities of the particle are calculated by the routine PARTV. The distance that a given particle is displaced is equal to the particle velocity times the length of the timestep.

CALLED FROM: SUBSUR

SUBROUTINE CALLED: AVGSIG

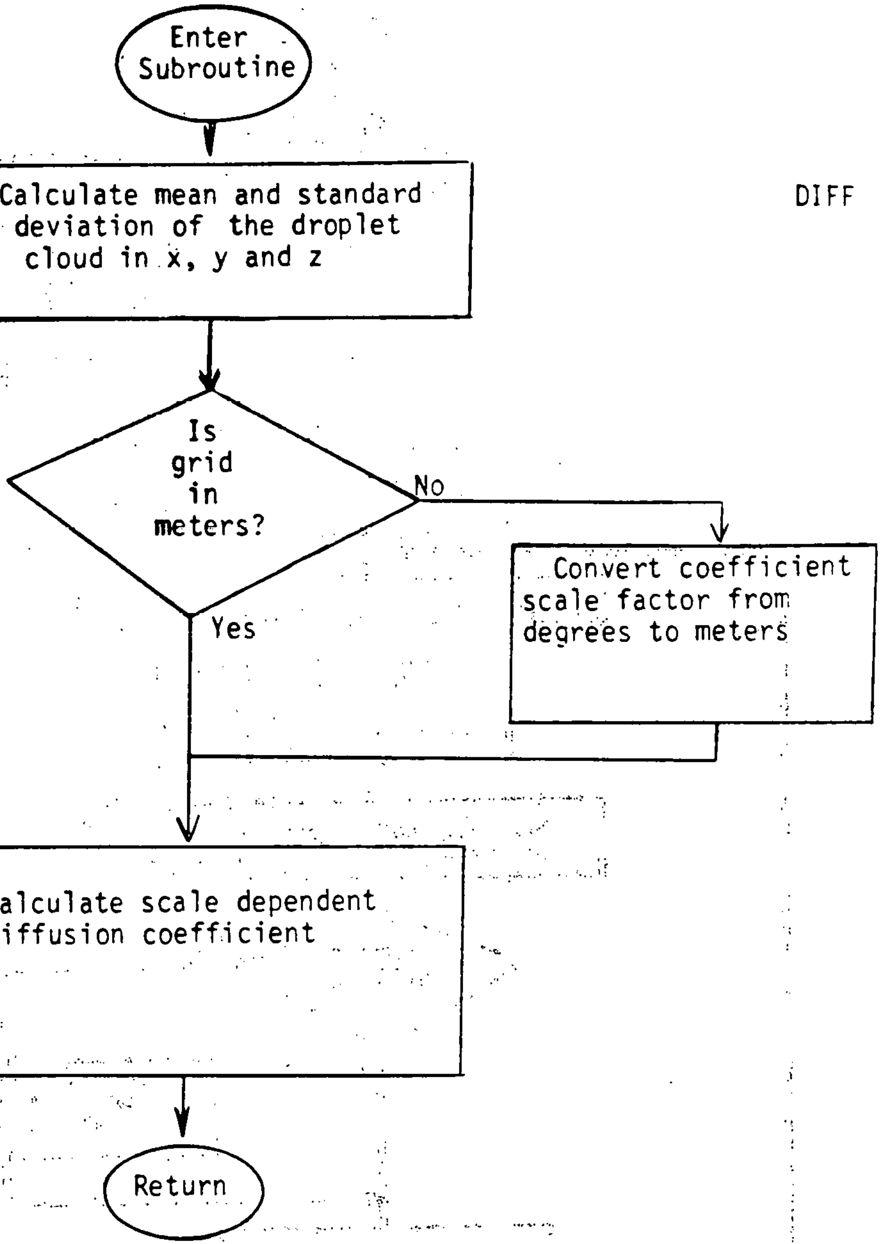


Figure IV. -11. Flow Chart for subroutine DIFF.

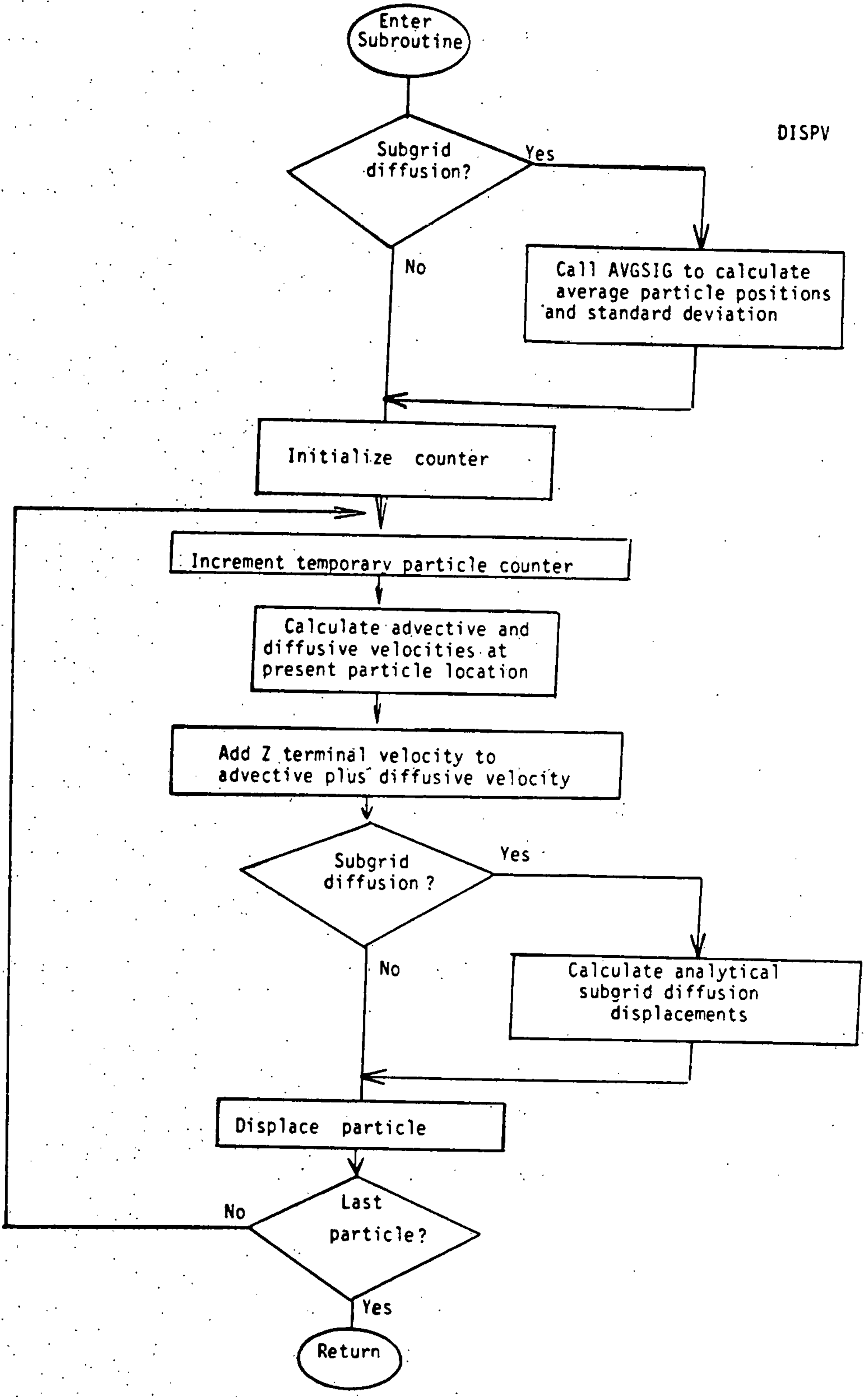


Figure IV - 12. Flow Chart for subroutine DISPV

Important Local Variables:

DFLT-depth of water at floating grid locations

HFLT-sea surface evaluation at floating grid locations.

Subroutine DIST

This subroutine, see Figure IV-13 for its flow chart, is used to calculate the horizontal separation between any pair of points. The separation is always returned either in meters or in degrees as determined by the control parameter NO. If NO is equal to either 2 or 5, the values returned are the x and y separation in the rectangular coordinate system locally aligned with lines of constant longitude and latitude. If NO is other than 2 or 5, the great circle distance between the two points is returned. The distinction between a value of 2 or 5 for NO stems from two different storage modes for point locations. If NO equals 2, the input locations are assumed to be in longitude and latitude and the result is returned in meters. If NO equals 5, no conversion is performed so if the input is in meters, so is the output.

CALLED FROM: ADD, CLNUP, ENTRN, LOC8, ROTAT, TREAT

SUBROUTINES CALLED: None

Important Local Variables:

X1,Y1 - longitude and latitude of the first point. This point should be south and west of the second point.

X2,Y2 = longitude and latitude of the second point.

NO = 1 calculate the great circle distance between the points (meters).

= 2 calculate the X and Y spacing between the points (meters).

= 5 calculate the X and Y spacing between the points in the same units as the input.

ANG - angle if one point is defined on a rotated grid.

D - distance between the two points if NO=1.

XSP,YSP distance between the two points if NO=2 or 5.

Subroutine ENTMAS

This subroutine, see Figure IV-14 for its flow chart, calculates the mass entrained under natural conditions, i.e. no dispersant. It uses the rate obtained by the formulation of Andunsun (1979). Specifically, the

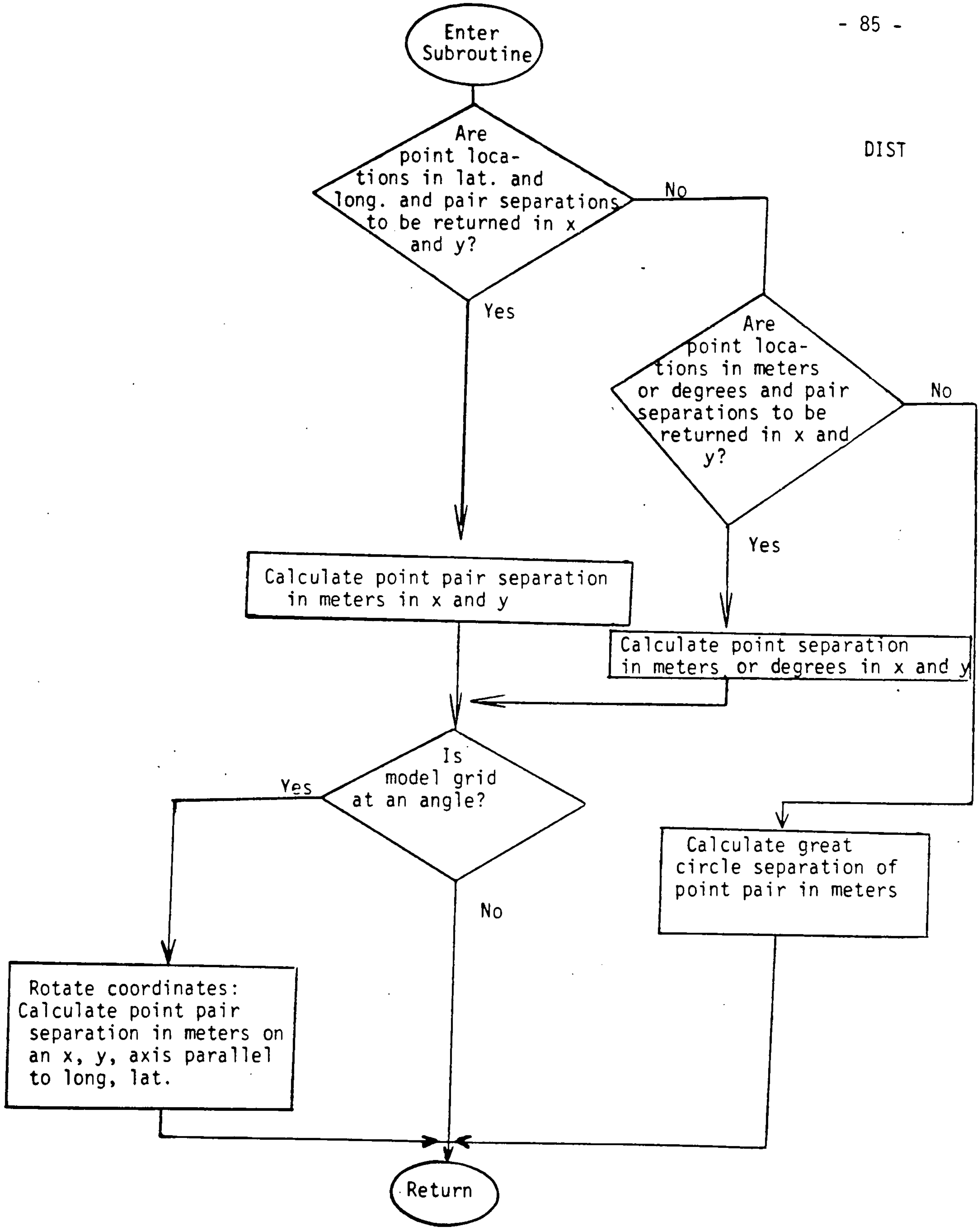


Figure IV. - 13. Flow Chart of subroutine DIST.

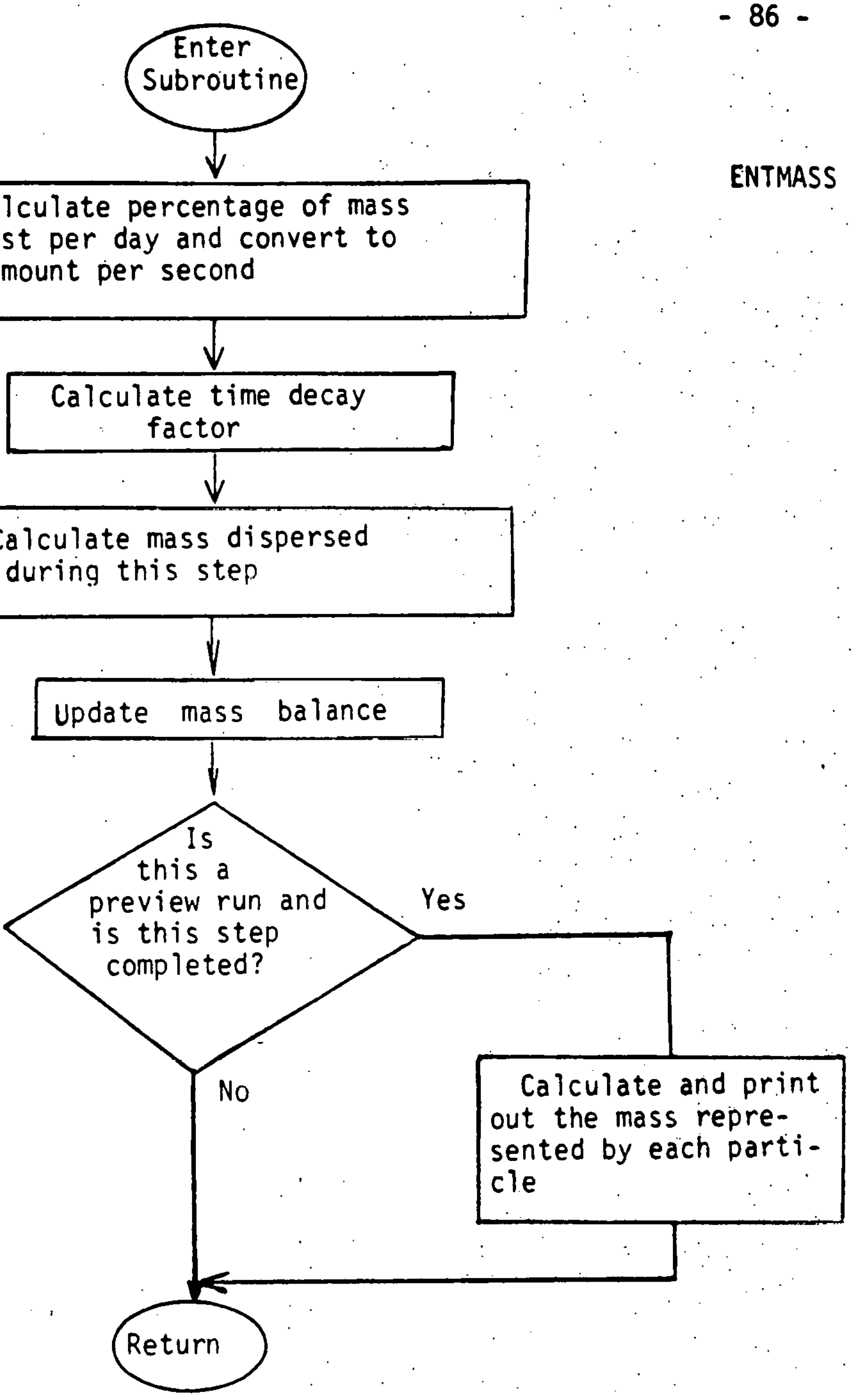


Figure IV - 14. Flow Chart for subroutine ENTMASS.

fraction of oil entrained per day is given by:

$$\text{Amount} = 0.1 \frac{u^2}{w_0^2}$$

where W_0 = 8.5 (a constant)
u = wind speed (m/sec)

In the URI model, this quantity is modified by an exponential decay factor with a time constant of two days. This exponential decay of the volume of oil entrained was selected in an ad hoc fashion, as was the two day time constant, to compensate for the expected decreases in entrainment with time due to emulsification and other weathering properties which tend to solidify the slick.

The second section of the routine is used only in the preview mode. At the end of each step, the mass of oil represented by each entrained is calculated.

CALLED FROM: SURFES

SUBROUTINES CALLED: None

Important Local Variables:

WSP - mass of spillet (metric tons).

BSP - time of start of spillet (seconds).

DCN - time constant for the exponential decay of the entrainment rate currently set at 2 days (172800 seconds).

SEC - number of seconds in one day.

AO - constant for dispersion equation.

WO - wind constant for dispersion equation (m/sec).

AMT - percent entrained per second.

PERCEN - amount of oil entrained per time step (fraction).

DIF - ratio of amount entrained per step and total amount in water column at that step.

DCY - time decay factor given by $e^{-(\text{time} - \text{BSP})} / \text{DCN}$

Subroutine ENTRN

This routine controls the injection of the oil droplets into the water column. Its flow chart is shown in Figure IV-15.

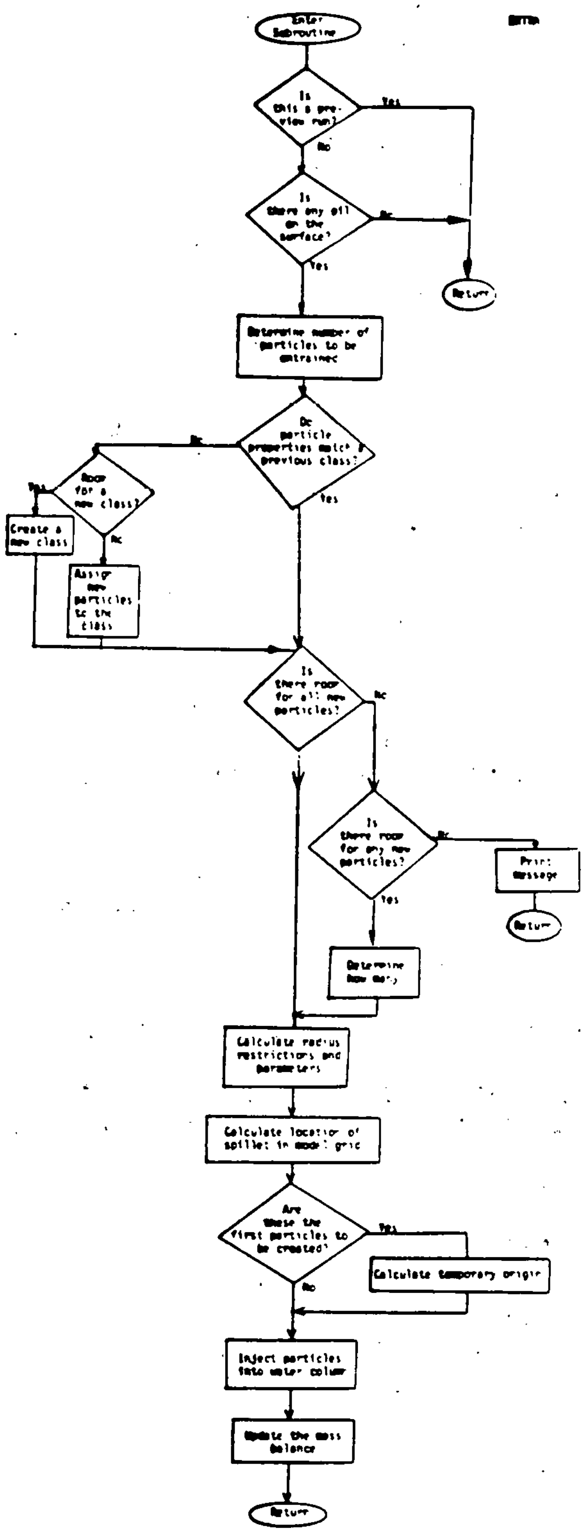


Figure IV - 15. Flowchart of subroutine ENTRN.

The first step is to determine from the input parameter, NRUN, whether or not this simulation is a preview. In the Preview mode, no particles are entrained. In the full simulation mode, the number of particles is determined according to the mass of oil entrained from the spillet and the mass assigned to each particle. The particle properties are determined from the properties of the oil in the slick, which in turn determines the class to which the particle belongs. A maximum of 200 classes are currently allowed. The user may change this maximum by increasing or decreasing the input variables NTCLAS. If NTCLAS is increased, then array sizes in the common block PTYP must also be increased.

The next step is to calculate the radius restrictions on the particle positions. These are determined in an ad hoc manner due to a lack of data regarding entrainment. The horizontal position is defined by a radial component and an angular component about the center of the spillet. The angle, measured clockwise from the positive y axis is selected at random from a uniform distribution. The radial position is divided into two regions as defined by RLIM. For radii smaller than RLIM, the distribution increases linearly from zero. This coupled with the uniform distribution in angle gives an equal probability per unit area for particle location within RLIM. For radii larger than RLIM, the distribution decreases linearly to zero at RMAX. The maximum radius, RMAX, is a variable which decreases with the age of the spillet. This procedure was adopted to provide sufficient extent to the subsurface distribution during the early time steps to avoid singularities in the diffusion equation, i.e., it is an ad hoc fashion of avoiding numerical instabilities in the early time history of the spillet. A more elaborate procedure was not thought to be justified at this time because of our general ignorance regarding the entrainment process in general. In addition, there is certainly a thin surface sheen that spreads beyond the limits of our model prediction from which particles might be entrained.

The final step of the routine is to convert the polar coordinates of the entrained particle positions to model grid coordinates.

CALLED FROM: SURFES

SUBROUTINES CALLED: DIST, INJECT

Important Local Variables

RSPIL - spillet radius

$A = \frac{RO}{AFRAC}^{2} = \frac{RSPIL}{AFRAC^{2}} (RIFRAC)$ describes particle distribution within region one.

RMAX = RSPIL* (1.0 + ((HENT/50)/(ROFRAC(TIME-BSPIL) + 1.0))

maximum radius for initial particle distribution.

$$D = (RO/A)^{1/2} = \frac{RO*\ AFRAC^2}{RO} = AFRAC$$ Temporary Variable

$$B = \frac{(RMAX - RO)}{(1.0 - D)} = \frac{RMAX - \frac{RSPIL}{RIFRAC}}{(1.0 - AFRAC)}$$ Temporary Variable

$$C = \frac{(RO - RMAX + D)}{(1.0 - D)} = \frac{(\frac{RSPIL}{RIFRAC} - RMAX * AFRAC)}{(1.0 - AFRAC)}$$ Temporary Variable

XC, YC - position of center of spillet with respect to depth grid origin in number of grid units from origin.

IX, IU, P - constants for random number generation used in subroutine Rand.

POMIN - minimum distance in x and y direction between the first two particles (meters).

RX, RY, RZ - random numbers between zero and one resulting from subroutine RAND.

RLIM - D - boundary of uniform distribution.

RADIUS - initial radial location of a droplet from the center of the spillet.

$A*RX^2$ - within RLIM
$B*RX+C$ - outside of RLIM

Also see Common Block INJC in Appendix III.

Subroutine EVPOR8

The mathematical formalism used in this subroutine is the same as that described by Wang, Yang, and Hwang (1976) but the numerical solution adopted in the present model is different. The equation to be solved for C_i, the average value of the percent weight of fraction i over the slick thickness, is:

$$d\bar{C}_i/dt = - \bar{D}_{ie}\bar{\bar{C}}_i$$

where D_{ie} is the average value of the evaporation diffusion coefficient over the slick thickness. The values of the diffusion coefficients are discussed in detail in the report of Wang et al. (1976) as well as in the original paper by McKay and Matsugu (1973) and will not be further discussed here.

Wang et al. used the fourth-order Runge-Kutta method to determine $\bar{C}_i$. The difficulty with this method is that it requires storing all variables for two time steps. Because of the complexity of the model, use of the Runge-Kutta method resulted in a substantial requirement on computer memory. The following method was, therefore, adopted to determine $\bar{C}_i$ (t), given $\bar{C}_i$ (t - Δt) where Δt is the step size. The interval Δt was divided into N intervals of duration δt, i.e., Δt = (N)(δt). The evaporation diffusion coefficient is assumed to be constant over each subinterval, although it may vary from one interval to the next. This then leads to:

$$\bar{C}_i(t) = C_i - (t - \Delta t)\,e^{-\left(\sum_{i=1}^{n} \bar{D}_{ie}\,(t - (j - 1/2)\,\delta t)\,\delta t\right)}$$

where D_{ie} (t-(j-1/2)δt) represents the value of D_{ie} at time t-(j-1/2) δt. Solutions using this method were compared with solutions for the same input conditions using the model of Wang et al. (1976) and were found to differ by less than ten percent for N=1. The execution time was less by a factor of four and the memory requirements were significantly reduced (about twenty kilobytes).

The variable D_{ie} is defined by:

$$D_{ie} = km\,(P_i - P_{i\infty})\,/(RT_s)$$

where P_i - hydrocarbon vapor pressure of fraction i at the interface.

$P_{i\infty}$ - hydrocarbon vapor pressure of fraction i at infinite altitude.

R - the gas constant.

T_s - the oil slick temperature.

and

$$km = CONST * e^{(Q\ WVEL)} * AREA^R$$

where CONST, Q and R are constants defined wthin the routine,

WVEL - wind velocity in meters/sec.

A - area of spillet in square meters.

See Figure IV-16 for a flow chart of this subroutine.

<u>CALLED FROM:</u> SURFES

<u>SUBROUTINES CALLED:</u> None

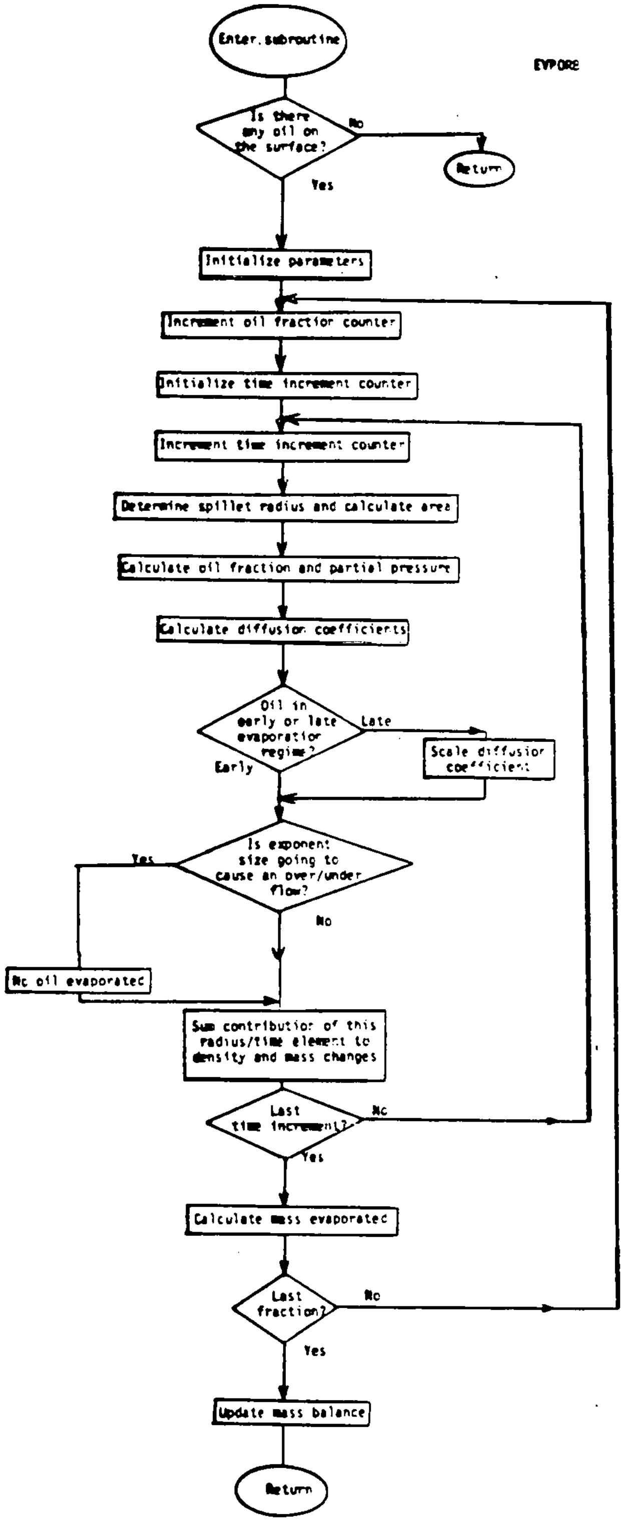


Figure IV.-16. Flow chart for subroutine EVPORE.

Important Local Variables:

ABSZERO absolute zero (degrees centigrade).

AREA area of spillet (meters^2).

CON1, CON2 - array of constants for Antoines equation of partial pressure.

DAGRES - average temperature over the slick (degrees centigrade).

RAD - radius of the spillet during the integration process (meters).

DELTA - time of the substep in the integration (sec).

NINT - number of steps in the integration procedure.

OLDRAD - radius of spillet at the last time step (meters).

P - vapor pressure.

Q,R,CONST - constants for diffusion coefficient.

RC - universal gas constant.

Subroutine GRIDEX

This subroutine (see Figure IV-17 for its flow chart) expands and translates the floating grid so as to incorporate all of the marker particles. It determines the maximum and minimum positions of the particles and creates a grid with a particle free region 1.5 grid units wide around the entire periphery. This is required by the interpolation technique. If any particles get too close to the edge of the fixed depth grid, the floating grid is moved away from the boundary and the particle is lost. This routine prints a description of the floating grid every NPRSUB steps. The print parameter, NPRSUB also determines whether or not the means and standard deviations of the particle locations are to be calculated and printed. These last values are not passed out of the subroutine.

CALLED FROM: SUBSUR, PRINT

SUBROUTINES CALLED: None

Important Local Variables: None

Subroutine INITSS

This subroutine (see Figure IV-18 for a flow chart), called by the main section, initializes all of the subsurface drift and diffusion variables and parameters. It also initializes the droplet properties and subsurface print parameters. (See INPUT parameter description).

CALLED FROM: Main

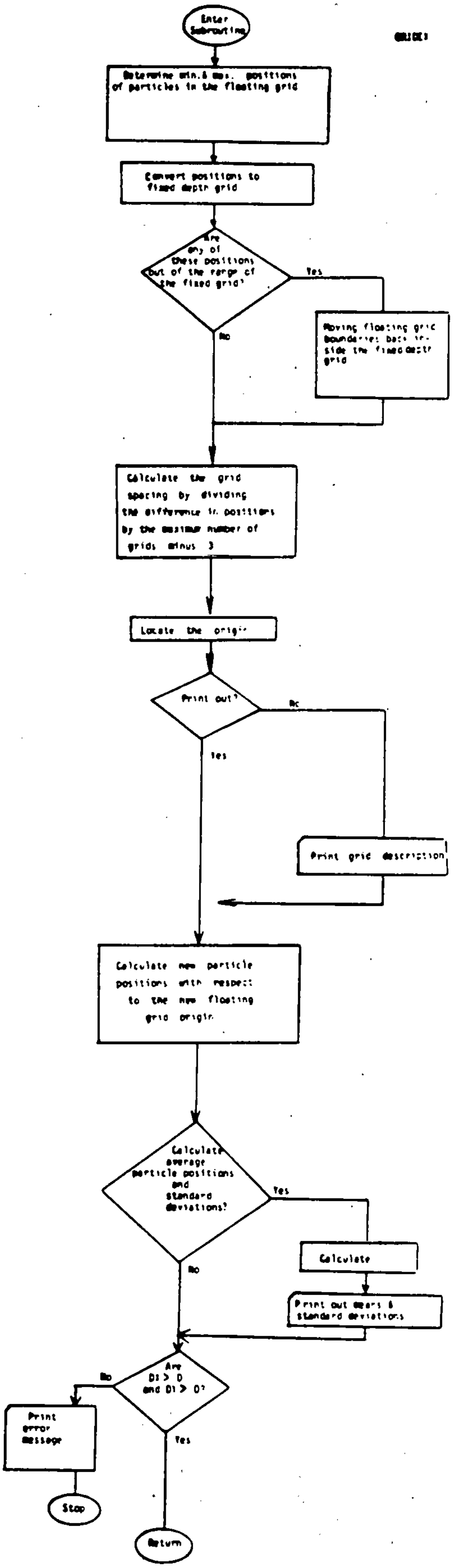


Figure IV.-17 Flow Chart for subroutine GRIDZ1.

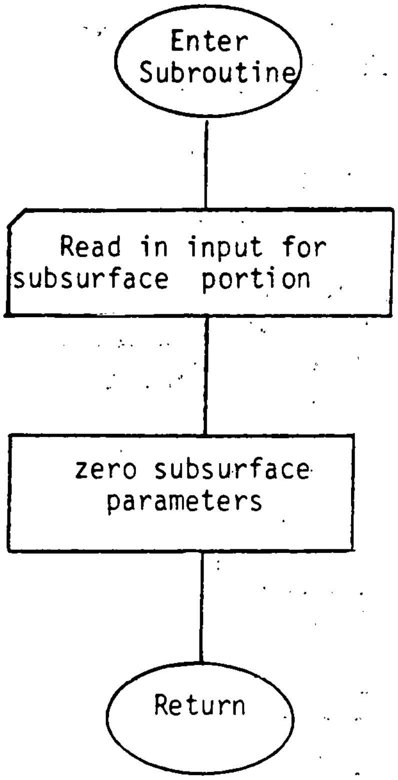


Figure IV.-18. Flow Chart for subroutine INITSS.

Subroutines called: READI, READF

Important local variables: None

Subroutine INJECT

This subroutine uses the radii restrictions calculated in ENTRN to determine the initial particle positions. A random number generator (see subroutine RAND) is used to obtain three dummy variables. The first one (RX) is used to determine the spacing of the marker particle from the center of the spillet. The second random number (RY) is used to determine the random angle. The angle and radius determine the particles location in polar coordinates which is then converted to the rectangular grid. The particles location in the model grid undergoes two tests. First, the particle must be within the fixed grid. Second, if this is the first step, the first two particles created must have a separation that exceeds the input variable POMIN. This insures that a floating grid can be created in both directions. A third random number is used to determine the particle's position in the vertical which on the average is located at the depth by the input variable DEPC. See Figure IV-19 for a flow chart of the subroutine.

CALLED FROM: ENTRN

SUBROUTINES CALLED: RAND

Important Local Variables: see ENTRN for a description of variables used in inject.

Subroutine LOC8

This subroutine, flowcharted in Figure IV-20, determines the smallest rectangle of fixed grid elements that contains a spillet. It is used to determine for which grid nodes the values of the specified environmental variable must be averaged. All nodal values falling on the edge of and within the rectangle completely containing the spillet are used. These values are averaged and returned to the calling routine. If the fixed grid consists of only one value, that value is used. If the spillet lies completely outside of the specified fixed grid, a message is written and the control parameter MDLSPL is changed from 0 to 1. If this condition arises, none of the surface processes will be executed on return to the calling routine except for shoreline interaction if, indeed, the spill has hit the shore.

CALLED FROM: SURFES

SUBROUTINES CALLED: DIST

Important Local Variables:

MDSLPL	- 0 if the spillet is in the study area. - 1 if the spillet is outside one of the environmental grids.
NGRD	- number of grids that define a variable.

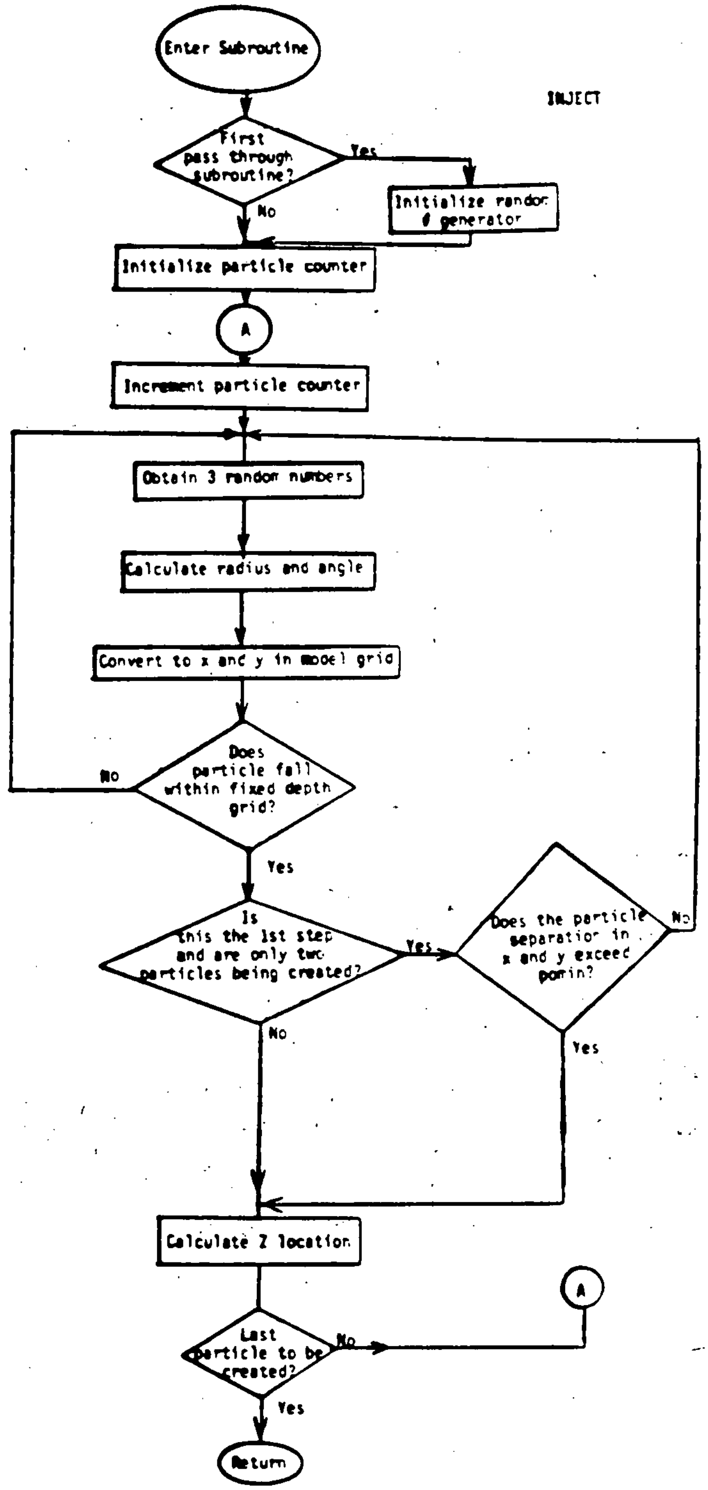


Figure IV - 19. Flowchart for subroutine INJECT.

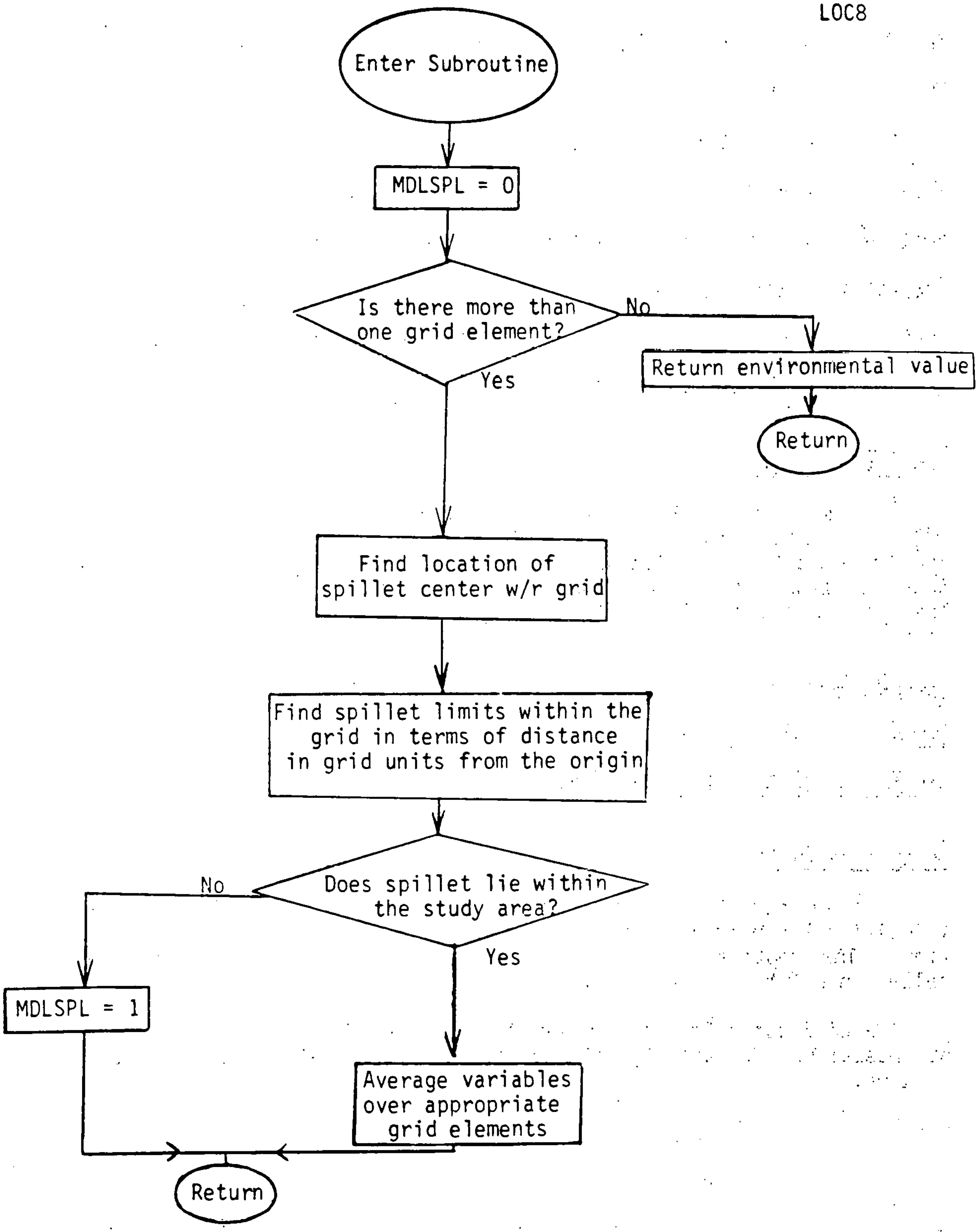


Figure IV - 20. Flowchart for subroutine LOC8.

NX, NY - maximum number of grids in X and Y direction.

ANG - angle between x axis and lines of constant latitude.

XL, YL - Longitude and Latitude of (1,1) grid position.

XS,YS - grid spacing in X and Y direction (meters or degrees).

VAR1,VAR2, - input arrays, if NGRD is 1, VAR2 is not used.

VAL1,VAL2 - averaged values of the above arrays.

XC,YC - Longitude and Latitude of the center of the spillet.

R - spillet radius (meters).

Subroutine MASSC

This subroutine, flowcharted in Figure IV-21, calculates and writes the mass balance both in terms of the total amount of oil in each region and the percentage of oil in each region. In addition to the mass balance, it also writes out statistics on the number of particles present, lost or deposited. The mass data may be written to disk and/or the line printer.

CALLED FROM: Main

SUBROUTINES CALLED: None

Important Local Variables: None

Subroutine PARTV

This subroutine uses the bilinear weighting scheme to interpolate the velocities known at the floating grid notes to the marker particle position. The routine is flowcharted in Figure IV-22. The subroutine is called once for each particle.

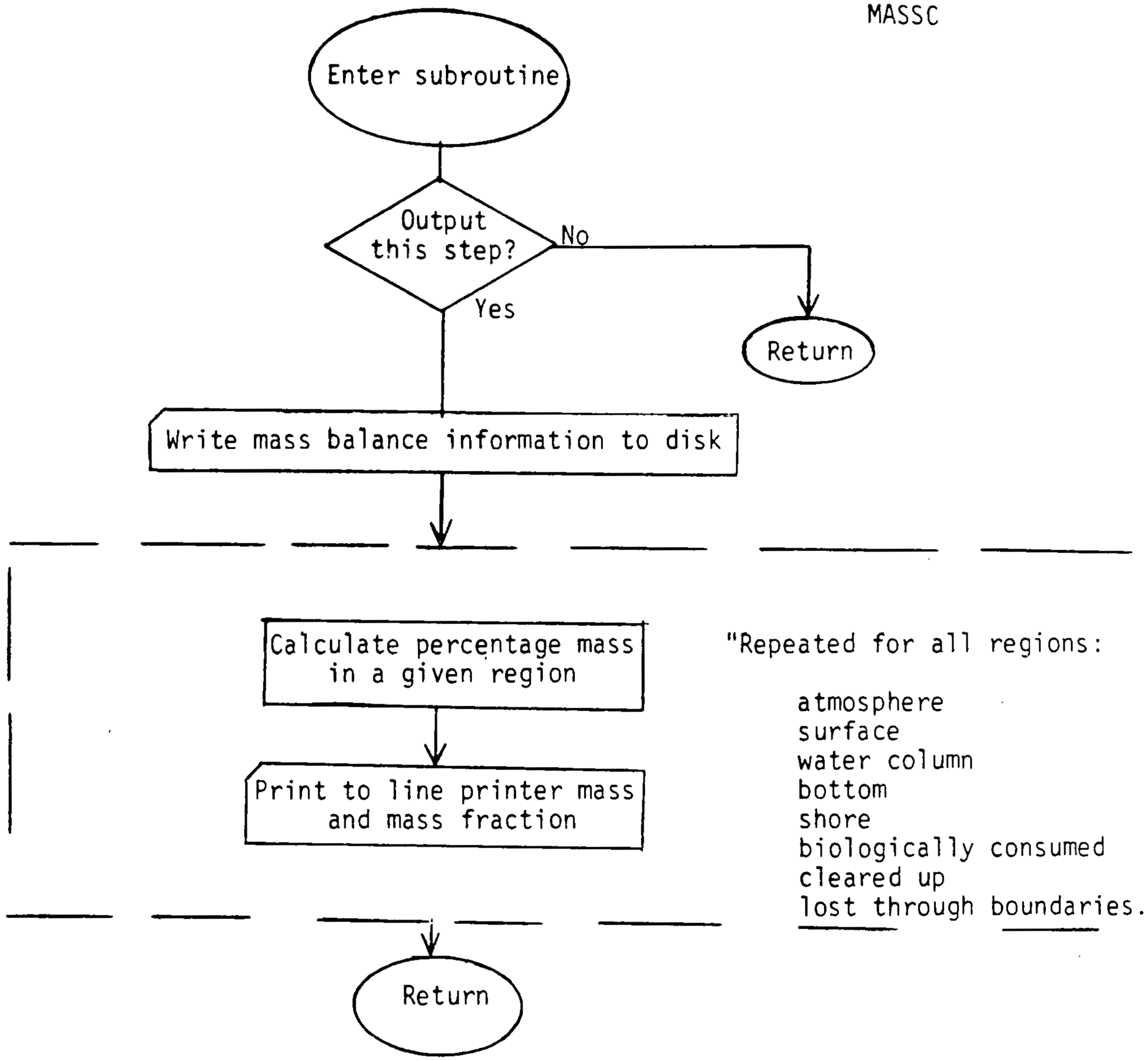
The bilinear weighting scheme obtains the value of a variable located at positions f_x and f_y in a grid element, see Figure IV-23, as follows:

$$U = (U_1 + f_x (U_2 - U_1)) + f_y ((U_1 = f_x (U_2 - U_1) - (U_3 + f_x (U_4 - U_3)))$$

where U is the value sought and all other values are defined in Figure IV-22.

CALLED FROM:

SUBROUTINES CALLED: None



"Repeated for all regions:

atmosphere
surface
water column
bottom
shore
biologically consumed
cleared up
lost through boundaries.

Figure IV - 21. Flowchart for subroutine MASSC.

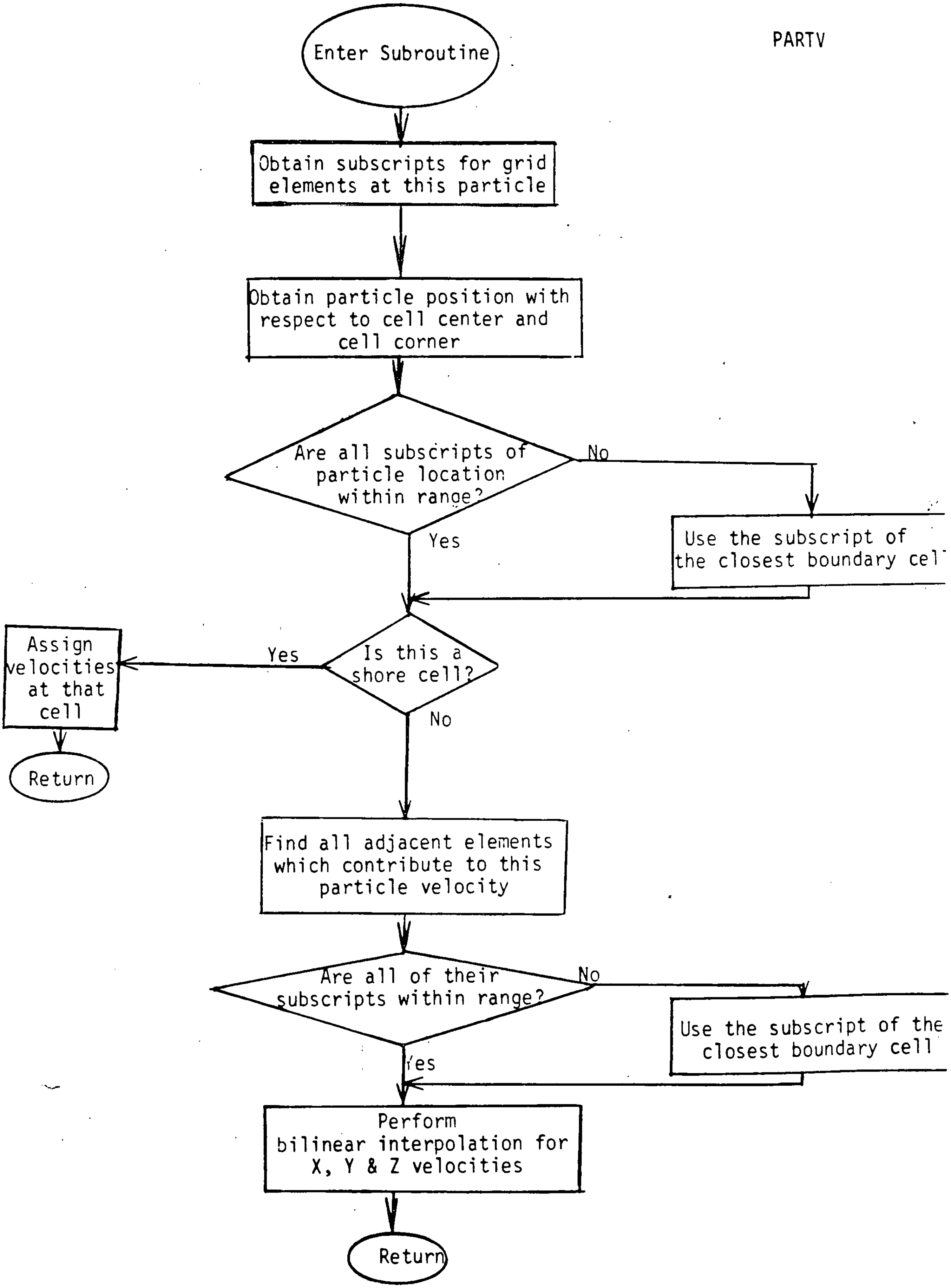


Figure IV - 22. Flowchart for subroutine PARTV.

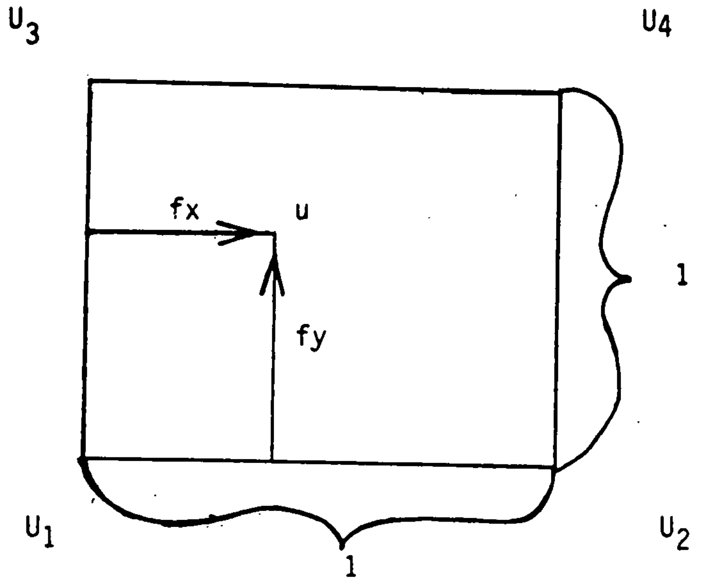


Figure IV. - 23. Defining figure for Bilinear interpolation scheme.

Important Local Variables: None

Subroutine PRINT

This subroutine handles most of the output operations for the subsurface section of the model. The output is controlled by print control parameters described in common block PRINT. These parameters control both the paper and the disk output. The subroutine will print out the velocity field and the concentration matrix on the floating grid with headers locating the floating grid with respect to the origin of the fixed depth grid (in meters or degrees). In addition, the actual location of each marker particle can be printed if desired. When printing these positions, the depth is calculated and printed in meters if a z transformation is being used in the simulation. Printout is controlled by KPRTV, KPRTC and KPRTP for the velocity and concentration grids and the particle positions, the value of these control parameters specifies the step interval between printing. If the parameter is equal to zero, no printout for the corresponding variable is generated.

Output to disk is controlled first by the parameter NPRD. If it is zero, subroutine PRINT will output nothing to disk. If NPRD equals 1, then the parameters NPRV, NPRC, and NPRP define the step interval at which the various data sets are to be output.

A flow chart of this subroutine is shown in Figure IV-24.

CALLED FROM: SUBSUR

SUBROUTINES CALLED: BOUNV, CONC, GRIDEX

Important Local Variables:

NCALL1	- flag so as not to call the subroutine CONC twice. - 0 call CONC the second time it is encountered. - 1 call CONC only during the first concentration printout.
RIO(IMSUB)	- 15 - X positions of the floating grid cells (meters or degrees).
RJO(IMSUB)	- 15 - Y positions of the floating grid cells (meters or degrees).
XTEMP,YTEMP,ZTEMP	- particle positions with respect to the fixed depth grid (degrees or meters).

Subroutine RAND

This routine generates random numbers from a uniform distribution between 0.0 and 1.0. The input variables to this routine are all initialized in subroutine INJECT.

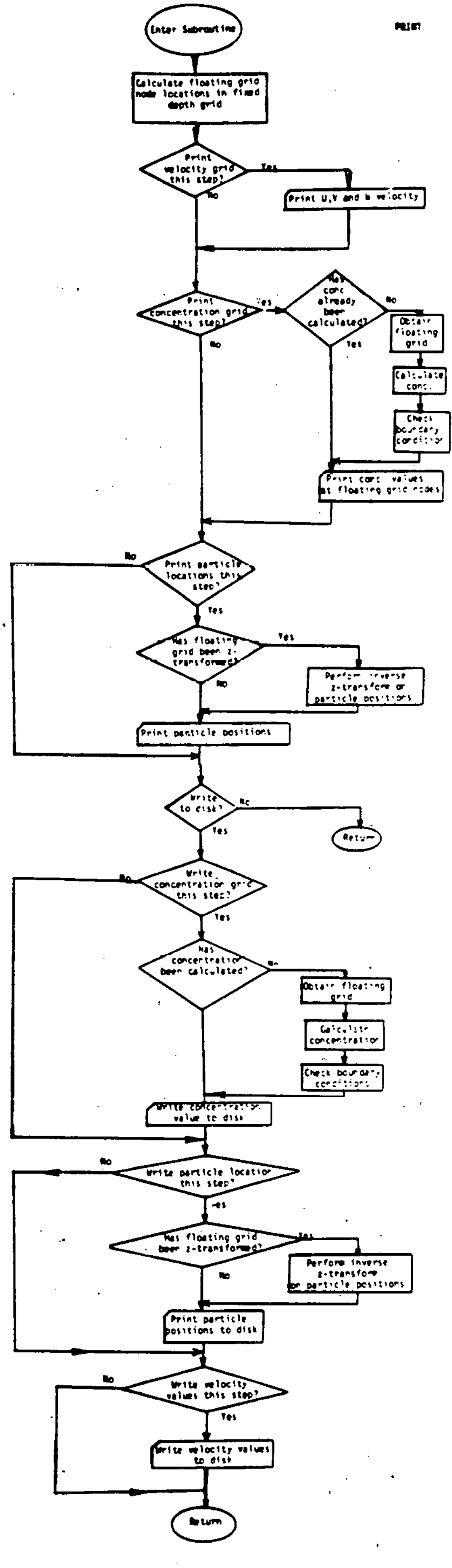


Figure IV - 24. Flowchart for subroutine PRINT.

CALLED FROM: INJECT

SUBROUTINES CALLED: None

Important Local Variables: None

Subroutine READI

This subroutine, flowcharted in Figure IV-25, is used to input, and check to some degree, all scalar integer variables. The required input format is described in Appendix I. The subroutine reads the value of the variable and the variable name. If the variable name that it reads does not agree with the name of the variable passed to it from the calling routine, an error message is written and execution of the program terminates. This prevents reading cards out of order. In addition, if the value of the variable does not lie in some predefined range again passed to it from the calling routine, an error message in written and execution terminates. This is to help avoid exceeding the limits of various arrays as well as reducing the chance of an abnormally long run resulting from the improper positioning of the input parameter. If the upper and lower limits specified in the call to READI are equal, any value may be entered.

CALLED FROM: MAIN, INITSS

SUBROUTINE CALLED: NONE

Important Local Variables:

I - value read from input and passed back to the main program.

NL - lowest value permitted.

NU - greatest value permitted.

XNAME - name of variable to be read.

XPNAME - name of variable read from input stream.

Subroutine READF

This subroutine is used to input, and to check to some degree, all single real variables. It is identical to READI except that:

1. It reads floating point numbers rather than integers.
2. There are no restrictions on the range of the number read in other than those of the computer.

Subroutines called: None

CALLED FROM: MAIN, INITSS

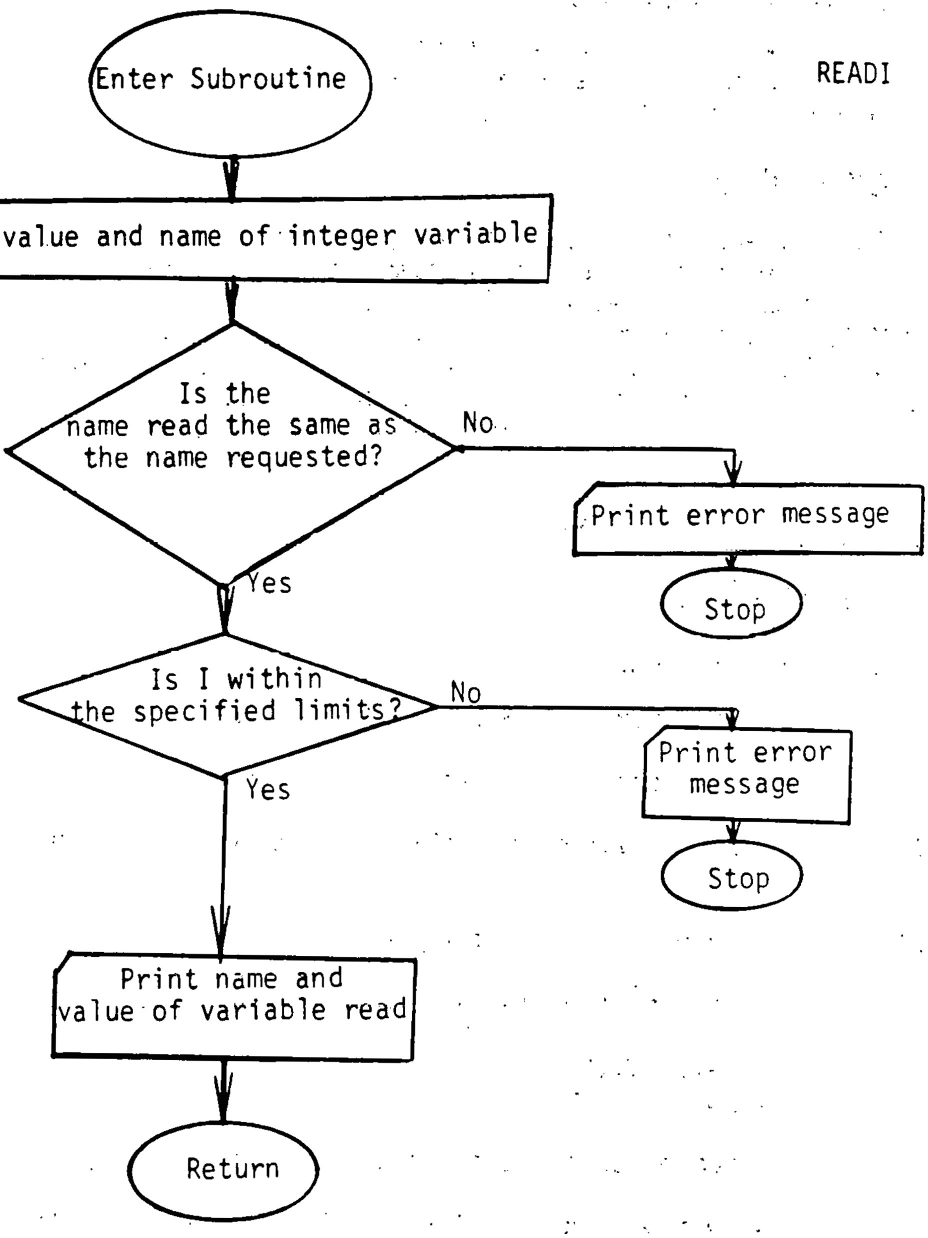


Figure IV - 25. Flowchart for subroutine READI.

Important Local Variables:

X - value of variables read in and passed to the calling routine.
XNAME - name of the variable to be read.
XPNAME - name of the variable read from the input stream.

Subroutine REMOV

Each cleanup and treatment effort initiated has associated with it a duration. When this length of time has been exceeded, the effort is to be terminated and removed from the list of cleanup/treatment efforts. REMOV is used to remove an expired effort from the list (see Figure IV-26 for its flow chart). The routine removes an effort by simply moving the last effort on the list into the location occupied by the expired effort and then decrements the counter specifying the number of active efforts by one.

CALLED FROM: CLNUP, TREAT

SUBROUTINES CALLED: None

Important Local Variables:

BEG - beginning of this effort (hour).

DUR - duration of this effort (hours).

DUM - dummy variable which is equivalenced in the Subroutines TREAT and CLNUP.

MEM - number of current efforts.

NVAR - length of variables in the common bloc.

- 7-for CLEN
- 10-for CHEM

JTEMP - number of expired efforts this step.

MTEMP - last efforts on list; this one is moved to expired efforts placed in list

LTEMP - effort which has expired and is being replaced.

Subroutine ROTAT

This subroutine, flowcharted in Figure IV-27, converts locations from the fixed depth grid to any of the environmental grids. It is used primarily to map values of environmental variables into the floating grid. The depth grid is used as the reference because the floating grid is defined with respect to it. The output of this routine is the x and y location of the point of interest referred to the new environmental grid.

CALLED FROM: BOUNV, VELC

SUBROUTINE CALLED: DIST

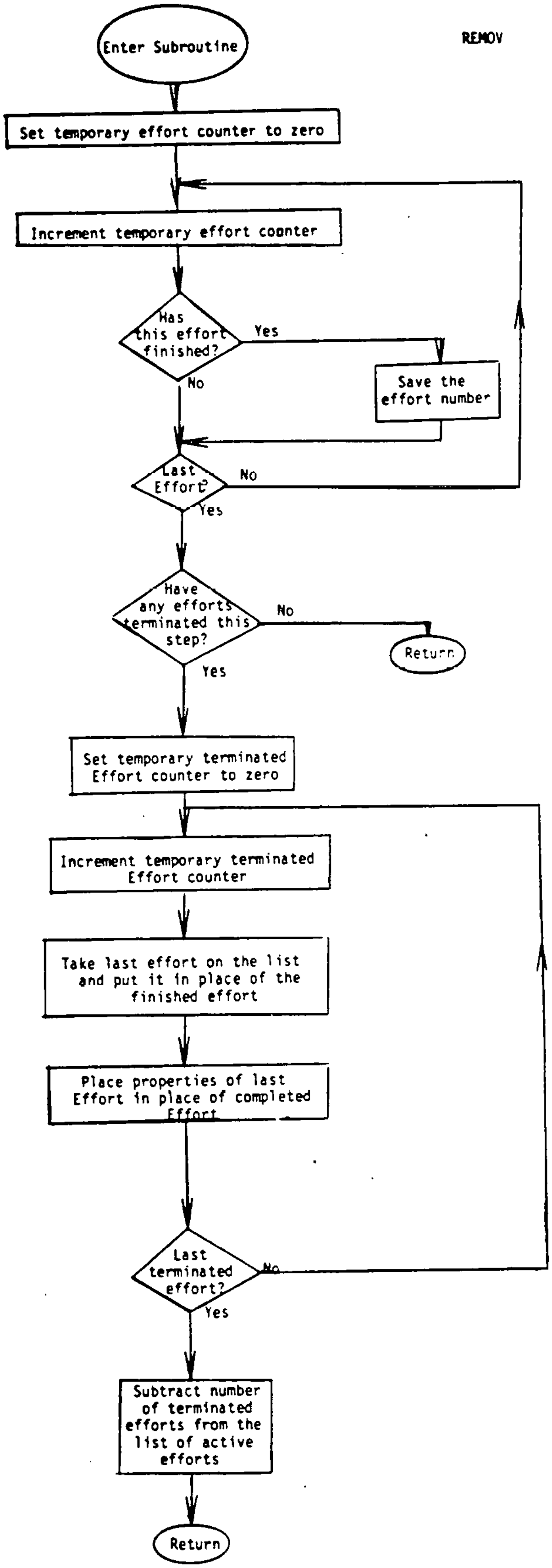


Figure. IV. - 26. Flowchart for subroutine REMOV.

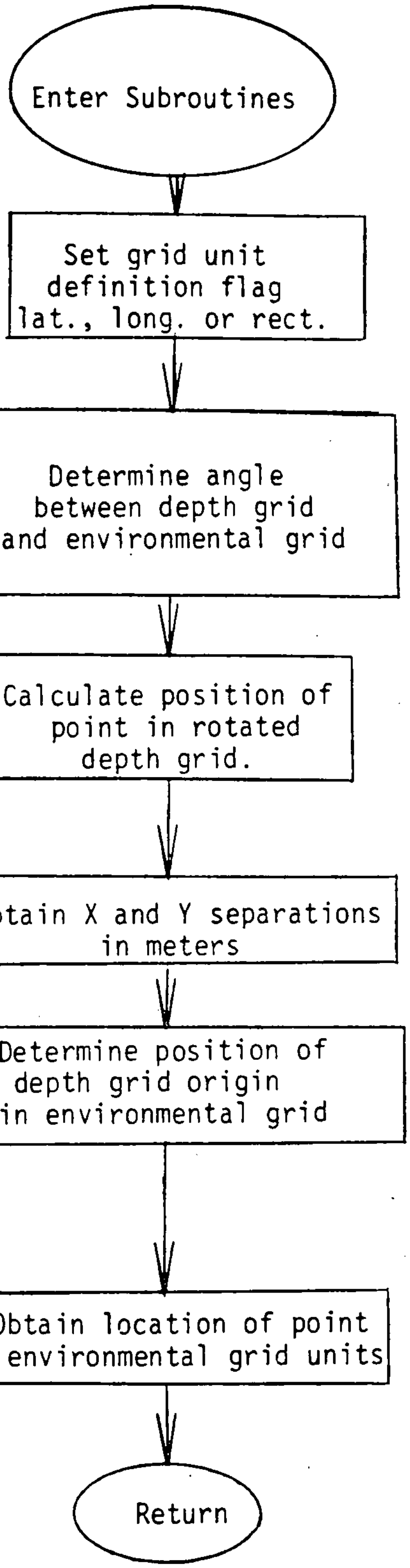


Figure IV. - 27. Flowchart of subroutine ROTAT.

Important Local Variables:

XL,Y1 - longitude and latitude of the (1,1) location of the grid of interest.

XD,YD - grid spacing in X and Y direction for the grid of interest (meters or degrees).

ANG - angle of X axis with lines of constant latitude for the grid of interest.

XO,YO - position of point which is to be converted. This is with respect to the depth grid.

XG,YG - grid position of point with respect to the grid of interest.

XSP,YSP - distance between origins of depth grid and grid of interest.

Subroutine SHORE

This subroutine reads the longitude and latitude values of the points defining the shoreline. The subroutine is always called but if the study area includes no shoreline, then no points are read.

CALLED FROM: MAIN

SUBROUTINE CALLED: None

Important Local Variables: None

Subroutine SPILIN

This subroutine reads in all new spillet parameters and initializes any properties not read in. The user is referred to Appendix IX for general oil properties. The routine will also print all current spillet information at the step interval specified by the parameter NSPPRP (see input variables). Spillet information may also be written to a disk data set at a step interval defined by the parameter NSPPRD. Finally, a section is included in the routine for restart runs. It reads in old spillet information and skips the initialization which have already been performed (see Figure IV-28 for a flow chart of the subroutine).

CALLED FROM: MAIN

SUBROUTINES CALLED: None

Important Local Variables: None

Subroutine SPREAD

The spreading process is described by the simple three regime spreading mechanism proposed by Fay (1969). The only peculiarity in this model

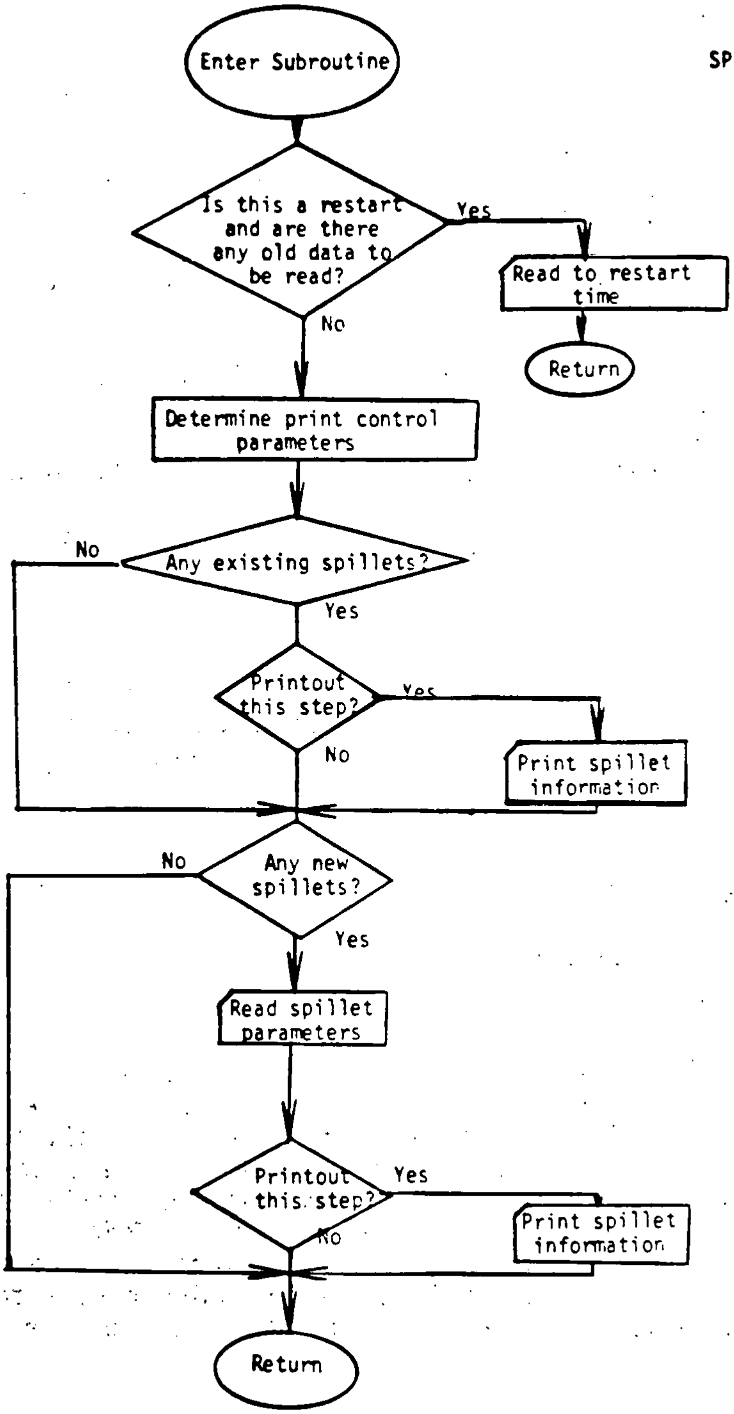


Figure IV. - 28. Flowchart for subroutine SPILIN.

with regard to spreading is the fashion in which the time, t, used in the various equations for the radius is determined. In this model, a fictious time is determined by solving each of the three different regime radius equations for time using the value of the radius from the previous step and the volume of spilled oil remaining at this time step. From these three values of "time," the appropriate regime is determined. Then the derived value of time is incremented by the time step of the model and the new radius is calculated. For a simple spill with no new oil added or oil previously in the slick removed, this yields the same value of radius with time as the original Fay formulation. However, for the case where oil is removed or added, this allows for the rate of spreading to jump from one regime to another. It is obvious that this is necessary if one considers a slick in the third regime which is treated with a chemical dispersant which lowers the spreading tension, by an order of magnitude. In this case, without changing the "time" variable used in the spreading equation, the radius changes by a factor of three. Equally drastic changes would result from the removal or addition of oil by any of the means available in the model. It is as a result of this regime changing mechanism that Fay's spreading formalism is used rather than the combined spreading-horizontal diffusion mechanism used in some of the more recent models (Wang, Campbell and Ditmars, 1975). See the flow chart in Figure IV-29.

CALLED FROM: SURFES

SUBROUTINES CALLED: None

Important Local Variables:

COEF1 - spreading coefficient for first regime.

COEF2 - spreading coefficient for second regime.

COEF3 - spreading coefficient for third regime.

DELTA - (water density - oil density)/water density.

GRAV - gravitational acceleration (cm/sec**^{2}).

RAD - radius of spillet (cm).

RHOW - density of sea water (gm/cc).

RMAX - maximum radius for a spillet containing a given volume of oil.

SIG - spreading tension (dynes/cm = gm/sec**^{2}).

T_{ij} - time at which spillet goes from Regime i to Regime j.

VISHZO - viscosity of sea water (stokes = cm**^{2}/sec.

VISRTZ - square root of VISHZO.

VMIN - maximum volume for which Fay's Regime 2 is skipped.

SPREAD

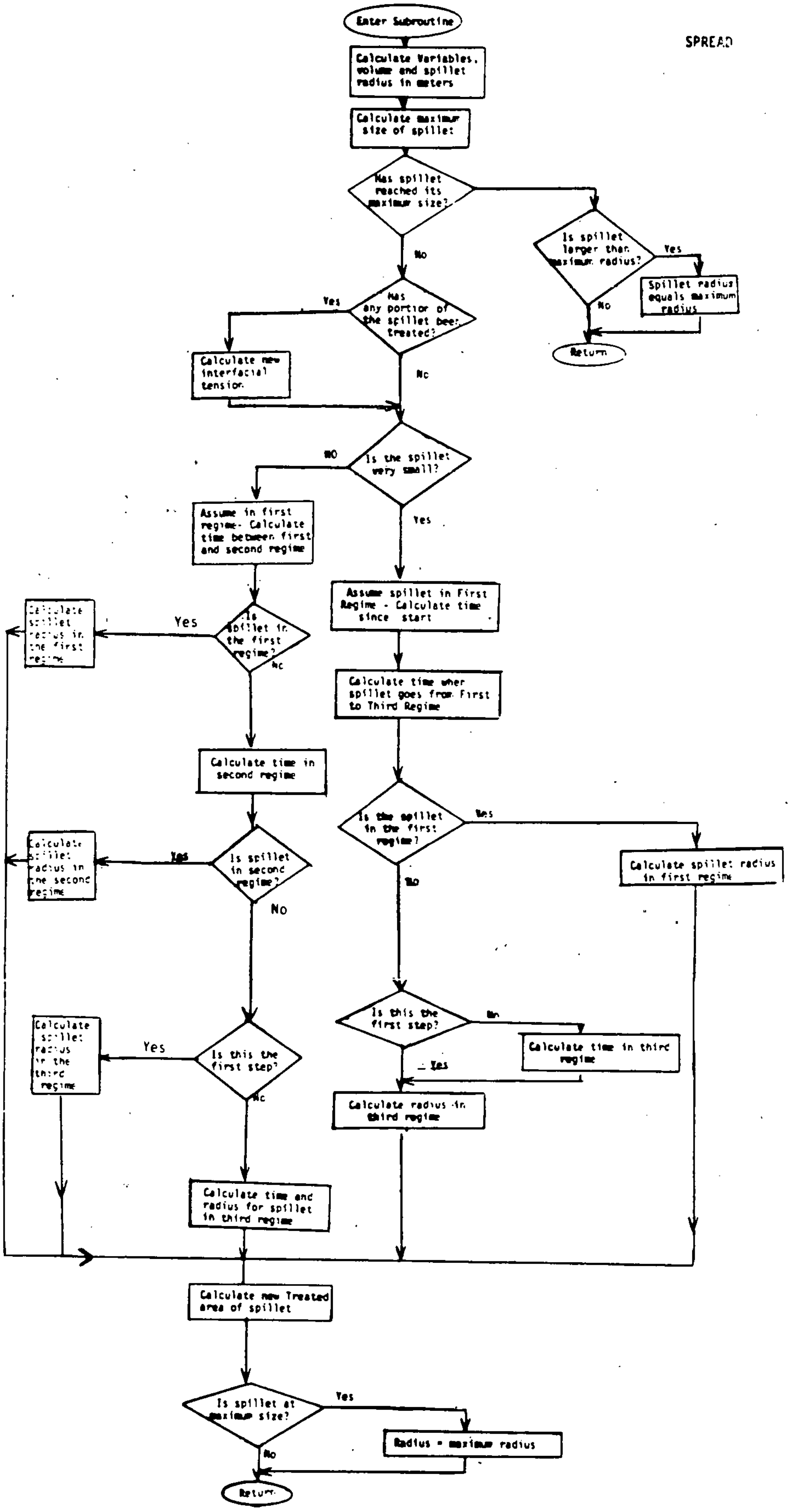


Figure IV. - 29. Flowchart for Subroutine SPREAD

VOL - volume of spilled oil (cc).

Subroutine SUBSUR

This subroutine calls the seven main subroutines which advect and diffuse the subsurface droplets in the water column. The method is based on the Water-Advective-Particle-In-Cell method developed by Pavish and Spaulding (1976-1977). A brief overview of the numerical scheme, along with a discussion of those factors which have been modified specifically for this application, is presented below.

The three-dimensional mass transport equation is solved using a particle-in-cell method. This is a quasi Monte Carlo technique in which representative particles are sampled at random from a predetermined distribution. The space which these "marker" particles occupy is then divided into a number of rectangular cells. The concentration distribution of the particles is determined by calculating the number of particles in each cell, i.e., this yields the concentration at the center of that cell. The model then obtains the concentration gradient and calculates the resulting diffusive velocity, which it adds to the advective velocity input to the program, to obtain the total particle velocity. Finally, the particle velocity is used to move the individual particles.

The fundamental equation being solved is the transport diffusion equation:

$$\frac{\partial C}{\partial t} + \vec{U}_A \cdot \vec{\nabla} C = \vec{\nabla} \cdot k_{ij} \vec{\nabla} C + S_i$$

where C is the concentration of oil droplets,

K_{ij} is the diffusivity tensor,
U_A is the advection velocity assuming incompressibility, and
S represents either a source or sink of oil.

This equation may be rewritten in the advective-diffusion form:

$$\frac{\partial C}{\partial t} + \vec{\nabla} \cdot (C \vec{U}_T) = 0$$

where

$\vec{U}_T = U_A + U_D$

$\vec{U}_T$ - Total particle velocity

$\vec{U}_A$ - Advective velocity

and

$\vec{U}_D$ - Diffusion velocity, defined by

$$\vec{U}_D = - \frac{k_{ij}}{C} \vec{\nabla} C$$

The total particle velocity is solved using a finite difference representation on the space staggered grid shown in Figure IV-30.

This sophisticated subsurface drift model was selected for several reasons, the main one being that it allows for oil droplets of varying properties, for example some denser than water that may sink and some less denser than water that may resurface as well as neutrally buoyant drops to represent the dissolved portion of the spill. In addition, the chemical properties of the droplets may vary, and this variability may be a function of particle size.

Another important feature of the subsurface portion of the model is the mixed Eulerian-Lagrangian coordinate system. The Eulerian coordinate system is the one on which the tidal currents, the bathymetry and the computational cells are defined. The Lagrangian coordinate system is the one on which the oil droplet concentration is defined. This system expands and translates so as to always include all particles. Variables defined on the Eulerian system are interpolated to the Lagrangian system. The Lagrangian system also allows for a coordinate transformation on z, the vertical variable, such that the water column at every horizontal node is divided into the same number of equally spaced layers. This means that as the water becomes shallower, the vertical grid spacing becomes smaller, thus keeping the same relative vertical resolution.

The flow of this routine, Figure IV-31, is quite straightforward.

CALLED FROM: MAIN

SUBROUTINES CALLED: BOUNV, CONC, COURAN, DISPV, GRIDEX, PRINT, VELCT

Important local variables:

C(IMSUB,JMSUB,KMSUB)	15,15,10 - oil concentration on the floating grid (mg of oil/ml of water).
M(IMSUB,JMSUB,KMSUB)	15,15,10 - computational cell definitions of the floating grid.
NST	step number.
HFLT(IMSUB,JMSUB,KNSUB)	15,15,10 - tidal elevations at the floating grid nodes (meters).
DFLT(IMSUB,JMSUB,KNSUB)	15,15,10 - depths at the floating grid nodes (meters).
CC(IMSUB,JMSUB)	15,15 - concentration values averaged over the water column.
NPTFLT	interval print control for subsurface information.

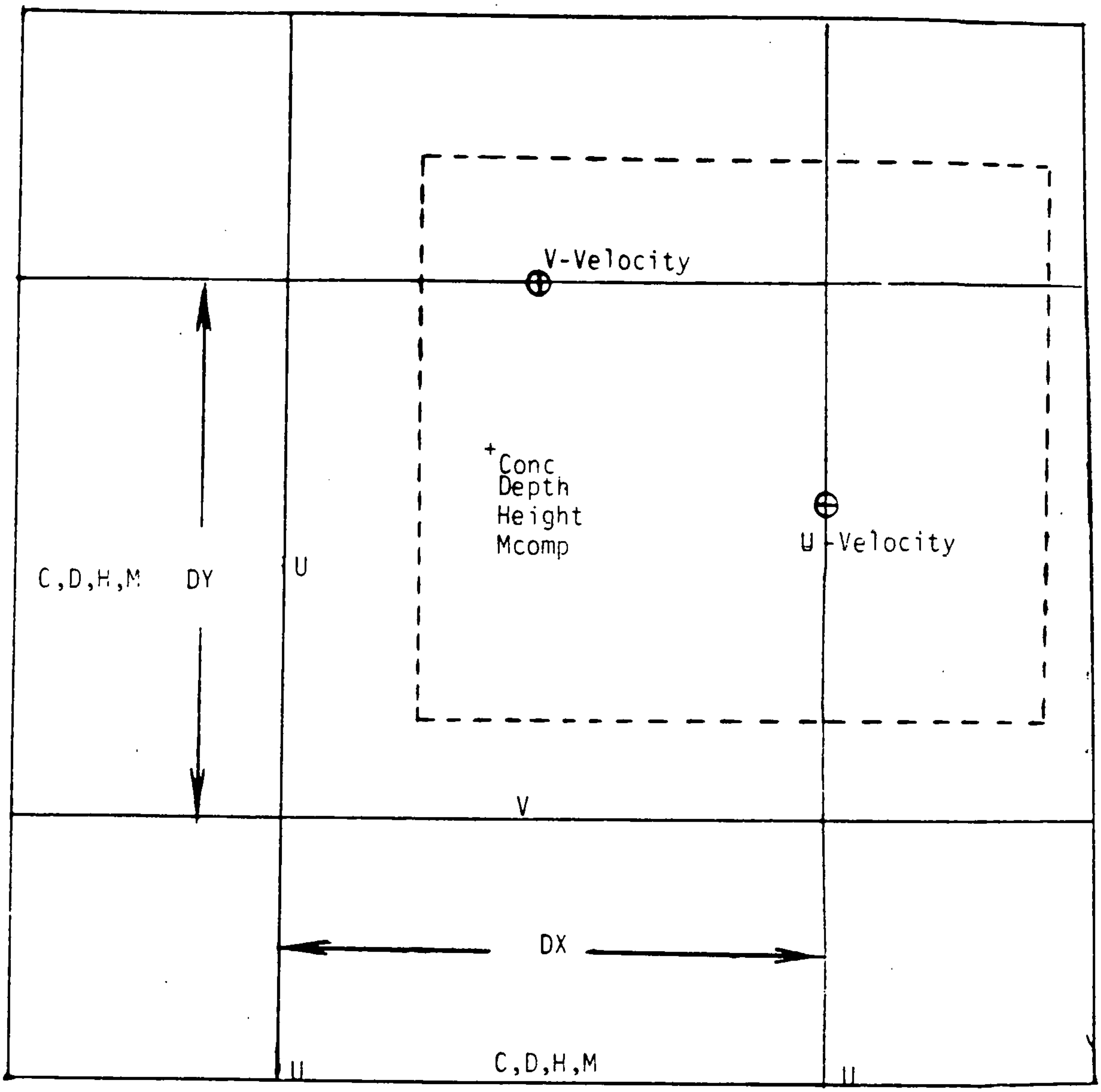
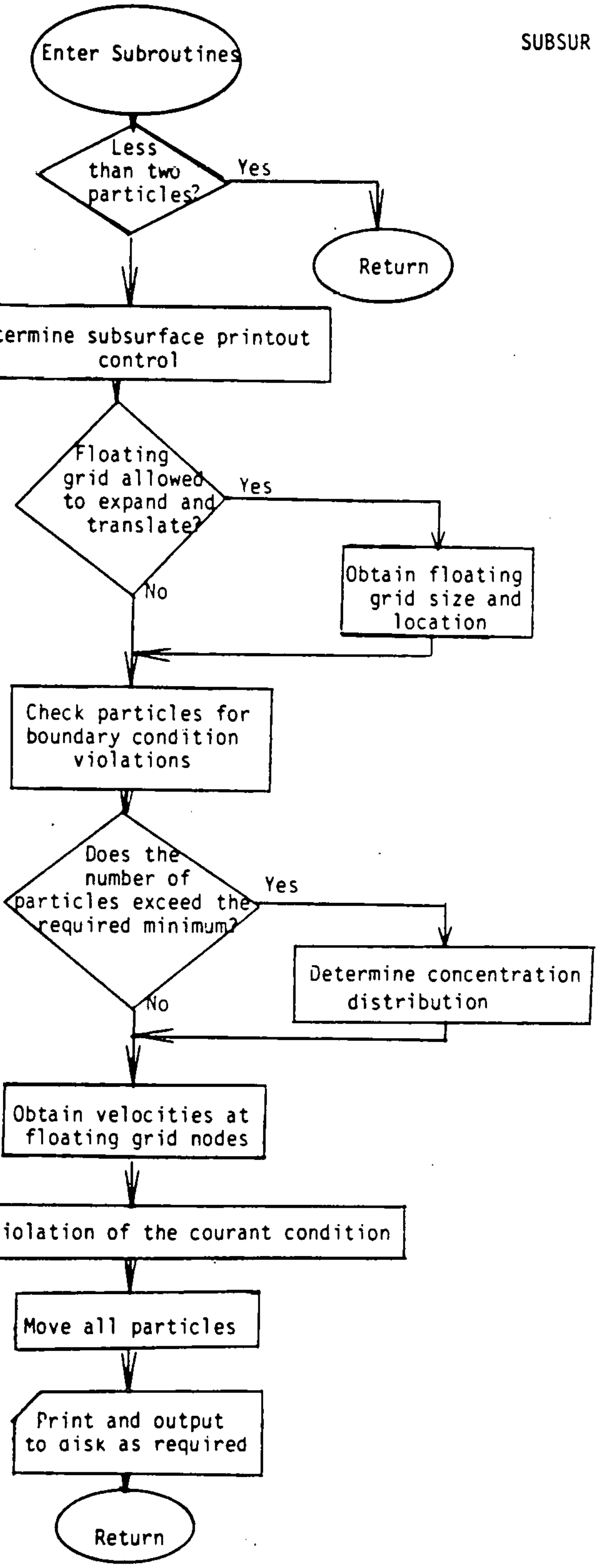


Figure IV-30. Space Staggered System
(Values Inside of Square have the same Indeces)



Figures IV.-31. Flowchart for subroutine SUBSUR.

NPTSUB print control parameter as determined by NPTFLT

printout this step, 0 - no printout this step.
1 - printout this step.

Subroutine SUMMUP

This subroutine, flowcharted in Figure IV-32, writes to disk all of the variables describing the disposition of the spilled oil (the Restart data set). It also outputs active cleanup and treatment efforts. The subroutine is called at a step interval defined by the input parameter NSUMM, as well as at the end of the run. It codes the output with the step number. If the user wishes to restart the run from this point, new input and output data sets are to be used if NSTFN is set equal to zero (by the user). The reason for outputting the parameters outlined above is to allow the run to be restarted following its termination. Because the restart data set is overwritten everytime, SUMMUP is called, the run may be restarted only from the step at which the parameters were last written.

CALLED FROM: MAIN

SUBROUTINES CALLED: None

Important Local Variables: None

Subroutine SURDFT

This subroutine, outlined in Figure IV-33, is used to advect the surface portion of the oil spill, specifically, the spillets. The advective velocity is taken equal to the vector sum of the ocean velocity, input to the model, and a scaler constant times the wind velocity, also input to the model. The scaler factor multiplying the wind velocity, WINFC, is presently set to .035 in the model and can only be changed by modifying the appropriate data statement. If the ocean current is in degrees/second, it will be converted in the subroutine to meters/second.

CALLED FROM: SURFES

SUBROUTINES CALLED: None

Important Local Variables

UCRNT - water current in x direction passed to the routine.

UWIND - wind speed in x direction passed to the routine.

VCRNT - water current in y direction passed to the routine.

VWIND - wind speed in y direction passed to the routine.

WINFC - wind factor defined in the routine.

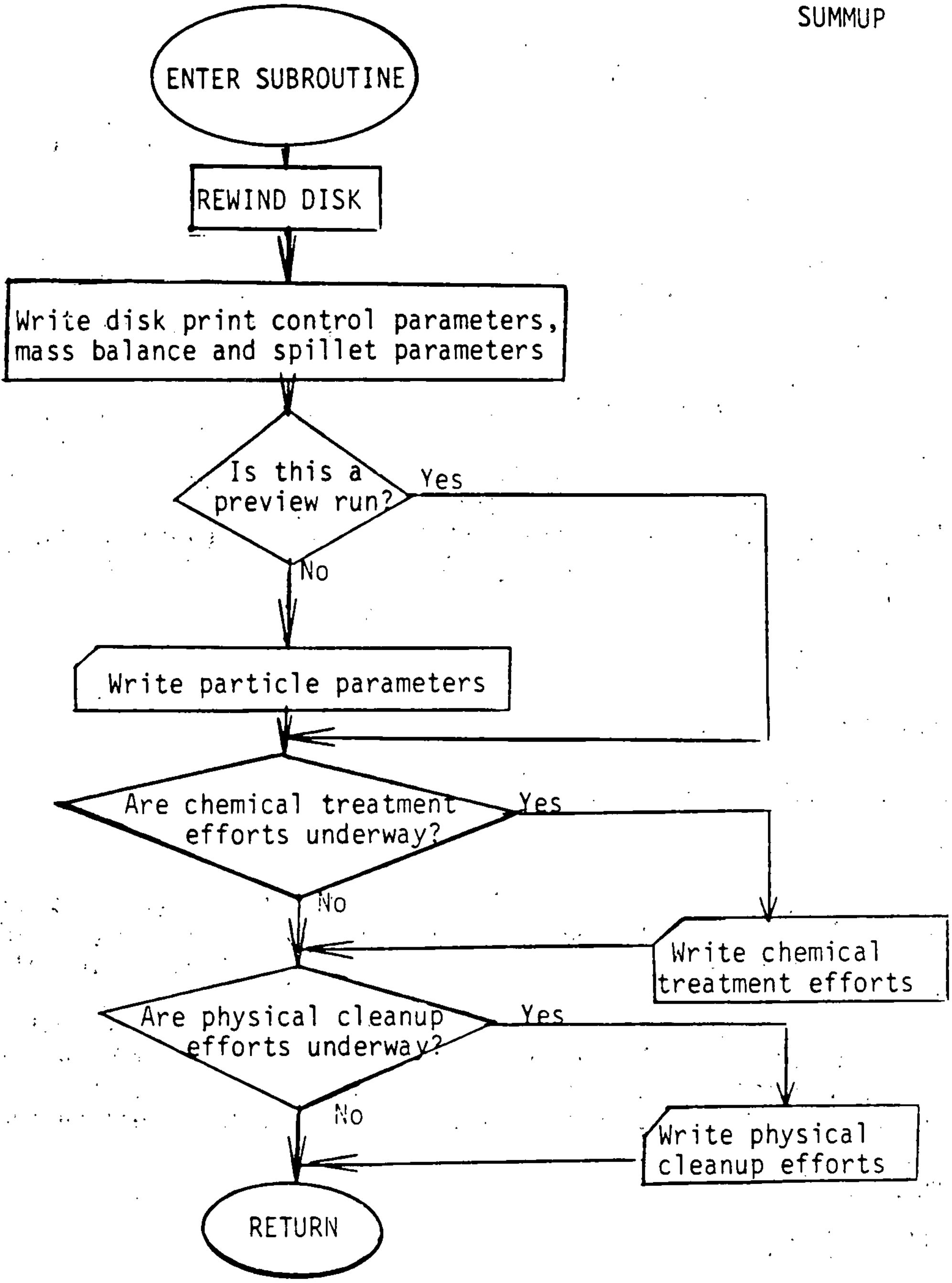


Figure IV. - 32. Flowchart for subroutine SUMMUP.

SURDFT

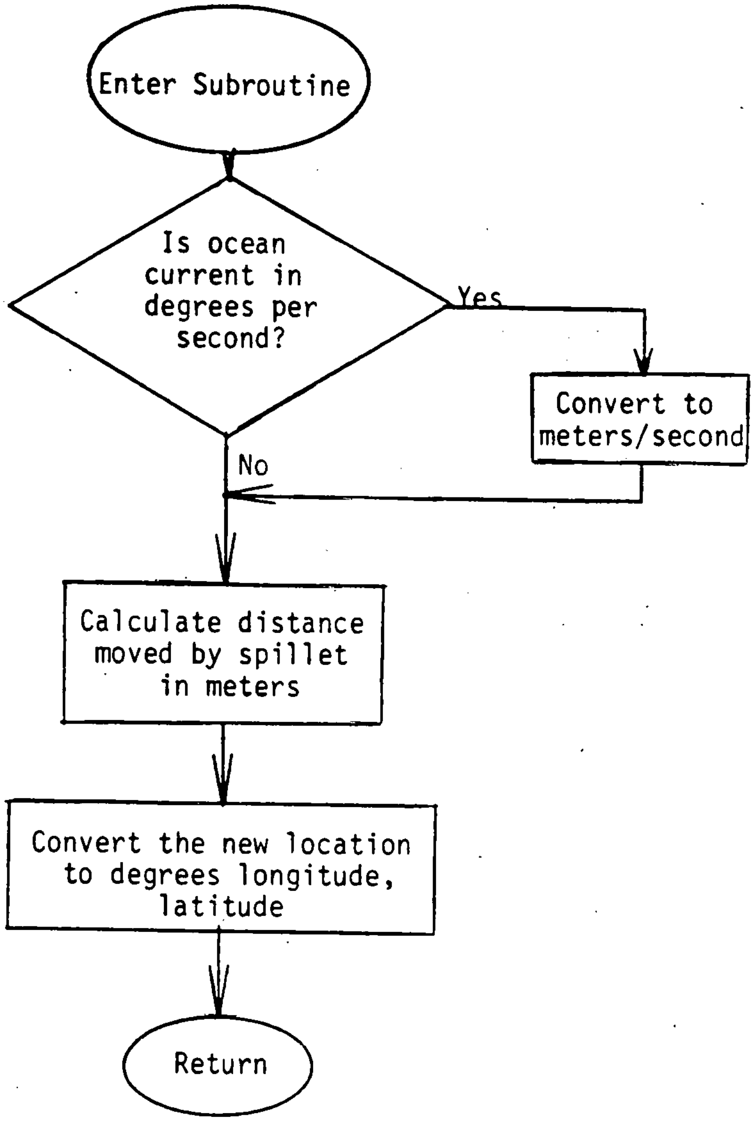


Figure IV. - 33. Flowchart for subroutine SURDFT.

Subroutine SURFES

The simulation model might be viewed as consisting of four major sections: the main program; the input module; the surface module, and; the subsurface module. Each of the last three sections consist of a number of subroutines. The subroutine, SURFES, controls the surface section, calling all of the subroutines that effect the disposition of the surface slick. With the exception of the shoreline interaction process, all processes are treated separately for each spillet, i.e., the subroutine representing a process is called once for each spillet. The flow through this subroutine (see Figure IV-34 for flow chart) is quite straightforward.

CALLED FROM: MAIN

SUBROUTINES CALLED: ASHOR, CLNUP, ENTMAS, ENTRN, EVPOR8, LOC8, SPREAD, SURDFT, TREAT

Important Local Variables:

SUMAS - Amount of mass entering the water column from one spillet during one step.

NDLSPL(NSPIL) - 99 - 0 - spillet is within study area.
1 - spillet is at edge of study area. This spillet is no longer subject to any processes.

MDLSPL - Parameter in subroutine LOC8 which indicates whether or not the spillet is in the study area.
- 0 - within study area
- 1 - out of study area

ENMAS - Mass of oil entrained this step. This is used in the preview run to determine the amount of mass to be represented by each droplet.

UCRNT - Average current over spillet in X direction (m/sec or deg/sec).

VCRNT - Average current over spillet in Y direction (m/sec or deg/sec).

UWIND - Average windspeed over spillet in X direction (m/sec).

VWIND - Average windspeed over spillet in Y direction (m/sec).

WVEL - Total magnitude of windspeed over spillet (m/sec).

DEPLOC - Average depth under spillet (meters).

HTLOC - Average tidal elevation around spillet (meters).

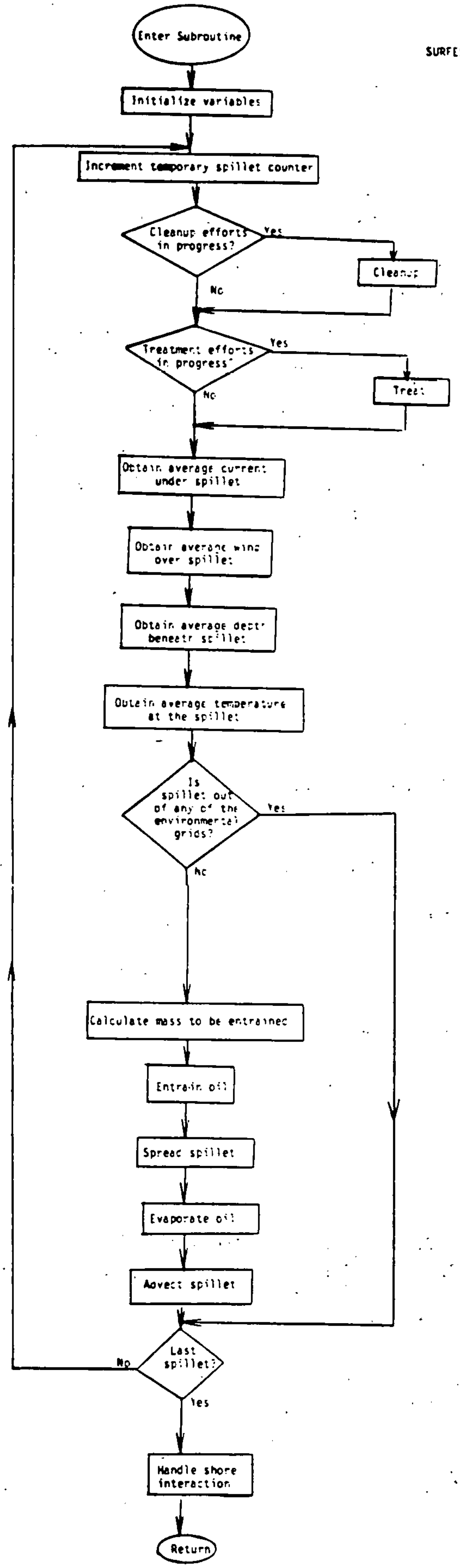


Figure IV.-34. Flowchart for subroutine SURFES.

Subroutine TREAT

This subroutine, see Figure IV-35 for its flow chart, handles the chemical treatment of the surface slicks. A number of treatment efforts may be in progress at any one time. Within range of a treatment effort, spillets are treated in the order in which they occur, i.e., if the fifth, seventh and twelfth spillet fall within range of a treatment effort, the fifth, then the seventh and finally the twelfth would be treated by this effort. If the area treated is less than the area of a spillet, then only a fraction of the spillet is treated and the next treatment effort is dealt with. In this case, the fraction of oil which is dispersed is the ratio of the treated area to the total spillet area. If, on the other hand, the area to be treated is greater than that remaining in the spillet, then it is treated and the next spillet is treated, etc. The percentage of oil dispersed in this case is defined by PCHEM. The area treated is stored and in the next time step, only the remaining untreated area is treated.

CALLED FROM: SURFES

SUBROUTINES CALLED: DIST, REMOV

Important Local Variables:

TRAREA - Area to be treated at this step (meter^2).

DIS - Distance between the center of treatment effort and the center of spillet of interest (meters).

SPAREA - Area of the spillet which has not been treated (meters^2).

PER - Fraction of oil which is entrained.

XMSDP - Mass entrained by this effort (metric tons).

SUMAS - Mass entrained this step (metric tons).

AMNT - Area treated (meters^2).

Subroutine VELC

This routine, Figure IV-36, calculates from the appropriate fixed grids, the water depth, the tide height and the current velocities at each of the corresponding floating grid locations using a bilinear interpolation (see the description of subroutine PARTV for a discussion of the bilinear interpolation). If the floating grid comes too close to the edge of the corresponding fixed grid for proper interpolation, a warning is written. The program will continue to execute but interpolation errors are probable at this point or in other routines of the model. Due to the space staggered system and the possible rotation of some of the grids, each grid is interpolated separately.

CALLED FROM: CNVRTZ, VELCT

SUBROUTINES CALLED: ROTAT

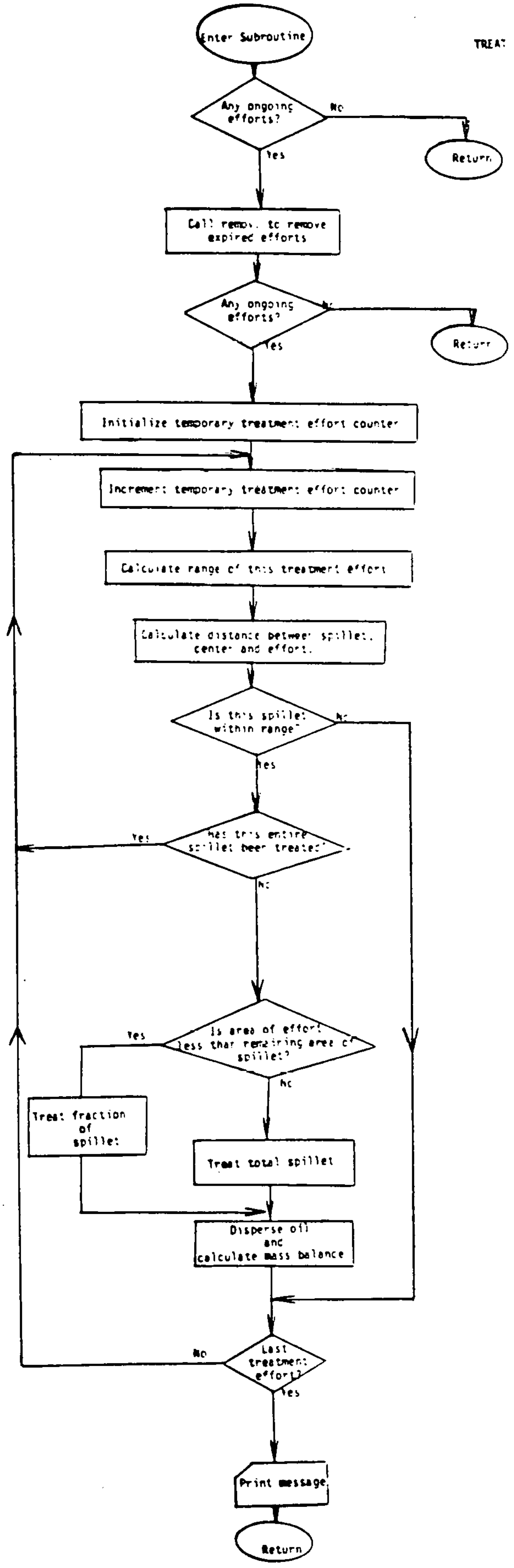


Figure IV.-35. Flowchart for subroutine TREAT.

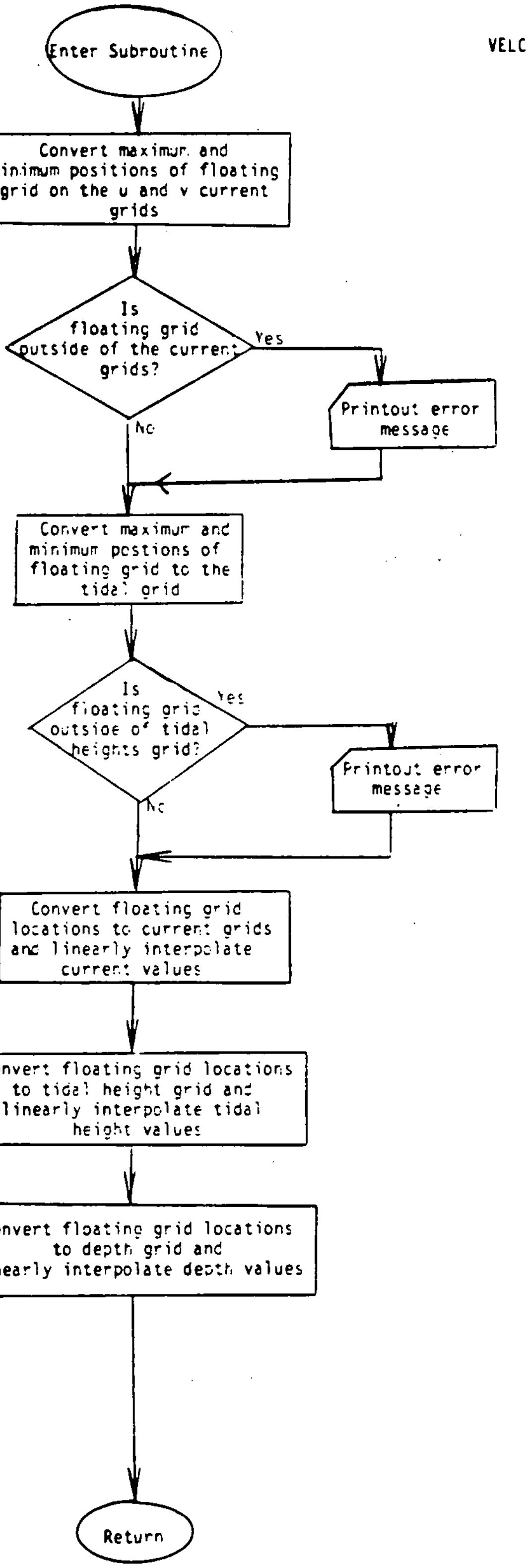


Figure IV. - 36. Flowchart for subroutine VELC.

DIS - Distance between the center of treatment effort and the center of spillet of interest (meters).

SPAREA - Area of the spillet which has not been treated (meters^2).

PER - Fraction of oil which is entrained.

XMSDP - Mass entrained by this effort (metric tons).

SUMAS - Mass entrained this step (metric tons).

AMNT - Area treated (meters^2).

Subroutine VELC

This routine, Figure IV-36, calculates from the appropriate fixed grids, the water depth, the tide height and the current velocities at each of the corresponding floating grid locations using a bilinear interpolation (see the description of subroutine PARTV for a discussion of the bilinear interpolation). If the floating grid comes too close to the edge of the corresponding fixed grid for proper interpolation, a warning is written. The program will continue to execute but interpolation errors are probable at this point or in other routines of the model. Due to the space staggered system and the possible rotation of some of the grids, each grid is interpolated separately.

CALLED FROM: CNURTZ, VELCT

SUBROUTINES CALLED: ROTAT

Important Local Variables: None

Subroutine VELCT

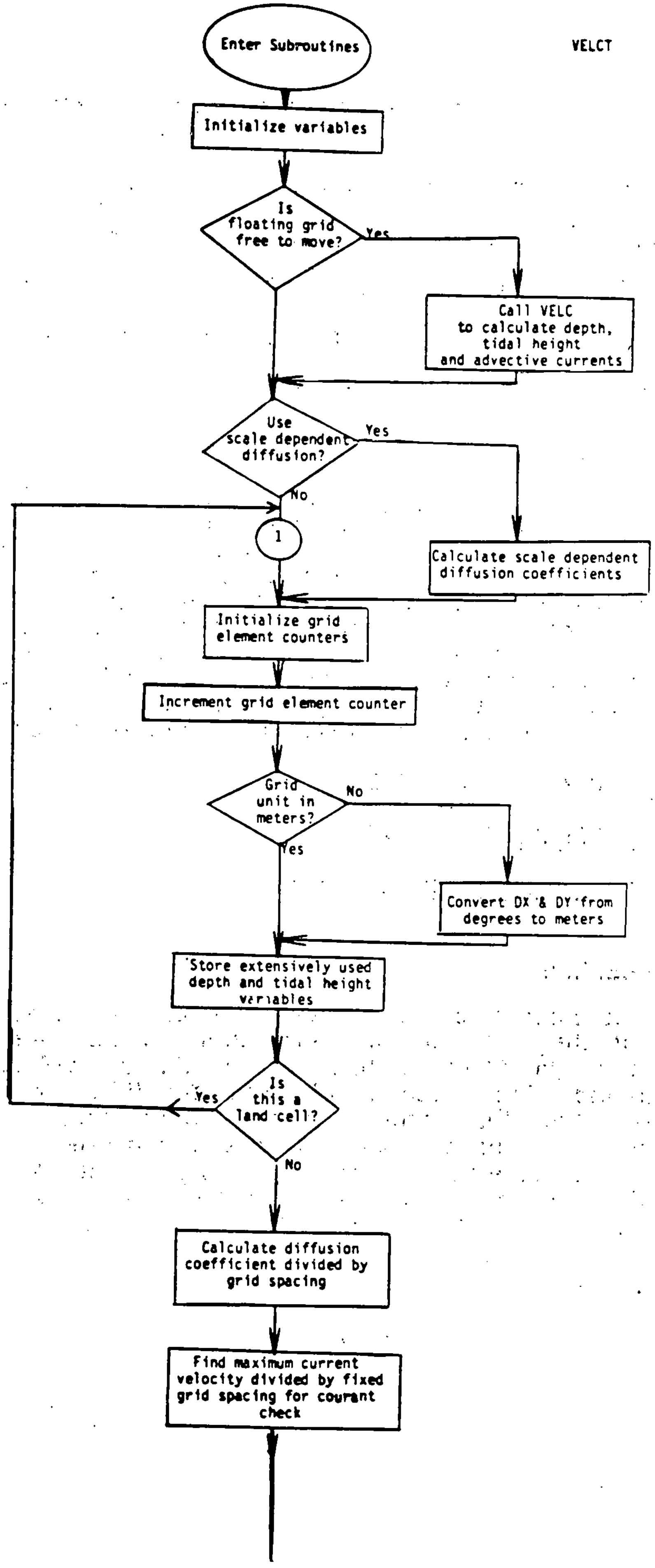
This subroutine, Figure IV-37, calculates the diffusion velocities at each of the grid nodes and adds these to the advective terms. If the number of particles is less than NCRIT, the diffusion velocity is not calculated. The procedure calculates the diffusion coefficients and then locates the four closest concentration nodes. The difference is determined in the X,Y, and Z direction and used to calculate the three velocity components. If the large scale mode is used, the horizontal velocity components must be converted to degrees/sec. The maxiumum advective and diffusive velocities (divided by the grid spacings) are also determined.

CALLED FROM: SUBSUR

SUBROUTINES CALLED: DIFF, VELC

Important Local Variable: None

VELCT


Enter Subroutines
Initialize variables
Is floating grid free to move?
Yes
Call VELC to calculate depth, tidal height and advective currents
Use scale dependent diffusion?
Yes
No
1
Calculate scale dependent diffusion coefficients
Initialize grid element counters
Increment grid element counter
Grid unit in meters?
No
Yes
Convert DX & DY from degrees to meters
Store extensively used depth and tidal height variables
Is this a land cell?
Yes
No
Calculate diffusion coefficient divided by grid spacing
Find maximum current velocity divided by fixed grid spacing for courant check

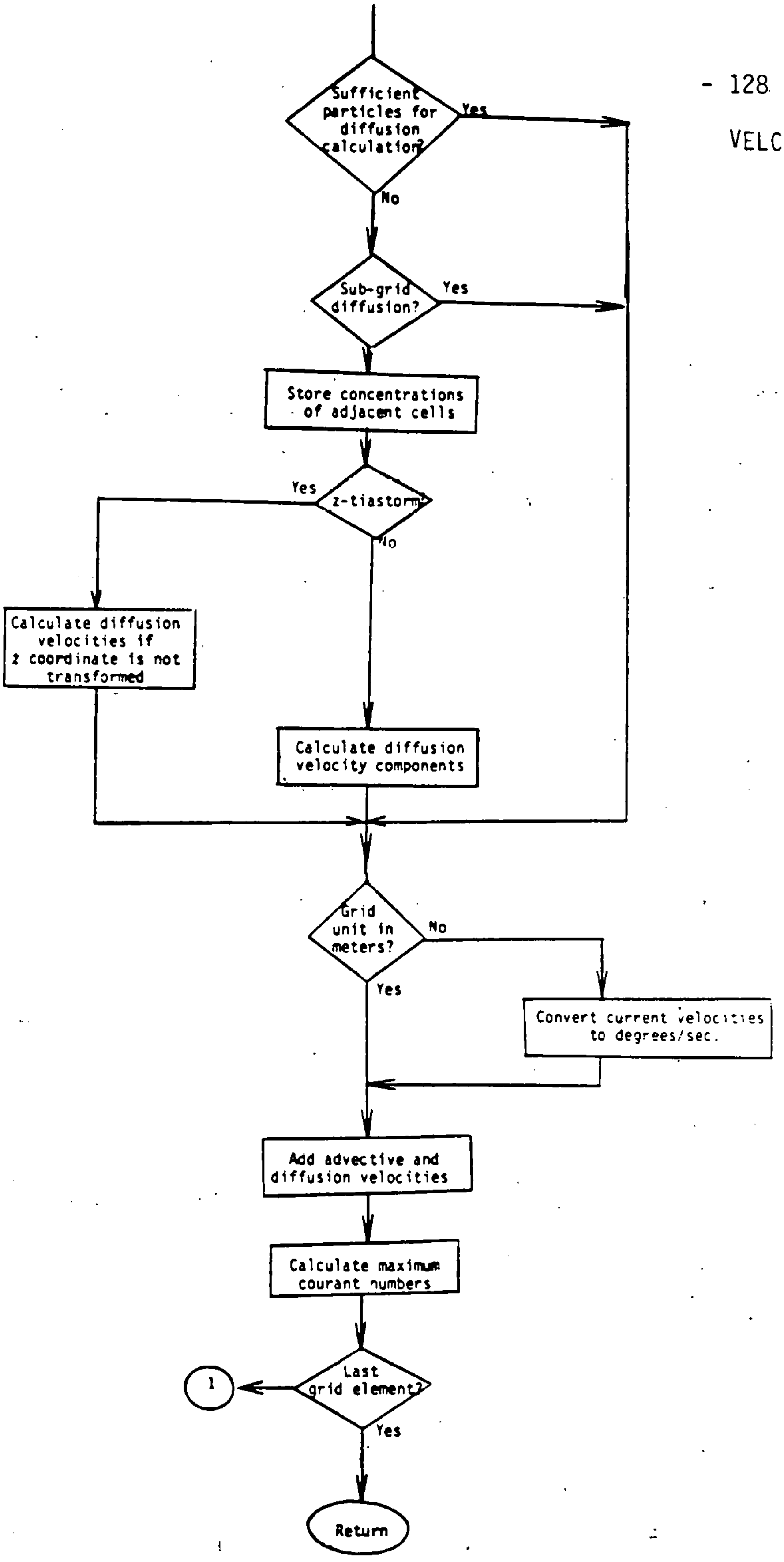


Figure. IV. - 37. Flowchart for subroutine VELCT.

APPENDIX V. Input Programs

This Appendix gives the details necessary to use the input programs GRIDS and CHECDATA.

A. GRIDS

As described in Chapter II, this program serves to format environmental data for input into either a preview run or a complete simulation. The general flow through this program is shown in Figure V-1. The first step is to read the grid control variables i.e., the variables that control the execution of the run. These variables are shown in the upper half (above the dotted line) of Table V - 1 in the order in which GRIDS will read them. The subroutines READI and READF described in Appendix IV are used to input these parameters. The formats required by READI and READF are specified in Appendix I, Section D2.

The next step is to read the grid definition variables, i.e., the variables that define the grid, such as, number of grid elements, the angle of rotation, the various names, etc. This is done in subroutine READU which again uses READI and READF to read fixed and floating point variables, respectively. Two new subroutines are also called in READU; READN2 and READN3. The structure of these subroutines is identical to READF, the only difference being that they are used to input character data, i.e., grid names and units, instead of numerical values. READN2 will enter an 8 character name and READN3 is used to enter a 12 character name. The format for READN2 is:

```
(7X, 2A4, 5X, A8)
```

while that for READN3 is:

```
(3X, 3A4, 5X, A8)
```

These formats are to be compared to that of READF:

```
(F15.5, 5X, A8)
```

The variables input in this step, their order of input and the appropriate input subroutine is shown in the lower half of Table V - 1.

Following the entry of GRID control parameters and environmental definition variables the title of the environment grid is checked to see that it is one of:

'BATHYMETRY'
'TEMPERATURE'
'WIND VEL'
'UTID CURRENT'
'VTID CURRENT'
'TIDE LEVEL'

If the grid title is not one of these spelled exactly as above, an error message is written and the program stops.

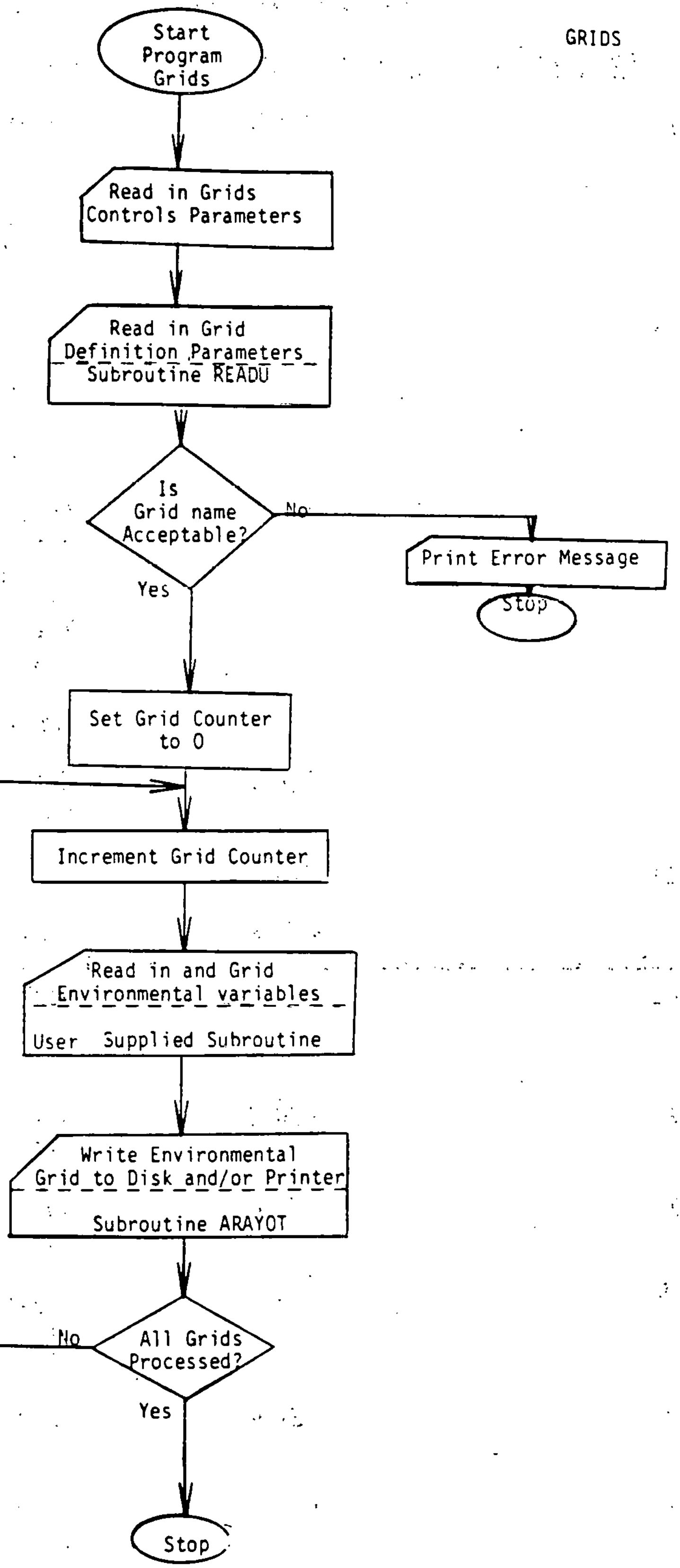


Figure V.-1. Flowchart for input program GRIDS.

Table V - 1. List of Variables for GRIDS
Input Parameters - in order of entrance

Input Parameters	Subroutine used	Description
NPRTA	READI	Print control parameter. -1 - no diagnostic print out 0 - limited print out - prints out line to tell the step and the time. 1 - full print out - formatted print out of what goes to cards, disk or tape.
NO	READI	Number of variables per grid.
NU	READI	Format control for cards or disk printout of environmental grids. 1 - unformatted real variables 2 - unformatted integer variables 3 - formatted real variables 4 - formatted integer variables
NUM	READI	Number of steps to be written out.
ND	READI	Unit number data is to be written to.
NUNIT	READI	Unit number data is to be read from.
DT	READF	Time step between data values.
ISCAL	READI	Control parameter for scale mode. 1 - small scale (meters) 2 - large scale (degrees)
IMAX	READI	Number of elements in the x direction.
JMAX	READI	Number of elements in the y direction.
ANGLE	READF	Angle measured in the counter clockwise direction from East to the positive x-axis (in degrees).
XS,YS	READF	Spacing between grid lines in x and y direction (in meters or degrees).
XL,YL	READF	Location of (1,1) point of the grid (in Longitude and Latitude).
TITLE	READN3	- 12 character variable giving the name of the grid. This must be

		correct in order to print out.
VAR1,VAR2	READN2	8 character variable giving the name of the variable in the grid.
UNITS1,UNITS2	READN3	12 character variable giving the dimensions for print out. If there is only one grid, VARS2 and UNITS2 are not needed.
UNITS3	READN2	8 character variable giving the units of XS and YS.
Other Variables in GRIDS		
NAMCH		Correct titles to be used by the program, if these are not correct and in the order required by the main program, the run will terminate.
ARRAY1,ARRAY2		The values of the grid data when the data is real. If there is only one grid, ARRAY1 is used.
MARAY1,MARAY2		The values of the grid data when the data in integer. If there is only one grid, then MARAY1 is used.

If the grid title is acceptable then a do loop is executed over the number of time steps, NUM, for which the particular grid is to be updated. In this loop, the user supplied subroutine, FIX, is employed to read the environmental data values and then to perform the necessary operations to work them into a rectangular grid.

Finally, this grid is output by the subroutine ARAYOT. This subroutine is an exact duplicate of ARAYIN discussed in Appendix IV except all READ statements have been changed to WRITE statements. The appropriate output formats are described in Appendix I, section A.

A brief summary of the GRIDS and its subroutines is included below.

1) Main Section - This section reads in several input parameters, does a check on the title, then loops over the number of grids to be entered, by the variable NUM.

   Calls Subroutines READI, READU, Fix, and ARAYOT.

2) Subroutine READU Reads in all necessary input variables and units. Calls Subroutines READI, READF, READN3, and READN2.

3) Subroutine FIX -The Subroutine must be written by the user. It reads the environmentaldata and does any necessary calculations or manipulations needed to work the data into a form compatible with the structure of ARRAY1 and/or ARRAY2. In the example, a current data set is read in and converted to degrees/sec.

4) Subroutine ARAYOT - Writes the variables to unit ND in the format defined by the previous parameters.

5) Subroutine READI, READF, READN3, READN2 - reads and checks input parameters. If the spelling is incorrect or the title is not in the correct column, the run terminates.

Formats		
	READI	(I15, 5X, A8)
	READF	(F15.5, 5X, A8
	READN3	(3X, 3A4, 5X, A8
	READN2	(7X, 2A4, 5X, A8)

B. READATA

The purpose of this Subroutine is to verify that the environmental data is in the proper format for input to the preview program or the full simulation. The Subroutine is extremely straight forward. Five control parameters are read specifying the print control, the number of variables per grid (1 or 2), the format of the data, the number of grids (time steps for which the environmental grid is to be updated) to be read and the unit number from which the data is to be read. Table V -¯2 lists all input variables to READATA. All of these variables being fixed point or integer are read in with the Subroutine READI (see Appendix IV for a description of READI and Appendix I, Section 2 for a description of the appropriate format). A do loop is then executed over the number of grids. The interior of this do loop is an exact duplicate of the working part of the Subroutine ARAYIN described in Appendix IV including the checks that are made on the title of the environmental array.

Table V - 2. List of Variables for READATA displayed in order of entrance.

Input Variable	Subroutine Used	Description
NPRTA	READI	Print control parameter (see program GRIDS).
NO	READI	Number of variables per grid.
NU	READI	Format control (see GRIDS).
NUM	READI	Number of steps to be read in.
ND	READI	Unit number form which data is to be read.
ISCAL	READI	Control parameter for scale mode. 1 - small scale (meters) 2 - large scale (degrees)

Appendix VI: Output Programs Descriptions

This appendix is included to provide the user with the details necessary to run the output programs. There are six such programs which are either run independently or in conjunction with one or more of the others. The relationship between the various programs are discussed in Chapter V and will only be repeated here as necessary for their use. All plots are generated with standard CALCOMP software.

A. PLOTMASS

A detailed flow chart for PLOTMASS is presented in Figure VI-1, a simpler flow chart is shown in Figure 8. This program requires two different sets of control parameters in addition to the input data available from the simulation model. One set controls the run itself, specifically how many timesteps are to be used, NST, and the number of simulated data sets to be plotted, NPLOT. These two parameters are read in with the subroutine READI discussed in Appendix IV. The second set of input parameters read as one logical record controls which variables in the mass balance are to be plotted. The format used to read these parameters is given by:

```
    READ (5,200) NUN, NATM, NBIO, NBOT, NCLN, NLOS, NSHR, NSUR, NSUS, NDMP

200 FORMAT (2X,10I4)
```

The meaning of each of these variables is outlined in Table VI-1.

The results of two different runs may readily be compared by specifying NPLOT equal to 2 and NUN equal to 0. The first set of data will then be plotted with solid lines and the second with dashed lines on the same plot.

A second option in this program is to plot the same data set a number of times in different ways on different plots. In this case NPLOT would be set equal to 1 and NUN to 1.

The IBN Job Control Language for the output data set required to run this model is:

```
    // FT F001  DD Ds NAME = MASS. PLOT,
    //          DISP = (NEW,CATLG).
    //          UNIT = SYSDA,
    //          DCB = (RECFM = UBS, BLKSIZE = 1954),
    //          SPACE = (TRK(2,2))
```

An example plot is shown in Appendix VIII.

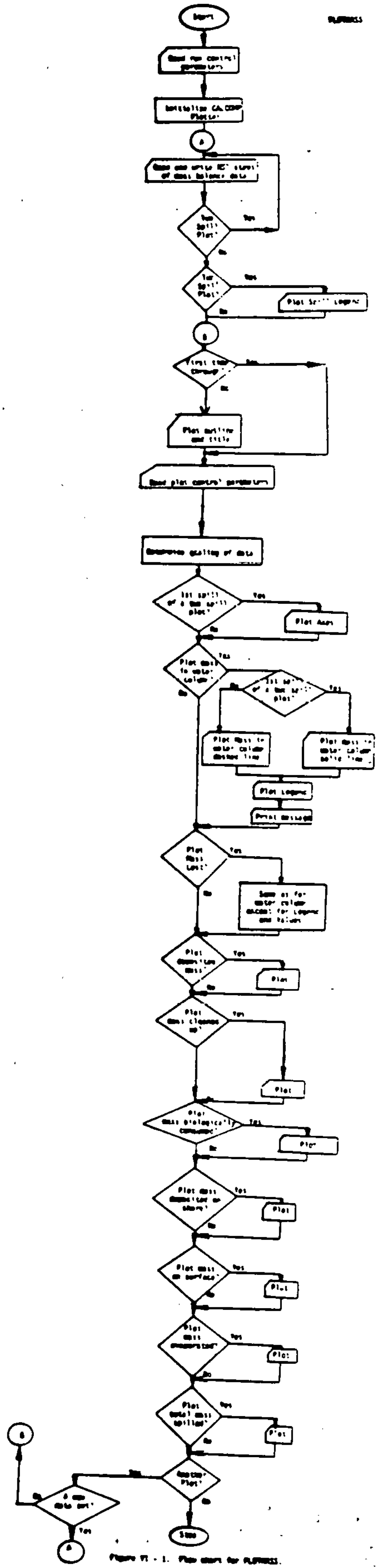


Figure VI - 1. Flow chart for PLOTMASS.

Table VI-1

Input to Plotmass

Variable	Range	Format	Description
NST	1-100	READI	# of model timesteps in plot
NPLOT	1-6	READI	# of data sets on one plot
NUN	0-1	14	0-Use same mass balance data 1-Read in new data
NATM	0-1	14	0-Do not plot mass in atmosphere 1-Plot mass in atmosphere
NBIO	0-1	14	0-Do not plot mass consumed biologically 1-Plot mass consumed biologically
NBOT	0-1	14	0-Do not plot mass deposited on the bottom 1-Plot mass deposited on the bottom
NCLN	0-1	14	0-Do not plot mass cleaned up 1-Plot mass cleaned up
NLOS	0-1	14	0-Do not plot mass lost to an open open boundary 1-Plot mass lost to an open boundary
NSHR	0-1	14	0-do not plot mass deposited on shore 1-Plot mass remaining on the surface
NSUS	0-1	14	0-Do not plot mass in the water column 1-Plot mass in the water column
NDMP	0-1	14	0-Do not plot total mass spilled 1-Plot total mass spilled

Program PARTICLE

This program (Figure VI - 2) is used to change the resolution of a floating grid using data which has been previously written to disk. The particle parameter data set is read in the main program and used by subroutine PRINT. The user specifies the number of grid elements in the X and Y directions. These values are then used to calculate a new floating grid and new concentration values. The new concentration values are then written out to disk for use in the OUTPUT programs. The subroutines used to determine the new grid location and shape, GRIDEX, to calculate the hydrocarbon concentration on this grid, CONC, and to write and print the results of these calculations, PRINT are identical to those used in the main simulation. All three subroutines are described in detail in Appendix IV.

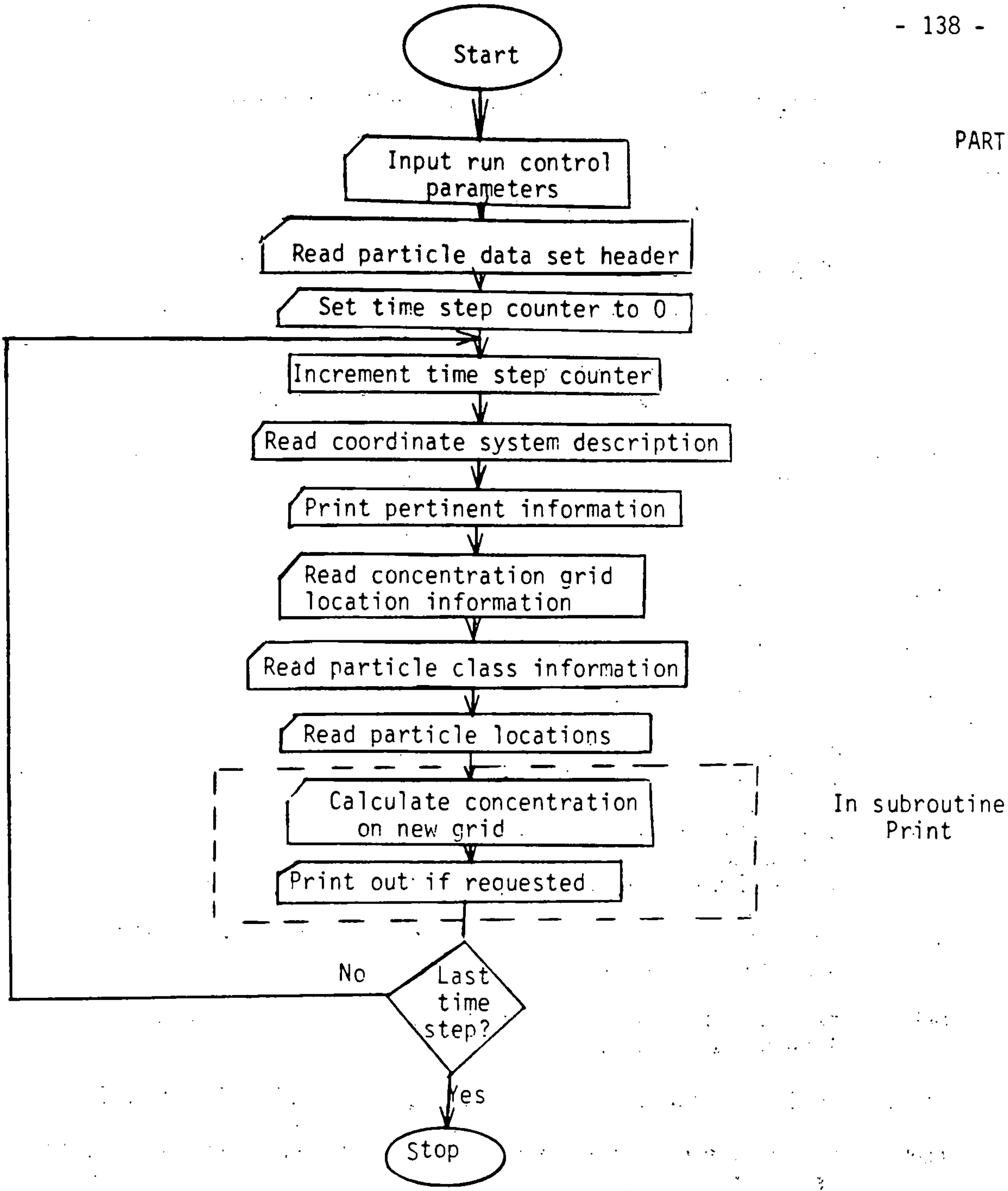


Fig. VI -2 Flow chart for Program PARTICLE

Calls Subroutines CONC, GRIDEX, PRINT, READI AND READN2.

Input Variables (In order)

NMAX - maximum number of particles allowed.

NSTEP - number of time steps this program is to be run.

ISCAL - size scale parameter. This must be the same as the previous simulation run.
  1 - does horizontal calculations in meters.
  2 - does horizontal calculations in degrees.

NPTFLT - print control for floating grid information. This is the print interval in number of steps.

IMSUB - new number of grids in the x direction.

JMSUB - new number of grids in the y direction.

KMSUB - new number of grids in the z (vertical) direction.

KPRTC - concentration print control parameter.

KPRTP - particle position print control parameter, print out at this interval of time steps.

NPRD - disk data set print control parameter.
  0 - no data sets written out this step.
  1 - at least one data set written out this step.

NPRC - concentration disk data set print parameter, write out at this interval of steps.

NPRP - particle disk data set print parameter, write out at this interval of steps.

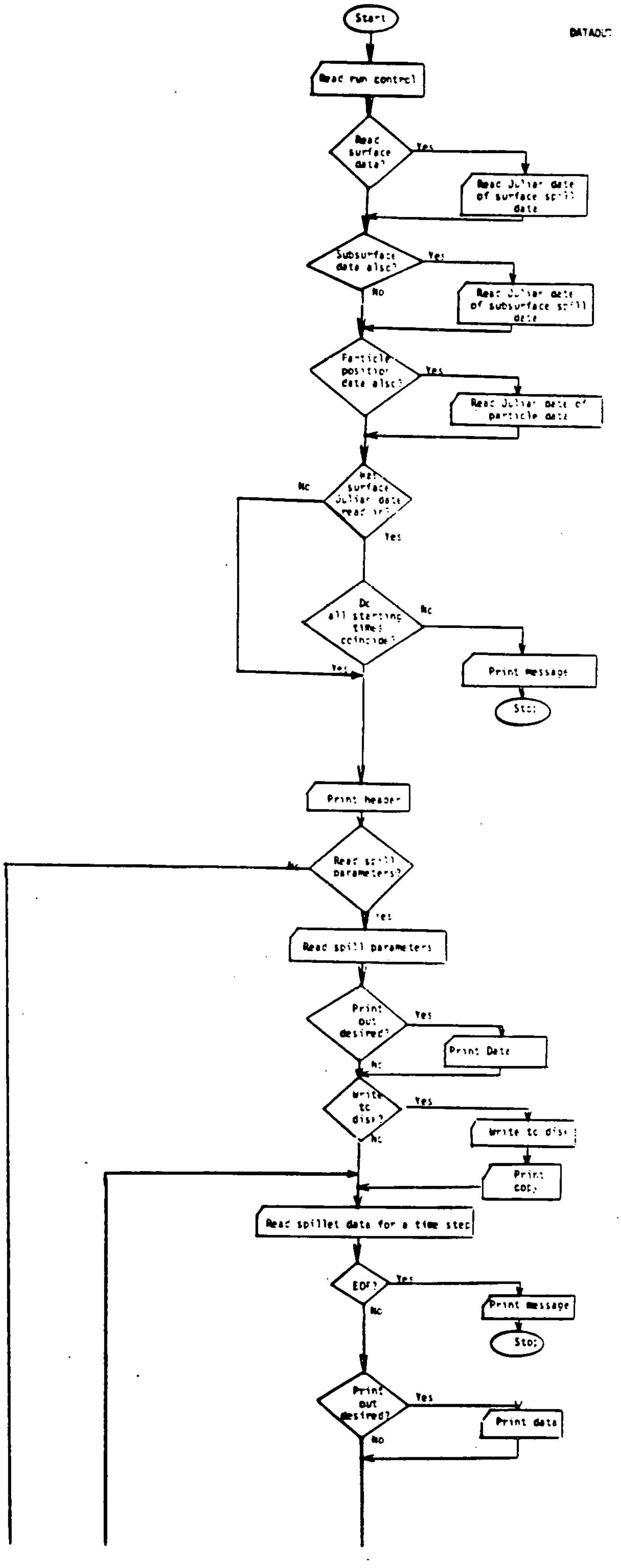
UNITS3 - units of new grid point spacing, e.g., DEGREES, METERS, etc.

NUNCN - the device number to which the new concentration grid is to be written.

NUNPT - the device number from which the particle positions are to be read.

C. DATAOUT

This program, flowcharted in Figure VI-3, is used to prepare data output by the simulation program for input to the surface and subsurface plotting programs. It may also be used to printout the output of the simulation program. The user may select whether this printout is to be simply a copy of the simulation data sets and/or a printout similar to that available from the simulation mode, i.e., formatted for easier interpretation. These options are selected by specifying different combinations of the six run control variables. The run control parameters,


Start
DATAOUT
Read run control
Read surface data?
Yes
Read Julian date of surface spill date
Subsurface data also?
Yes
No
Read Julian date of subsurface spill date
Particle position data also?
Yes
Read Julian date of particle data
Was surface Julian date read in?
No
Yes
Do all starting times coincide?
No
Yes
Print message
Stop
Print header
Read spill parameters?
No
Yes
Read spill parameters
Print out desired?
Yes
No
Print Date
Write to disk?
Yes
No
Write to disk
Print copy
Read spillet data for a time step
EOF?
Yes
No
Print message
Stop
Print out desired?
Yes
No
Print data

DATAOUT CONT'D.

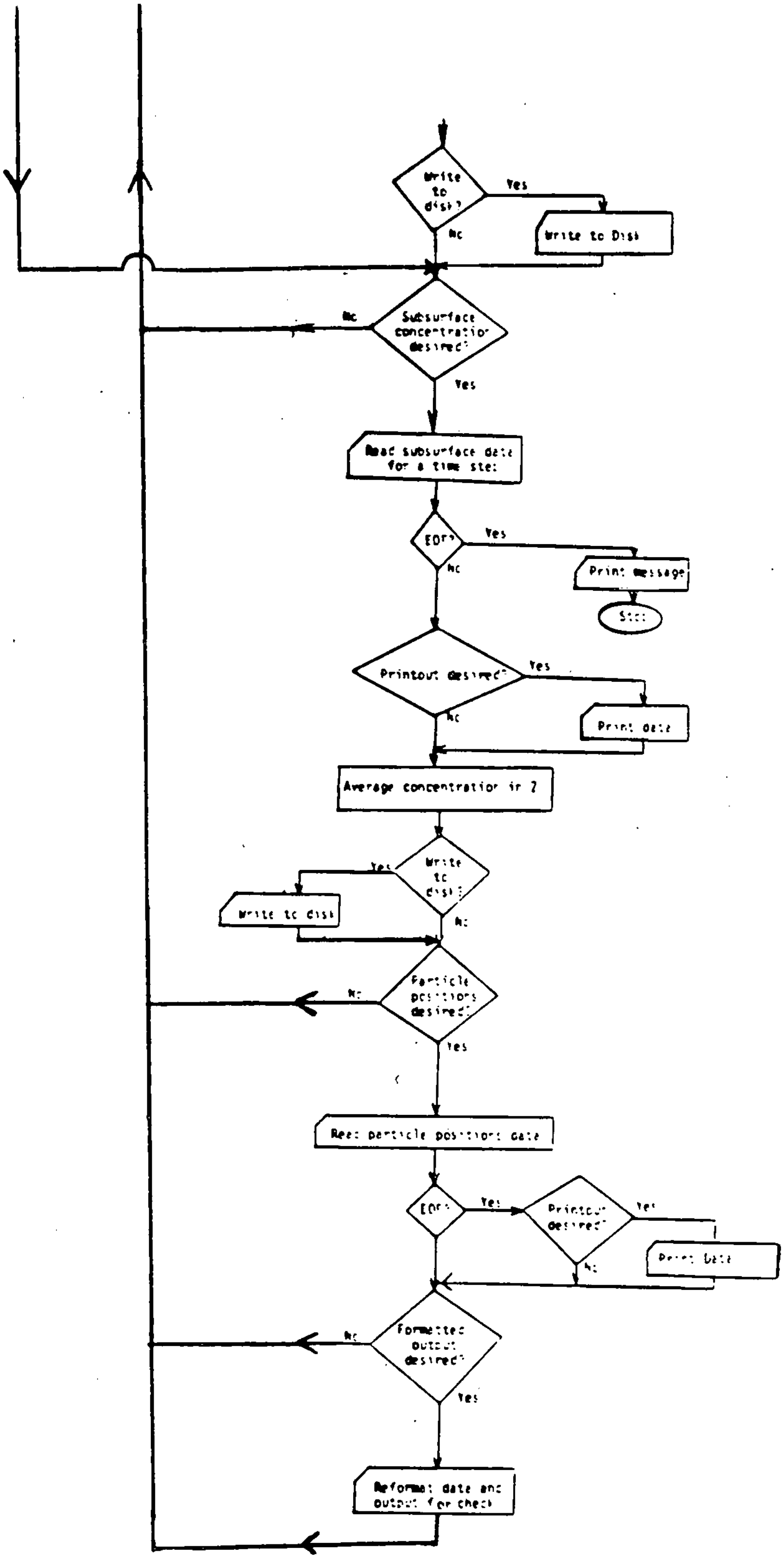


Figure VI - 3. Flow chart for Program DATAOUT.

tabulated in Table VI-2, are read in by the subroutine READI, discussed in Appendix IV. The variable NPRT is used to control the output of this program while the variables NRDSP, NRDCN and NRDPT determine whether or not spillet information, a concentration distribution and/or particle information is to be read. If these variables are zero then the associated data sets are not read. If they are not zero, then their value specifies the unit number from which the data is to be read.

The program will determine all grid elements in the horizontal for which the vertically averaged concentration exceeds the value of the run control parameter: CCUT. The location of these elements is output to the disk data set designated as input to the plotting programs.

The remaining run control parameter, ISCAL, is required by that part of the program calculating the location of the grid elements with a hydrocarbon concentration exceeding CCUT. If ISCAL = 2, the locations are written to disk in longitude and latitude. If ISCAL = 1, the locations are written to disk in meters from the fixed depth grid origin.

The user must supply the run control parameters described above, data set(s) from which the oilspill output data will be written and the data set to which the reconfigured data will be written. This last daa set is unformatted, variable locked. The IBM Data Definition statement defining it is:

```
//FTO FOO1 DD DSN=name, DISP=(NEW,CATLG)

//    DCB=(RECFM=VBS, LRECL=44, BLKSIZE=4404),

//    VOL=SYSDA,SPACE=(4404,(10,10))
```

Input Variables for Program DATAOUT:

NPRT - print control parameter.
- 1 write reduced output to disk.
- 0 no printout.
- 1 print data as read in.
- 2 print data as formatted output.
- 3 print both formatted and as read.

ISCAL - scale mode parameter, must be the same as specified in the original simulation.

NRDSP - print control parameter for spillet data set.
0 - spillet information not read in.
>0 - spillet information read in from this unit number .

NRDCN - print control parameter for concentration data.
0 - concentration data not read in.
>0 - concentration data read in from this unit number.

NRDPT - print control for particle data set.
0 - particles not read in.
>0 - read particle parameters from this unit number.

CCUT - controls the lowest value of concentration to be written out. This is read in as parts per thousand and converted to parts per billion for the printout.

CONC(IMSUB,JMSUB,KMSUB) - 30,30,10 - concentration of the levels of of the water column (ppt).

CC(IMSUB,JMSUB) - 30,30 - averaged concentration over the water column (ppt).

NSUM - number of elements exceeding CCUT.

CT(NSUM) - 899 - concentration of those elements which exceeds CCUT (ppb).

XG(NSUM), YG (SNUM) - longitude and latitude of these concentration values. If AD = 0, these are returned in meters.

THIC - thickness of the spillet (meters).

ZT(MMAX) - transformed depth of particle.

DX,DY - grid spacing in X and Y direction (meters).

X,Y,Z - particle positions.

See common blocks SPIL, PTYP, and DPTH for other variables.

D. Program CHECDATA

This program (figure VI-4) checks the data set output by the program DATAOUT. This data set, which includes the spillet parameters and concentration parameters, is read and printed in an easy to read fashion. The only input parameters required are those which specify the device from which the data is to be read, NUNIT, and the parameter, NRDCN, which specifies whether or not the subsurface concentration grid is included in the input data set. If NRDCN is equal to zero, then the subsurface concentration grid is not included. The program terminates after it has been read and printed all of the data available.

The variables used are the same as in DATAOUT. (Also see common block SPIL).

E. PROGRAM PLOTMAP

This program plots a map of the spilled oil exceeding a given thickness on the surface and exceeding a given concentration beneath the surface. The data is read in for the designated number of steps and the maximum extent of the oil is determined in terms of longitude and latitude. This defines the origin and the conversion factor, SCAL, required to convert degrees of longitude and latitude into plotter coordinates, inces. The routine then loops over the total number of time steps, generating a plot at time step intervals of HR. The spillets are plotted

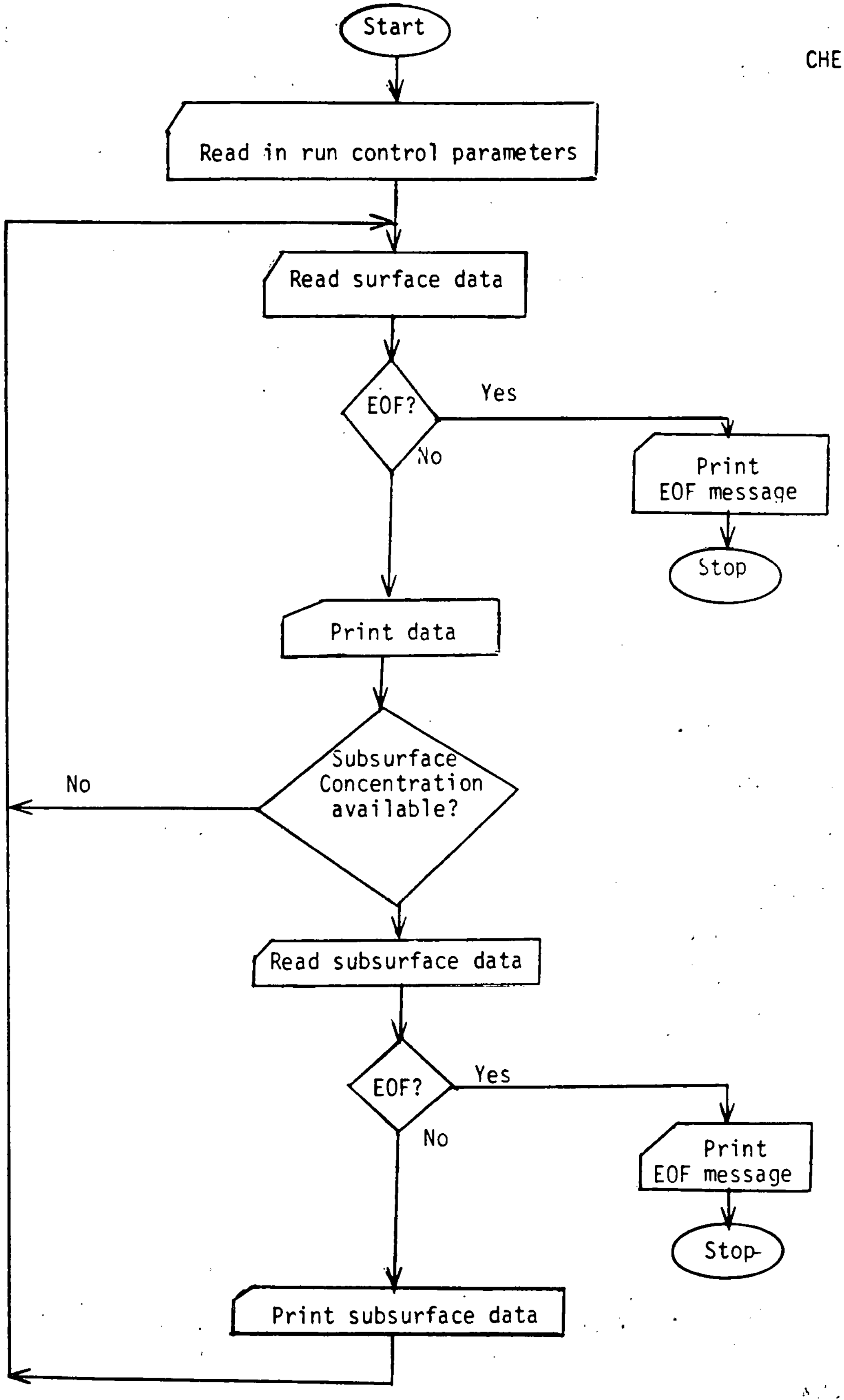


Figure VI - 4. Flow chart for Program CHECDATA.

as circles while the subsurface area exceeding a specified concentration values is outlined. The outline is constructed starting at the north and moving clockwise. The outline is started at the top (north) left hand corner of the concentration values if the floating grid is rotated. The number of data sets to be used is determined by NPLOT and the cases are plotted in order of ascending device number. The routine can only plot a maximum of two cases at one time. The first case is plotted using solid lines and the second case using dashed lines. The legend which includes a scale and other information is plotted in the upper right hand corner. Tick marks for longitude and latitude are drawn around the edges in intervals of a tenth of a degree. An example of such a plot is given in Appendix VIII. The two input parameters XLNG and YLTD give the interval at which the values of longitude and latitude respectively, are to be written. See Figure VI-5 for a flow chart of Plotmap.

A shoreline may be plotted by indicating the number of points to be plotted which is controlled by the parameter NSHOR. Plotmap calls subroutine READI, READF and POSIT in addition to standard CALCOMP routines.

Input Variables for Plotmap:

NPLOT - number of cases which are to be plotted. Tnis indicates the number of input units to be used.

NSTEP - number of steps to be read.

HR - interval for plotting. (Hours)

THICK - minimum thickness of spillet to be plotted (meters).

XLNG - interval between longitude tick marks (degrees).

YLTD - interval between latitude tick marks (degrees).

NRD10 - control parameter for subsurface outline
0 - plot surface spillets only
1 - plot surface and subsurface spillets.

ISCAL - scale mode control parameter
2 - floating grid is not rotated.
1 - floating grid may be rotated.

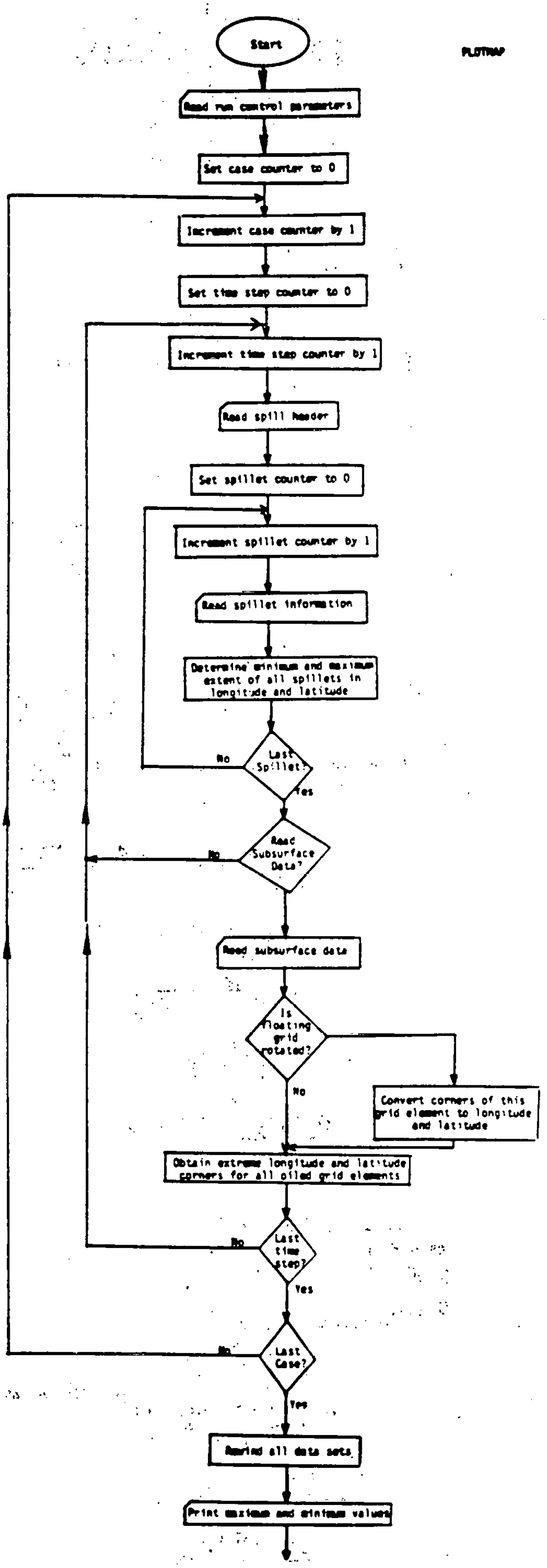
NSHOR - number of shoreline points to be plotted.

Other important variables for PLOTMAP:

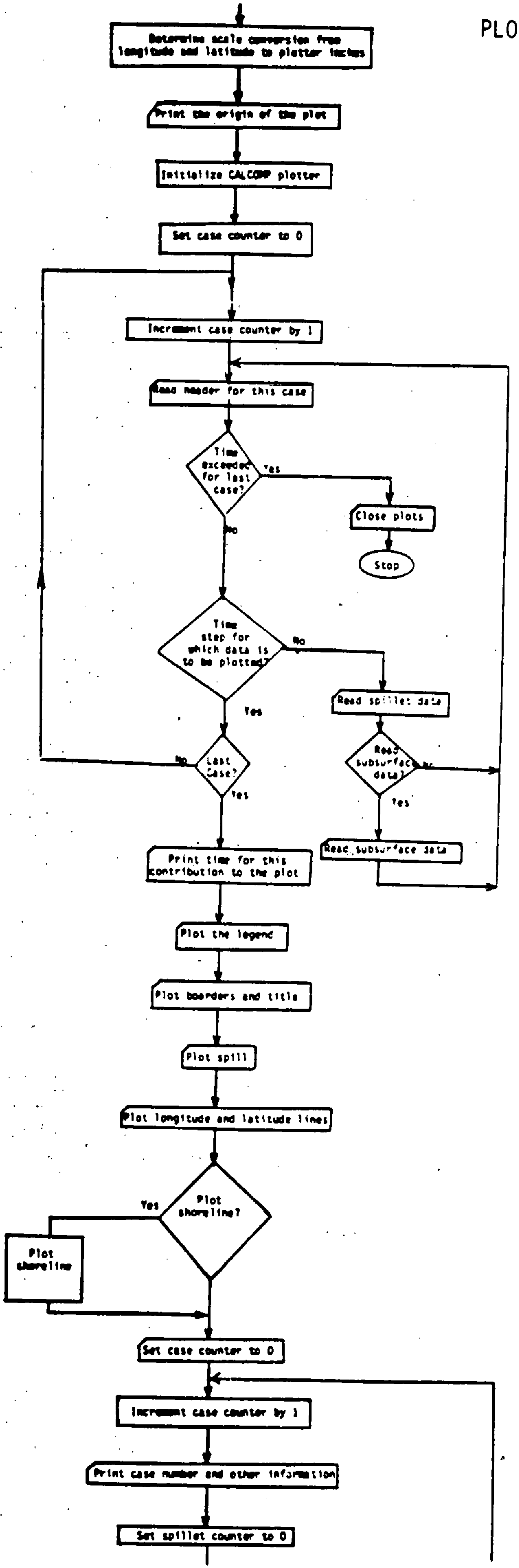
XMIN, XMAX - maximum extent of spillets and subsurface grids in longitude . (If the floating grid is rotated this is in meters).

XMIN, YMAX - maximum extent of spillets and subsurface grids in latitude. (If the floating grid is rotated, this is in meters).

NUMELM - number of elements which exceed the minimum cut.


PLOTMAP
Start
Read run control parameters
Set case counter to 0
Increment case counter by 1
Set time step counter to 0
Increment time step counter by 1
Read spill header
Set spillet counter to 0
Increment spillet counter by 1
Read spillet information
Determine minimum and maximum extent of all spillets in longitude and latitude
Last Spillet?
No
Yes
Read Subsurface Data?
No
Read subsurface data
Is floating grid rotated?
No
Convert corners of this grid element to longitude and latitude
Obtain extreme longitude and latitude corners for all oiled grid elements
Last time step?
No
Yes
Last Case?
No
Yes
Rewind all data sets
Print maximum and minimum values

PLOTMAP CONT'D.



PLOTMAP CONT'D.

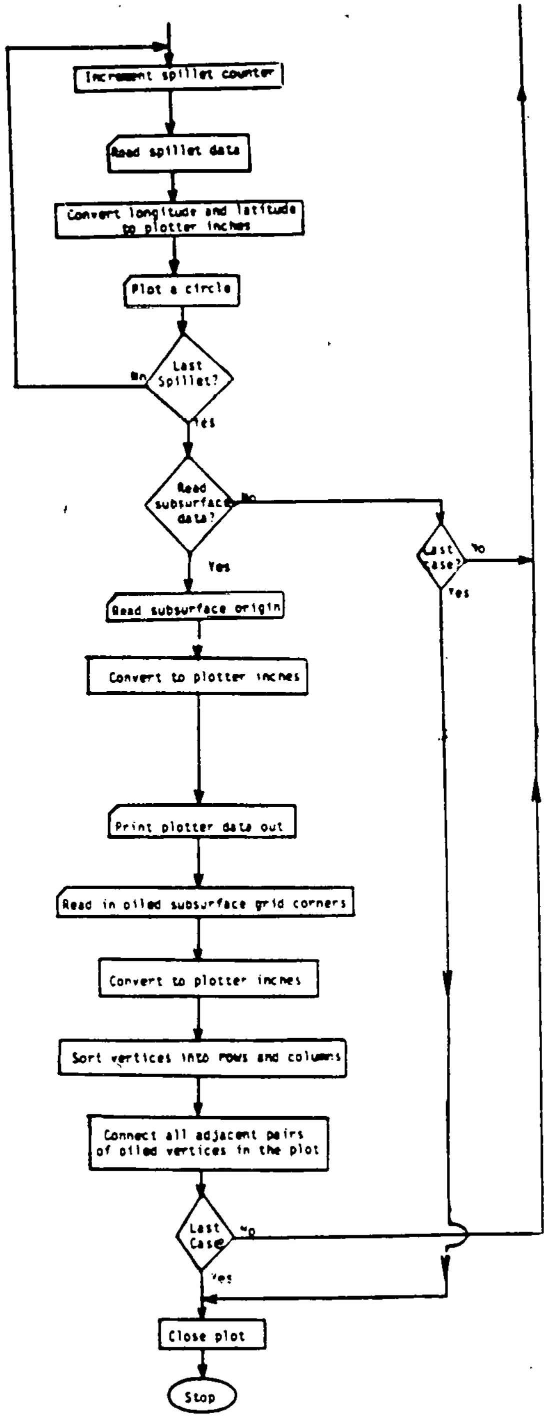


Figure. VI. - 5. Flowchart for Program PLOTMAP.

XSIT, YSIT - site of spill, location of first spillet at time zero is used (longitude and latitude).

XOR, YOR - origin used for plotting, this is located approximately at the middle bottom of the plotted area (longitude and latitude).

SCAL - scale factor for plot (degrees/inch).

XSPIL, YSPIL - center of spillet (longitude and latitude).

RSPIL - radius of spillet (meters).

THIC - thickness of spillet (meters).

XOILMN, XOILMX - minimum and maximum extent of subsurface oil (longitude).

YOILMN, YOILMX - minimum and maximum extent of subsurface oil (latitude).

DXT, DYT - grid spacing of floating grid elements in X and Y direction (meters).

XG, YG - position of grid element (longitude and latitude).

CG - concentration of grid element (ppb).

F. Program PLOTAREA

This program (Figure VI-6) will generate, using standard CALCOMP software, a figure of area covered by the surface and subsurface oil as a function of time. It calculates the area of each spillet but only includes this area if the thickness of the spillet is above the user defined minimum. The user determines which portion to plot by use of the variable, NAR. The subsurface grid areas are added up to determine the area for which the subsurface concentration exceeds some user defined minimum value. The user may display the results of several simulated spills at once, the data to be plotted coming from data sets identified by consecutive unit numbers beginning with 1. Because a scale is involved, the case which covers the most area should be plotted first so that all other curves will remain within the figure borders. The scale is determined from the total area covered at the last time step for the data set on unit one. An example plot is contained in Appendix VIII.

Input Variables for PLOTAREA:

NAR - control parameter.
- 1 plot surface only.
- 0 plot only subsurface area.
- 1 plot surface spillets and subsurface area.

NPLOT - number of cases (or data sets) to be plotted.

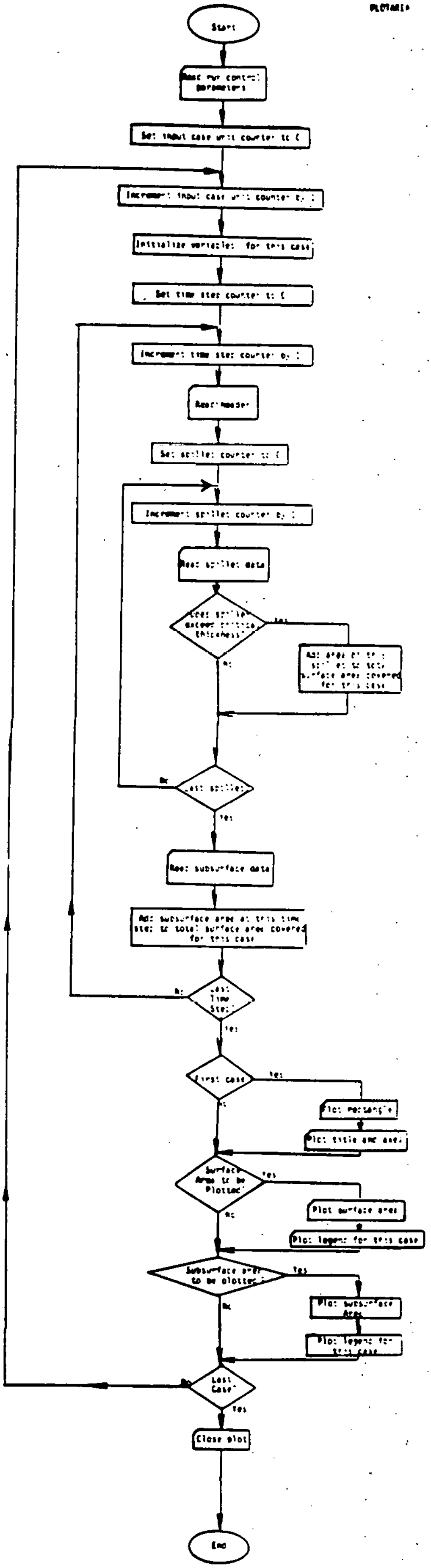


Figure VI. - 6. Flowchart for Program PLOTARIA.

THICK - minimum thickness of spillet to be plotted (meters).

NSTEP - number of steps to be plotted.

Other important variables of PLOTAREA:

TIME (NSTEP) - 103 - time of a model time step.

NSPIL - number of spillets of a model time step.

XSPIL (NSPIL), YSPIL (NSPIL) - 30 - longitude and latitude of spillet center.

RSPIL (NSPIL) - 30 - radius of spillet (meters).

THIC - thickness of spillet (meters).

ASUR (NSTEP) - 50 - area of surface of a model time step (km^2).

ASUB (NSTEP) - 50 - area covered by subsurface of a model time step (km^2).

ATOT (NSTEP - 50 - total area covered at the given model time step (km^2).

XOILMX, XOILMN, YOILMN, YOILMX - maximum extents of subsurface concentration in longitude and latitude.

DX, DY - grid spacing in the X and Y direction (meters).

APPENDIX VII, PROGRAM LISTINGS

In this Appendix, listings of all programs are presented as used for the simulation discussed in Appendix IV. The two input programs are presented first followed by the simulation model and then the five output programs. Note that as presented here the PREVIEW program and the Main Simulation program are the same. If the user wishes to reduce the core requirements, a separate PREVIEW program may be created in which all subsurface routines are removed and the main subsurface routine, SUBSUR, is replaced by a dummy one. The arrays corresponding to the subsurface particle locations and properties should also be reduced to a value of 1.

The JCL listed with these programs is not always accurate. The JCL is compatible with the URI system but it may not be the most efficient. This is especially true for the space parameters and the allocation data set names as these names have been used for previous work. The DD statements at the end of the programs are not always used. The IBM 370 system at the University of Rhode Island uses the symbols //* as a JCL comment statement, thus these statements are ignored.

The program listings are listed in order in columns, as shown in Figure VII-1 through VII-9

COLUMN 1

```
//R2345678 JOB (EXA100),'WRITE GRIDS ON DISK'
//*  EXEC SCRDSN,DSN='URI.EXA1.MARKCR.BITWINT.UDIP'
//*  EXEC DSALLOC
//*DSNAB DD DSN=URI.EXA1.MARKCR.BITWINT.UDIP,DISP=(,CATLG),
//*  UNIT=SYSDA,SPACE=(TRK,(20,10)),
//*  DCB=(RECFM=VBS,BLKSIZE=1954)
//  EXEC FORTGCG,REGION.GO=128K,P1='SYSOUT=(C,,2019)',
//  P3='SYSOUT=(C,,2019)'
//FORT.SYSIN DD *
C
C   THIS PROGRAM PUTS ANY DATA AVAILABLE IN THE PROPER FORMAT
C   FOR USE BY THE MAIN SIMULATION. THIS PROGRAM DOES NOT HAVE
C   TO BE USED BY BY THE USER WHEN RUNNING A SIMULATION BUT
C   CAN BE USED TO FACILITATE DATA HANDLING.
C  THE VARIABLES ARE DESCRIBED IN THE SUBROUTINE
C   ARAYIN WITH THE EXCEPTION OF :
C       NUNIT - THIS IS THE UNIT FROM WHICH THE DATA IS READ.
C       ND    - THIS IS THE UNIT TO WHICH THE DATA IS WRITTEN.
C       NUM   - THIS IS THE NUMBER OF STEPS TO BE WRITTEN.
C ...............................................................
       COMMON /DATA/  NAM(3), VAR1(2), ND, NUNIT, ISCAL,
      1      VAR2(2), UNITS1(3), UNITS2(3), UNITS3(2),
      1       IMAX, JMAX, ANGLE, XL, YL, XS, YS
        EQUIVALENCE (MARAY1(1,1),ARRAY1(1,1))
        EQUIVALENCE (MARAY2(1,1),ARRAY2(1,1))
       DIMENSION NMRCH(6,3)
       DIMENSION ARRAY1(30,30),ARRAY2(30,30),MARAY1(30,30),MARAY2(30,30)
       DATA TIME, NW /0.0, 6/
       DATA NARCH(1,1),NARCH(1,2),NARCH(1,3)/'BATH','YMET','RY  '/
       DATA NARCH(2,1),NARCH(2,2),NARCH(2,3)/'TEMP','ERAT','URE '/
       DATA NARCH(3,1),NARCH(3,2),NARCH(3,3)/'WIND',' VEL','    '/
       DATA NARCH(4,1),NARCH(4,2),NARCH(4,3)/'UTID',' CUR','RENT'/
       DATA NARCH(5,1),NARCH(5,2),NARCH(5,3)/'VTID',' CUR','RENT'/
       DATA NARCH(6,1),NARCH(6,2),NARCH(6,3)/'TIDE',' LEV','EL  '/
C
C READ THE INFORMATION NEEDED FOR UNITS
C
         WRITE(NW,447)
 447     FORMAT('1      INPUT PARAMETERS')
C
         CALL READI( NPRTA, 'NPRTA    ', -1, 1)
         CALL READI(    NO, 'NO       ', 1, 2)
         CALL READI(    NU, 'NU       ', 1, 4)
         CALL READI(   NUM, 'NUM      ', 1, 900)
         CALL READI( NI, 'ND       ', 1, 19)
         CALL READI( NUNIT, 'NUNIT    ', 1, 19)
         CALL READF( DT, 'DT       ')
C
C  READ IN GRID DEFINITIONS
C
         CALL READU(NO)
C
C  TEST TO SEE IF THE TITLES ARE RIGHT
C
        DO 600 I=1,6
        IF((NAM(1).EQ.NARCH(I,1)).AND.(NAM(2).EQ.NARCH(I,2)).AND.
     1  (NAM(3).EQ.NARCH(I,3))) GO TO 601
 600    CONTINUE
        WRITE(NW,69) NAM


 69     FORMAT(2X,' TITLES DO NOT MATCH', 3A4, ' READ IN')
        STOP
 601    CONTINUE
C
C DO LOOP OVER STEPS FOR COMPUTATIONS AND WRITING
C
      DO 70 KK=1,NUM
      CALL FIX(KK,ARRAY1,ARRAY2,MARAY1,MARAY2)
      CALL ARAYOT ( NPRTA, NO, NUM, ND, TIME,
     1  ARRAY1, ARRAY2, MARAY1, MARAY2)
      TIME = TIME + DT
 70   CONTINUE
      STOP
      END
      SUBROUTINE READU(NO)
C
C  THIS READS FROM UNIT 5 ALL THE UNITS AND CONSTANTS
C
C...............................................................
       COMMON /DATA/  NAM(3), VAR1(2), ND, NUNIT, ISCAL,
     1      VAR2(2), UNITS1(3), UNITS2(3), UNITS3(2),
     2       IMAX, JMAX, ANGLE, XL, YL, XS, YS
C
C  READ IN INFORMATION
        CALL READI( ISCAL, 'ISCAL    ', 1, 2)
         CALL READI( IMAX, 'IMAX     ', 1, 30)
        CALL READI( JMAX, 'JMAX     ', 1, 30)
        CALL READF(  ANGLE, 'ANGLE    ')
        CALL READF( XS, 'XS       ')
        CALL READF( YS, 'YS       ')
        CALL READF( XL, 'XL       ')
        CALL READF( YL, 'YL       ')
        CALL READN3( NAM, 'TITLE    ')
        CALL READN2( VAR1, 'VAR1     ')
        CALL READN3( UNITS1,'UNITS1   ')
       CALL READN2( UNITS3, 'UNITS3   ')
        IF(NO.EQ.1) RETURN
       CALL READN2( VAR2, 'VAR2     ')
       CALL READN3( UNITS2, 'UNITS2   ')
       RETURN
       END
       SUBROUTINE FIX(KK,ARRAY1,ARRAY2,MARAY1,MARAY2)
C
C  THIS SUBROUTINE PERFORMS THE NECESSARY STEPS TO
C  READ THE DATA NEEDED FOR ARAYOT
C
       DIMENSION ARRAY1(30,30),ARRAY2(30,30),MARAY1(30,30),MARAY2(30,30)
      COMMON /DATA/  NAM(3), VAR1(2), ND, NUNIT, ISCAL,
     1     VAR2(2), UNITS1(3), UNITS2(3), UNITS3(2),
     2      IMAX, JMAX, ANGLE, XL, YL, XS, YS
        DATA ICT / 0 /
      PI = 3.14159
      SCAL = 6371.0*1000.0*PI/180.0
C
        DO 800 I=1,IMAX
 500    FORMAT(15F6.2)
        READ(NUNIT,500) (ARRAY1(I,J),J=1,JMAX)
 800    CONTINUE
        DO 801 I=1,IMAX
        READ(NUNIT,500) (ARRAY2(I,J),J=1,JMAX)
```

COLUMN 2

```
 801    CONTINUE
C
C  THIS SECTION CONVERTS THE ARRAY FROM METERS/SEC TO
C  DEGREES/SEC IF NEEDED.
       IF(ISCAL.EQ.1) RETURN
       DO 900 I=1,IMAX
       YLAT = YL
       DO 901 J=1,JMAX
       ARRAY1(I,J) = ARRAY1(I,J)/(SCAL*COS(YLAT/57.296))
       ARRAY2(I,J) = ARRAY2(I,J)/SCAL
       YLAT = YLAT + YS
 901   CONTINUE
 900   CONTINUE
       RETURN
       END
      SUBROUTINE ARAYOT ( NPRTA, NO, NUM, ND, TIME,
     1   ARRAY1, ARRAY2, MARAY1, MARAY2)
C              SUBROUTINE DESCRIPTION
C
C     THIS SUBROUTINE READS IN ONE OF TWO ARRAYS FOR THE VARIOUS
C   GRIDS USED IN THE PROGRAM, SPECIFICALLY THE DEPTH GRID, THE
C   WIND VELOCITY GRID, THE TEMPERATURE GRID AND THE SEA STATE
C   GRID.
C
C              VARIABLE DESCRIPTION
C
C     SUBROUTINE ARGUMENTS
C
C   (1) NU     - FORMAT CONTROL: 1 - UNFORMATTED REAL;
C                                2 - UNFORMATTED INTEGER;
C                                3 - FORMATTED REAL;
C                                4 - FORMATTED INTEGER.
C   (3) NO     - # OF ARRAYS TO BE READ IN.
C   (4) NAME   - DESCRIPTOR FOR VARIABLE TO BE READ IN.
C   (5) ARRAY1 - FIRST ARRAY READ IN.
C   (6) ARRAY2 - SECOND ARRAY READ IN.
C   (7) IMAX   - # OF ELEMENTS IN X IN THE INPUT ARRAYS.
C   (8) JMAX   - # OF ELEMENTS IN Y IN THE INPUT ARRAYS.
C   (9) ANGLE  - ANGLE BETWEEN THE X AXIS FOR THE INPUT VARIABLES
C                AND LINES OF CONSTANT LATITUDE.
C   (10) XL     - LONGITUDE OF THE ORIGIN OF THE FLOATING GRID.
C   (11) YL     - LATITUDE OF THE ORIGIN OF THE FLOATING GRID.
C   (12) XS     - GRID SPACING IN X.
C   (13) YS     - GRID SPACING IN Y.
C   (14) MARYA1 - EQUIVALENCED TO ARRAY1 IN THE CALLING PROGRAM.
C   (30) MARAY2 - EQUIVALENCED TO ARRAY2 IN THE CALLING PROGRAM.
C
C     OTHER VARIABLES USED IN THE SUBROUTINE
C
C   NAM    - THE DESCRIPTOR OF THE INPUT VARIABLE STORED
C              WITH THE DATA.
C   VAR1   -2- NAME OF ARRAY1 TO BE USED IN PRINTOUT HEADER.
C   VAR2   -2- NAME OF ARRAY2 TO BE USED IN PRINTOUT HEADER.
C   UNITS1 -3- UNITS OF ARRAY1 TO BE USED IN PRINTOUT HEADER.
C   UNITS2 -3- UNITS OF ARRAY2 TO BE USED IN PRINTOUT HEADER.
C
C     NOTE 1: THE ARRAYS ARRAY1 AND ARRAY2 ARE EQUIVALENCED IN THE
C             MAIN PROGRAM TO THE ARRAYS MARAY1 AND MARAY2. THE
C             PARAMETER NU DETERMINES IF AN INTEGER OR A FLOATING
C             POINT VALUE IS TO BE READ IN.


C
C...............................................................
C
C              DIMENSION STATEMENTS
C
      DIMENSION KX(15), ARRAY1(30,30), ARRAY2(30,30),
     1  MARAY1(30,30), MARAY2(30,30)
      DIMENSION ARAY1T(30,30), ARAY2T(30,30)
      COMMON /DATA/  NAM(3), VAR1(2), ND, NUNIT, ISCAL,
     1     VAR2(2), UNITS1(3), UNITS2(3), UNITS3(2),
     2    IMAX, JMAX, ANGLE, XL, YL, XS, YS
C
C              DATA STATEMENTS
C
      DATA PI, NW, NPT / 3.14159, 6, 1/
      DATA KX/ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15/
      DATA NAB1, NAB2 /'UTID', 'VTID'/
C
C              S T A R T   H E R E
C
C  DETERMINE DIMENSIONS OF GRIDS
C
C
C   READ IN GRID DEFINITION VARIABLES (FORMATTED).
C
      IF(NU.LE.2) GO TO 20
      WRITE (ND,100) NAM, VAR1, UNITS1, VAR2, UNITS2
 100  FORMAT(13A4)
      WRITE (ND,105) IMAX, JMAX, ANGLE, XL, YL, XS, YS, UNITS3
 105  FORMAT(2I5,3F10.6,2F10.2,2A4)
      GO TO 25
C
C   READ IN GRID DEFINITION VARIABLES (UNFORMATTED).
C
 20   CONTINUE
      WRITE (ND) NAM, VAR1, UNITS1, VAR2, UNITS2
      WRITE (ND) IMAX, JMAX, ANGLE, XL, YL, XS, YS, UNITS3
C
C   CHECK THAT THIS IS THE DATA REQUESTED.
C
 25   CONTINUE
      IF(NPRTA) 10,11,12
C
C   WRITE GRID DEFINITION VARIABLES AND HEADER IF OUTPUT REQUESTED.
C
 12   CONTINUE
      PRIT = TIME / 3600.0
      WRITE (NW,200) NAM, PRIT, NAM, IMAX, XS, UNITS3, JMAX, YS, UNITS3
 200  FORMAT('1',40X,3A4,' INPUT DATA ',F10.2,'  HOURS  AFTER',
    1        ' THE BEGINNING OF THE SPILL'//4X,'THE ',3A4,
    2        ' GRID HAS ',I5,' DIVISIONS IN X SPACED ',G12.3,
    3        2A4,' APART'/26X,'AND ',I5,
    4        ' DIVISIONS IN Y SPACED ',G12.3,2A4,' APART.'/)
      WRITE (NW,210) NAM, XL, YL
 210  FORMAT(4X,'THE (1,1) GRID LOCATION OF THE ',3A4,
    1        ' COORDINATE SYSTEM IS AT ',
    1        F10.6,' DEGREES LONGITUDE AND ',F10.6,
    2        ' DEGREES LATITUDE.'/)
      IF(ANGLE.NE.0.0) WRITE (NW,215) NAM, ANGLE
 215  FORMAT(4X,'FINALLY THE X AXIS OF THE ',3A4,
```

Figure VII.-1. GRIDS

```
     1         ' GRID MAKES AN ANGLE (COUNTERCLOCKWISE) OF',F10.6,
     2         ' DEGREES WITH LINES OF'/4X,'CONSTANT LATITUDE.')
      ANGLE = ANGLE * PI / 180.0
      GO TO 10
C
C   HERE ONLY IF THE SHORT DIAGNOSTIC FORM IS DESIRED.
C
 11   CONTINUE
      WRITE (NW,230) NAM, TIME
 230  FORMAT(4X,'NEW ',3A4,' INFORMATION IS BEING READ IN',F10.2,
     1         ' SECONDS INTO THE SPILL')
C
C   HERE TO READ IN THE DATA.
C
 10   CONTINUE
C
C   BRANCH TO READ DIFFERENT FORMAT TYPES.
C
      GO TO (40,50,60,70), NU
C
C   HERE TO READ UNFORMATTED REAL VARIABLES.
C
 40   CONTINUE
      WRITE (ND) ((ARRAY1(I,J),I=1,IMAX),J=1,JMAX)
      IF(NC.EQ.1) GO TO 80
      WRITE (ND) ((ARRAY2(I,J),I=1,IMAX),J=1,JMAX)
      GO TO 80
C
C   HERE TO READ UNFORMATTED INTEGER VARIABLES.
C
 50   CONTINUE
      WRITE (ND) ((NARAY1(I,J),I=1,IMAX),J=1,JMAX)
      IF(NC.EQ.1) GO TO 90
      WRITE (ND) ((NARAY2(I,J),I=1,IMAX),J=1,JMAX)
      GO TO 90
C
C   HERE TO READ FORMATTED REAL VARIABLES.
C
 60   CONTINUE
      DO 62 J=1,JMAX
         WRITE (ND,110) (ARRAY1(I,J),I=1,IMAX)
 110     FORMAT(10F6.2)
 62   CONTINUE
      IF(NC.EQ.1) GO TO 80
      DO 64 J=1,JMAX
         WRITE (ND,110) (ARRAY2(I,J),I=1,IMAX)
 64   CONTINUE
      GO TO 80
C
C   HERE TO READ FORMATTED INTEGER VARIABLES.
C
 70   CONTINUE
      DO 72 J=1,JMAX
         WRITE (ND,120) (NARAY1(I,J),I=1,IMAX)
 120     FORMAT(30I4)
 72   CONTINUE
      IF(NC.EQ.1) GO TO 90
      DO 74 J=1,JMAX
         WRITE (ND,120) (NARAY2(I,J),I=1,IMAX)
 74   CONTINUE



      GO TO 90
C
C   HERE TO PRINT REAL ARRAYS.
C
 80   CONTINUE
      IF(NPRTA.LE.0) RETURN
      DO 96 I=1,IMAX
      DO 96 J=1,JMAX
      ARAY1T(I,J) = ARRAY1(I,J)
 96   ARAY2T(I,J) = ARRAY2(I,J)
      NPT = 0
C
C  HERE TO SCALE VALUES FOR PRINTOUT IF ISCAL = 1
C
      IF(ISCAL.EQ.1) GO TO 56
      IF(NAM(1).EQ.NAM1) GO TO 55
      IF(NAM(1).NE.NAM2) GO TO 56
 55   NPT = 0
      WRITE(NW,24)
 24   FORMAT(2X,' ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED',
     1  ' BY 10 ** -6')
 56   CONTINUE
      IMAXX = IMAX
      IF(IMAXX.GT.15) IMAXX = 15
      WRITE (NW,220) VAR1, UNITS1, (NX(II),II=1,IMAXX)
 220  FORMAT(//50X,2A4,' VALUES IN UNITS OF ',3A4//4X,'Y',55X,
     1     'X ELEMENTS'/1X,'ELEMENTS',1X,15(I2,6X)//)
      IF(NPT.NE.1) GO TO 77
      DO 71 I=1,IMAX
      DO 71 J=1,JMAX
 71   ARAY1T(I,J) = ARAY1T(I,J) * (10**6.0)
 77   CONTINUE
      J = JMAX + 1
      DO 82 K=1,JMAX
         J = J - 1
         WRITE (NW,240) J, (ARAY1T(I,J),I=1,IMAX)
 240     FORMAT('0',I4,5X,15G8.1/(8X,15G8.1))
 82   CONTINUE
      IF(NC.EQ.1) RETURN
      WRITE (NW,220) VAR2, UNITS2, (NX(II),II=1,IMAXX)
      IF(NPT.NE.1) GO TO 79
      DO 76 I=1,IMAX
      DO 76 J=1,JMAX
 76   ARAY2T(I,J) = ARAY2T(I,J) * (10**6)
 79   CONTINUE
      J = JMAX + 1
      DO 84 K=1,JMAX
         J = J - 1
         WRITE (NW,240) J, (ARAY2T(I,J),I=1,IMAX)
 84   CONTINUE
      RETURN
C
C   HERE TO PRINT INTEGER ARRAYS.
C
 90   CONTINUE
      IF(NPRTA.LE.0) RETURN
      IMAXX = IMAX
      IF(IMAXX.GT.15) IMAXX = 15
      WRITE (NW,220) VAR1, UNITS1, (NX(II),II=1,IMAXX)
      J = JMAX + 1
```

```
      STOP
 100  WRITE (NW,30) X, INAME
  30  FORMAT(6X,3A4,5X,A8)
      RETURN
      END
      SUBROUTINE READN2( X, INAME)
      DIMENSION X(2)
      REAL*8 INAME, IPNAME
      DATA NR,NW/5,6/
      READ (NR,10) X, IPNAME
  10  FORMAT(7X,2A4,5X,A8)
      IF(INAME.EQ.IPNAME) GO TO 100
      WRITE (NW,20) IPNAME, INAME
  20  FORMAT(21H CARDS OUT OF ORDER. ,A8,6H READ ,A8,10H REQUESTED)
      STOP
 100  WRITE (NW,30) X, INAME
  30  FORMAT(9X,2A4,5X,A8)
      RETURN
      END
//GO.SYSIN DD *
                1      NPRTA
                2      NC
                1      NU
                1      NUP
                1      ND
                5      NUNIT
    10800.0            DT
                1      ISCAL
                5      IMAX
                5      JMAX
      20.0             ANGLE
     500.00            XS
     800.00            YS
      71.75            XL
      39.75            YL
  WIND VEL             TITLE
      U                VAR1
        M /SEC         UNITS1
       METERS          UNITS3
      V                VAR2
       M /SEC          UNITS2
  1.00    2.00    3.00    4.00    5.00
  1.00    2.00    3.00    4.00    5.00
  1.00    2.00    3.00    4.00    5.00
  1.00    2.00    3.00    4.00    5.00
  1.00    2.00    3.00    4.00    5.00
  0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00
//GO.FT01F001 DD DUMMY
//*GO.FT02F001 DD DSN=URI.XYA1.BURPUS,DISP=SHR
//*GO.FT03F001 DD DSN=URI.LCF1.WINDOIL.KURT,DISP=SHR
//
```

Figure VII.-1. GRIDS

```
//E2305678 JOB (EZA100,128,2,0),'READ DATA ON DISK'
//  EXEC FORTGCG,REGION.GO=128K,P1='SYSOUT=(C,,2019)',
//  P3='SYSOUT=(C,,2019)'
//FORT.SYSIN DD *
C                  SUBROUTINE DESCRIPTION
C
C      THIS SUBROUTINE READS IN ONE OR TWO ARRAYS FOR THE VARIOUS
C    GRIDS USED IN THE PROGRAM, SPECIFICALLY THE DEPTH GRID, THE
C    WIND VELOCITY GRID, THE TEMPERATURE GRID AND THE SEA STATE
C    GRID.
C
C                  VARIABLE DESCRIPTION
C
C      SUBROUTINE ARGUMENTS
C
C    (1) NU      - FORMAT CONTROL: 1 - UNFORMATTED REAL;
C                                  2 - UNFORMATTED INTEGER;
C                                  3 - FORMATTED REAL;
C                                  4 - FORMATTED INTEGER.
C    (2) ND      - UNIT FROM WHICH DATA IS READ.
C    (3) NO      - # OF ARRAYS TO BE READ IN.
C    (4) NAME    - DESCRIPTOR FOR VARIABLE TO BE READ IN.
C    (5) ARRAY1  - FIRST ARRAY READ IN.
C    (6) ARRAY2  - SECOND ARRAY READ IN.
C    (7) IMAX    - # OF ELEMENTS IN X IN THE INPUT ARRAYS.
C    (8) JMAX    - # OF ELEMENTS IN Y IN THE INPUT ARRAYS.
C    (9) ANGLE   - ANGLE BETWEEN THE X AXIS FOR THE INPUT VARIABLES
C                  AND LINES OF CONSTANT LATITUDE.
C    (10) XL      - LONGITUDE OF THE ORIGIN OF THE FLOATING GRID.
C    (11) YL      - LATITUDE OF THE ORIGIN OF THE FLOATING GRID.
C    (12) XS      - GRID SPACING IN X.
C    (13) YS      - GRID SPACING IN Y.
C    (14) NARAY1 - EQUIVALENCED TO ARRAY1 IN THE CALLING PROGRAM.
C    (30) NARAY2 - EQUIVALENCED TO ARRAY2 IN THE CALLING PROGRAM.
C
C      OTHER VARIABLES USED IN THE SUBROUTINE
C
C    NAM     - THE DESCRIPTOR OF THE INPUT VARIABLE STORED
C              WITH THE DATA.
C    VAR1     2 NAME OF ARRAY1 TO BE USED IN PRINTOUT HEADER
C    VAR2    -2- NAME OF ARRAY2 TO BE USED IN PRINTOUT HEADER.
C    UNITS1 -3- UNITS OF ARRAY1 TO BE USED IN PRINTOUT HEADER.
C    UNITS2 -3- UNITS OF ARRAY2 TO BE USED IN PRINTOUT HEADER.
C    NUM     - NUMBER OF STEPS TO BE READ.
C
C      NOTE 1: THE ARRAYS ARRAY1 AND ARRAY2 ARE EQUIVALENCED IN THE
C              MAIN PROGRAM TO THE ARRAYS NARAY1 AND NARAY2. THE
C              PARAMETER ND DETERMINES IF AN INTEGER OR A FLOATING
C              POINT VALUE IS TO BE READ IN.
C
C.............................................................
C
C                  DIMENSION STATEMENTS
C
      DIMENSION ARRAY1( 30, 30), ARRAY2( 30, 30), NAM(3), UNITS3(2)
      DIMENSION VAR1(2), VAR2(2), UNITS1(3), UNITS2(3)
      DIMENSION KI(15), NARAY1( 30, 30), NARAY2( 30, 30)
      DIMENSION ARAY1T(30,30), ARAY2T(30,30)
      DIMENSION NAMCH(6,3)
C
C                  DATA STATEMENTS
C
      DATA PI, NW / 3.14159, 6/
      DATA KI/ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15/
      DATA NAM1, NAM2 /'UTID', 'VTID'/
      DATA TIME/ 0.0/
      DATA NAMCH(1,1),NAMCH(1,2),NAMCH(1,3)/'BATH','YMET','RY  '/
      DATA NAMCH(2,1),NAMCH(2,2),NAMCH(2,3)/'TEMP','ERAT','URE '/
      DATA NAMCH(3,1),NAMCH(3,2),NAMCH(3,3)/'WIND',' VEL','    '/
      DATA NAMCH(4,1),NAMCH(4,2),NAMCH(4,3)/'UTID',' CUR','RENT'/
      DATA NAMCH(5,1),NAMCH(5,2),NAMCH(5,3)/'VTID',' CUR','RENT'/
      DATA NAMCH(6,1),NAMCH(6,2),NAMCH(6,3)/'TIDE',' LEV','EL  '/
C
C                  S T A R T   H E R E
C
         WRITE(NW,447)
  447    FORMAT('1          INPUT PARAMETERS')
         CALL READI( NPRTA, 'NPRTA    ', -1, 1)
         CALL READI(    NC, 'NC       ', 1, 2)
         CALL READI(    NU, 'NU       ', 1, 4)
         CALL READI(   NUM, 'NUM      ', 1, 200)
         CALL READI(   ND,'ND       ', 1, 19)
         CALL READI( ISCAL,'ISCAL    ', 1, 2)
         DO 999 KK=1,NUM
C
C  DETERMINE DIMENSIONS OF GRIDS
C
C
C    READ IN GRID DEFINITION VARIABLES (FORMATTED).
C
      IF(NC.LE.2) GO TO 20
      READ (ND,100) NAM, VAR1, UNITS1, VAR2, UNITS2
  100 FORMAT(13A4)
      READ (ND,105) IMAX, JMAX, ANGLE, XL, YL, XS, YS, UNITS3
  105 FORMAT(2I5,3F10.6,2F10.2,2A4)
      GO TO 25
C
C    READ IN GRID DEFINITION VARIABLES (UNFORMATTED).
C
   20 CONTINUE
      READ (ND) NAM, VAR1, UNITS1, VAR2, UNITS2
      READ (ND) IMAX, JMAX, ANGLE, XL, YL, XS, YS, UNITS3
   25 CONTINUE
C
C  TEST TO SEE IF THE TITLES ARE RIGHT
C
        DO 600 I=1,6
        IF((NAM(1).EQ.NAMCH(I,1)).AND.(NAM(2).EQ.NAMCH(I,2)).AND.
     1  (NAM(3).EQ.NAMCH(I,3))) GO TO 601
  600   CONTINUE
        WRITE(NW,69) NAM
   69   FORMAT(2X,' TITLES DO NOT MATCH', 3A4, ' READ IN')
        STOP
  601   CONTINUE
      IF(NPRTA) 10,11,12
C
C   WRITE GRID DEFINITION VARIABLES AND HEADER IF OUTPUT REQUESTED.
C
   12 CONTINUE
      PRIT = TIME / 3600.0
      WRITE (NW,200) NAM, PRIT, NAM, IMAX, XS, UNITS3, JMAX, YS, UNITS3
  200 FORMAT('1',40X,3A4,' INPUT DATA ',F10.2,' HOURS AFTER',
     1       ' THE BEGINNING OF THE SPILL'//4X,'THE ',3A4,
     2       ' GRID HAS ',I5,' DIVISIONS IN X SPACED ',G12.3,
     3       2A4,' APART'/26X,'AND ',I5,
     4       ' DIVISIONS IN Y SPACED ',G12.3,2A4,' APART.'/)
      WRITE (NW,210) NAM, XL, YL
  210 FORMAT(4X,'THE (1,1) GRID LOCATION OF THE ',3A4,
     1       ' COORDINATE SYSTEM IS AT ',
     1       F10.6,' DEGREES LONGITUDE AND ',F10.6,
     2       ' DEGREES LATITUDE.'/)
      IF(ANGLE.NE.0.0) WRITE (NW,215) NAM, ANGLE
  215 FORMAT(4X,'FINALLY THE X AXIS OF THE ',3A4,
     1       ' GRID MAKES AN ANGLE (COUNTERCLOCKWISE) OF',F10.6,
     2       ' DEGREES WITH LINES OF'/4X,'CONSTANT LATITUDE.')
      ANGLE = ANGLE * PI / 180.0
      GO TO 10
C
C    HERE ONLY IF THE SHORT DIAGNOSTIC FORM IS DESIRED.
C
   11 CONTINUE
      WRITE (NW,230) NAM, TIME
  230 FORMAT(4X,'NEW ',3A4,' INFORMATION IS BEING READ IN',F10.2,
     1       ' SECONDS INTO THE SPILL')
C
C    HERE TO READ IN THE DATA.
C
   10 CONTINUE
C
C    BRANCH TO READ DIFFERENT FORMAT TYPES.
C
      GO TO (40,50,60,70), NU
C
C    HERE TO READ UNFORMATTED REAL VARIABLES.
C
   40 CONTINUE
      READ (ND) ((ARRAY1(I,J),I=1,IMAX),J=1,JMAX)
      IF(NO.EQ.1) GO TO 80
      READ (ND) ((ARRAY2(I,J),I=1,IMAX),J=1,JMAX)
      GO TO 80
C
C    HERE TO READ UNFORMATTED INTEGER VARIABLES.
C
   50 CONTINUE
      READ (ND) ((NARAY1(I,J),I=1,IMAX),J=1,JMAX)
      IF(NO.EQ.1) GO TO 90
      READ (ND) ((NARAY2(I,J),I=1,IMAX),J=1,JMAX)
      GO TO 90
C
C    HERE TO READ FORMATTED REAL VARIABLES.
C
   60 CONTINUE
      DO 62 J=1,JMAX
         READ (ND,110) (ARRAY1(I,J),I=1,IMAX)
  110    FORMAT(10F6.2)
   62 CONTINUE
      IF(NO.EQ.1) GO TO 80
      DO 64 J=1,JMAX
         READ (ND,110) (ARRAY2(I,J),I=1,IMAX)
   64 CONTINUE
      GO TO 80
C
C    HERE TO READ FORMATTED INTEGER VARIABLES.
C
   70 CONTINUE
      DO 72 J=1,JMAX
         READ (ND,120) (NARAY1(I,J),I=1,IMAX)
  120    FORMAT(30I4)
   72 CONTINUE
      IF(NO.EQ.1) GO TO 90
      DO 74 J=1,JMAX
         READ (ND,120) (NARAY2(I,J),I=1,IMAX)
   74 CONTINUE
      GO TO 90
C
C    HERE TO PRINT REAL ARRAYS.
C
   80 CONTINUE
      IF(NPRTA.LE.0) GO TO 999
      DO 96 I=1,IMAX
      DO 96 J=1,JMAX
      ARAY1T(I,J) = ARRAY1(I,J)
   96 ARAY2T(I,J) = ARRAY2(I,J)
      NPT = 0
C
C  IF ISCAL = 2, SCALE THE VALUES FOR PRINTOUT.
C
      IF(ISCAL.EQ.1) GO TO 56
      IF(NAM(1).EQ.NAM1) GO TO 55
      IF(NAM(1).NE.NAM2) GO TO 56
   55 NPT = 1
      WRITE(NW,24)
   24 FORMAT(2X,' ALL VALUES  FOR PRINTOUT HAVE BEEN DIVIDED',
     1  ' BY 10** -6')
   56 CONTINUE
C
      IMAXX = IMAX
      IF(IMAXX.GT.15) IMAXX = 15
      WRITE (NW,220) VAR1, UNITS1, (KI(II),II=1,IMAXX)
  220 FORMAT(//50X,2A4,' VALUES IN UNITS OF ',3A4//4X,'Y',55X,
     1      'X ELEMENTS'/1X,'ELEMENTS',1X,15(I2,6X)//)
      IF(NPT.NE.1) GO TO 77
      DO 71 I=1,IMAX
      DO 71 J=1,JMAX
   71 ARAY1T(I,J) = ARAY1T(I,J) * (10**6)
   77 CONTINUE
      J = JMAX + 1
      DO 82 N=1,JMAX
         J = J - 1
         WRITE (NW,240) J, (ARAY1T(I,J),I=1,IMAX)
  240    FORMAT('0',I4,5X,15(1X,F7.3)/(8X,15(1X,F7.3)))
   82 CONTINUE
      IF(NO.EQ.1) GO TO 999
      IF(NPT.NE.1) GO TO 79
      DO 76 I=1,IMAX
      DO 76 J=1,JMAX
   76 ARAY2T(I,J) = ARAY2T(I,J) * (10**6.0)
   79 CONTINUE
      WRITE (NW,220) VAR2, UNITS2, (KI(II),II=1,IMAXX)
```

Figure VII. - 2. READATA

```
      J = JMAX + 1
      DO 84 K=1,JMAX
         J = J - 1
         WRITE (NW,240) J, (ARAY2T(I,J),I=1,IMAX)
 84   CONTINUE
      GO TO 999
C
C   HERE TO PRINT INTEGER ARRAYS.
C
 90   CONTINUE
      IF(NPRTA.LE.0) GO TO 999
      IMAXX = IMAX
      IF(IMAXX.GT.15) IMAXX = 15
      WRITE (NW,220) VAR1, UNITS1, (KX(II),II=1,IMAXX)
      J = JMAX + 1
      DO 92 K=1,JMAX
         J = J - 1
         WRITE (NW,250) J, (NARAY1(I,J),I=1,IMAX)
 250     FORMAT(1X,I5,4X,100I1)
 92   CONTINUE
      IF(NO.EQ.1) GO TO 999
      WRITE (NW,220) VAR2, UNITS2, (KX(II),II=1,IMAXX)
      J = JMAX + 1
      DO 94 K=1,JMAX
         J = J - 1
         WRITE (NW,250) J, (NARAY2(I,J),I=1,IMAX)
 94      CONTINUE
        TIME = TIME + 86400.0
 999   CONTINUE
C
C                 E N D   H E R E
C
      STOP
      END
      SUBROUTINE READI(I,INAME,NL,NU)
      REAL*8 INAME, XNAME
      DATA NR,NW/5,6/
      READ (NR,10) I,XNAME
  10  FORMAT(I15,5X,A8)
      IF(XNAME.EQ.INAME) GO TO 100
      WRITE (NW,20) XNAME, INAME
  20  FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
      STOP
 100  CONTINUE
      IF(NL.EQ.NU) GO TO 200
      IF( (I.GE.NL) .AND. (I.LE.NU) ) GO TO 200
      WRITE (NW,40) INAME, NL, NU, INAME, I
  40  FORMAT(16H0 THE LIMITS ON ,A8,5H ARE ,I5,4H TO ,I5,
     1  6H. BUT ,A8,16H WAS READ IN AS  ,I5)
      STOP
 200  CONTINUE
      WRITE (NW,30) I, INAME
  30  FORMAT(2X,I15,5X,A8)
      RETURN
      END
//GO.SYSIN DD *
               1      NPRTA
               1      NO
               1      NO
              10      NDR




               1      ND
               2      ISCAL
//GO.FT01F001 DD DSN=OPT.EEA1.ISCAL2.UDIR,DISP=SHR
//
```

Figure VII.-2.   READATA

```
C                 MODEL DESCRIPTION
C
C     THIS MODEL DOES THE BOOKKEEPING AS WELL AS THE PHYSICS
C     NECESSARY TO KEEP TRACK OF SPILLED OIL. THE ENVIRONMENT
C     IS DIVIDED UP INTO FIVE REGIONS - THE ATMOSPHERE - THE
C     WATER COLUMN - THE WATER SURFACE - THE BOTTOM - THE SHORE.
C     NOTE: SOME SUBROUTINES MAY ONLY BE DUMMY SUBROUTINES AND
C           PERFORM NO FUNCTION AT THIS TIME ALL PROCESSES
C           ARE NOT FULLY UNDERSTOOD SO SPACE HAS BEEN LEFT
C           SO THAT THESE MAY BE ADDED LATER.
C
C  EVERYTHING IS REFERENCED TO THE DEPTH GRID(IE. THE PARTICLES
C   AND THE SPILLETS).
C  THE INTEGER VARIBLE ISCAL TELLS THE PROGRAM WHETHER THE
C  SPILL AREA COVERS A LARGE ENOUGH FOR ERRORS IN CONVERTING
C  DEGREES TO METERS OR VISA VERSA. IF ISCAL=1, THEN THE
C  PROGRAM DOES THE CALCULATIONS IN METERS, OTHERWISE THE
C  CALCULATIONS ARE DONE IN DEGREES. IF ISCAL=2 THEN THE
C  PROGRAM WILL ONLY ACCEPT DATA IN DEGREES AND WITH NO
C  ANGLE WITH RESPECT TO LINES OF CONSTANT LATITUDE. THE
C  CALCULATIONS CONCERNING DEPTH(IE. CONCENTRATION) ARE
C  ALWAYS DONE IN METERS.(IE  THE DEPTH IS NEVER CONVERTED
C  TO ANY OTHER DIMENSION). THE FLOATING GRID ALWAYS HAS
C  THE SAME ORIENTATION AS THE DEPTH GRID(IE. THE ANGLE
C  OF THE FLOATING GRID WITH RESPECT TO LINES OF
C  CONSTANT LATITUDE IS THE SAME AS THE DEPTH GRID).
C
C                 MODEL VARIABLES
C
C      CHEMICAL TREATMENT: CHEM
C
C   LCHEM  - # OF NEW TREATMENT EFFORTS BEGUN DURING THIS STEP.
C   NCHEM  - # OF CURRENT TREATMENT EFFORTS AFTER ADDING LCHEM.
C   NCHL   - UNIT FROM WHICH THE TREATMENT DATA SHALL BE READ.
C   BCHEM  -NCHEM- TIME THIS TREATMENT EFFORT BEGINS (SEC).
C   DCHEM  -NCHEM- DURATION OF TREATMENT EFFORT (SECS)
C   RCHEM  -NCHEM- RADIUS OF TREATED AREA (METERS).
C   SCHEM  -NCHEM- INTERFACIAL TENSION OF TREATED OIL (DYNES/CM).
C   TCHEM  -NCHEM- TOXICITY OF TREATED OIL.
C   VCHEM  -NCHEM- VOLUME OF DISPERSANT USED PER HOUR (LITERS/HOUR).
C   WCHEM  -NCHEM- DISPERSANT USED PER SQ. METER (LITER/METER**2).
C   XCHEM  -NCHEM- CENTER OF TREATED AREA (LONGITUDE).
C   YCHEM  -NCHEM- CENTER OF TREATED AREA (LATITUDE).
C   PCHEM  -NCHEM- PERCENTAGE OF OIL ENTRAINED IF THE TREATED
C                  AREA EXCEEDS THE SPILL AREA
C
C      PHYSICAL CLEANUP: CLEN
C
C   LCLN   - # OF CLEANUP EFFORTS BEGUN DURING THIS TIME STEP.
C   NCLN   - # OF CURRENT CLEANUP EFFORTS AFTER ADDING LCLN.
C   NCLD   - UNIT FROM WHICH THE CLEANUP EFFORT DATA SHALL BE READ
C   BCLN   -NCLN- BEGINNING TIME OF THIS CLEANUP EFFORT (SEC).
C   DCLN   -NCLN- DURATION OF THIS CLEANUP EFFORT (SEC).
C   ECLN   -NCLN- EFFICIENCY OF THIS CLEANUP EFFORT (%).
C   RCLN   -NCLN- RADIUS OF THIS CLEANUP EFFORT (METERS).
C   VCLN   -NCLN- OIL RECOVERY RATE (TONS/HOUR).
C   XCLN   -NCLN- CENTER OF THIS EFFORT (LONGITUDE).
C   YCLN   -NCLN- CENTER OF THIS EFFORT (LATITUDE).
C


C      COMPUTATIONAL CELL GRID DEFINITION: COMP
C
C   MAXCX  - # OF GRID ELEMENTS IN X FOR THE COMPUTATIONAL GRID.
C   MAXCY  - # OF GRID ELEMENTS IN Y FOR THE COMPUTATIONAL GRID
C   NCD    - UNIT FROM WHICH THE COMPUTATIONAL DATA SHALL BE READ.
C   NCU    - FORMAT CONTROL: 1 - UNFORMATTED REAL;
C                            2 - UNFORMATTED INTEGER;
C                            3 - FORMATTED REAL;
C                            4 - FORMATTED INTEGER.
C   AC     - ANGLE BETWEEN THE X AXIS OF THE COMPUTATIONAL
C            GRID AND LINES OF CONSTATN LATITUDE (DEGREES).
C   NCOMP  -MAXCX,MAXCY- COMPUTATIONAL CELL DEFINITION
C   XCL    - LONGITUDE OF THE ORIGIN OF TH COMPUTATIONAL GRID.
C   YCL    - LATITUDE OF THE ORIGIN OF THE COMPUTATIONAL GRID.
C   XCS    - GRID SPACING IN X IN THE COMPUTAIONAL GRID (METERS)
C   YCS    - GRID SPACING IN Y IN THE COMPUTATIONAL GRID (METERS).
C
C      WATER DEPTH GRID: DPTH
C
C   MAXDX  - # OF GRID ELEMENTS IN X FOR THE DEPTH GRID.
C   MAXDY  - # OF GRID ELEMENTS IN Y FOR THE DEPTH GRID.
C   NDD    - UNIT FROM WHICH THE DEPTH DATA SHALL BE READ.
C   NDU    - FORMAT CONTROL (SEE NCU).
C   AD     - ANGLE BETWEEN THE X AXIS OF THE DEPTH GRID AND
C            LINES OF CONSTANT LATITUDE (DEGREES).
C   DEPTH  -MAXDX,MAXDY- DEPTH OF OCEAN AT EACH ELEMENT (METERS).
C   XDL    - LONGITUDE OF THE ORIGIN OF THE DEPTH GRID
C   YDL    - LATITUDE OF THE ORIGIN OF THE DEPTH GRID.
C   XDS    - GRID SPACING IN X IN THE DEPTH GRID (METERS).
C   YDS    - GRID SPACING IN Y IN THE DEPTH GRID (METERS).
C
C      TIDAL ELEVATION: ELVN
C
C   MAXEX  - # OF GRID ELEMENTS IN X FOR THE TIDAL ELEVATION GRID
C   MAXEY  - # OF GRID ELEMENTS IN Y FOR THE TIDAL ELEVATION GRID.
C   NED    - UNIT FROM WHICH THE TIDAL ELEVATION DATA SHALL BE READ
C   NEU    - FORMAT CONTROL (SEE NED).
C   AE     - ANGLE BETWEEN THE X AXIS OF THE TIDAL ELEVATION GRID
C            AND LINES OF CONSTANT LATITUDE.
C   HGHT   -MAXEX,MAXEY- ELEVATION OF SEA LEVEL DUE TO TIDE AT
C           EACH GRID POINT (METERS).
C   XEL    - LONGITUDE OF ORIGIN OF TIDAL ELEVATION GRID.
C   YEL    - LATITUDE OF ORIGIN OF TIDAL ELEVATION GRID.
C   XES    - GRID SPACING IN X IN THE TIDAL ELEVATION GRID (METERS).
C   YES    - GRID SPACING IN Y IN THE TIDAL ELEVATION GRID (METERS).
C
C      3-D FLOATING CURRENT GRID: FLOT
C
C   MAXFX  - # OF GRID ELEMENTS IN X FOR THE FLOATING CURRENT GRID.
C   MAXFY  - # OF GRID ELEMENTS IN Y FOR THE FLOATING CURRENT GRID.
C   MAXFZ  - # OF GRID ELEMENTS IN Z FOR THE FLOATING CURRENT GRID.
C   NFD    - UNIT FROM WHICH FLOATING CURRENT DATA SHALL BE READ.
C   NFU    - FORMAT CONTROL (SEE NCU).
C   NF     - 1 IF FLOATING CURRENTS ARE TO BE UPDATED THIS STEP,
C            0 OTHERWISE.
C   AF     - ANGLE BETWEEN THE X AXIS OF THE FLOATING CURRENT GRID
C            AND LINES OF CONSTANT LATITUDE (DEGREES).
C   UFLT   -MAXFX,MAXFY,MAXFZ- U COMPONENT OF CURRENT (M/SEC).
C   VFLT   -MAXFX,MAXFY,MAXFZ- V COMPONENT OF CURRENT (M/SEC).
C   WFLT   -MAXFX,MAXFY,MAXFZ- W COMPONENT OF CURRENT (M/SEC)


C   XFL    - LONGITUDE OF THE ORIGIN OF THE FLOATING CURRENT GRID.
C   YFL    - LATITUDE OF THE ORIGIN OF THE FLOATING CURRENT GRID.
C   ZFL    - DISTANCE BELOW SEA LEVEL OF THE ORIGIN OF THE
C            FLOATING CURRENT GRID (METERS);
C            OR -1000 IF THE FLOATING GRID IS VARIABLE TO THE BOTTOM.
C   XFS    - GRID SPACING IN X IN THE FLOATING CURRENT GRID (METERS).
C   YFS    - GRID SPACING IN Y IN THE FLOATING CURRENT GRID (METERS).
C   ZFS    - GRID SPACING IN Z IN THE FLOATING CURRENT GRID (METERS),
C            OR -1000 IF THE GRID SPACING IS VARIABLE.
C
C     MISCELLANEOUS: CNTL
C
C   IMSUB  - # OF GRID ELEMENTS IN X OF THE SUBSURFACE GRID.
C   JMSUB  - # OF GRID ELEMENTS IN Y OF THE SUBSURFACE GRID.
C   KMSUB  - # OF GRID ELEMENTS IN Z OF THE SUBSURFACE GRID.
C   NPRTA  - ARRAY PRINT CONTROL: -1 NO DIAGNOSTIC PRINTOUT;
C                                  0 LIMITED DIAGNOSTIC PRINTOUT;
C                                  1 FULL DIAGNOSTIC PRINTOUT.
C   NPRTC  - 1 - PRINT OUT CURRENT CLEANUP AND TREATMENT EFFORTS AND
C                SPILLET CHARACTERISTICS FOR EVERY TIME STEP.
C            0 - PRINT OUT ONLY WHEN NEW EFFORTS ARE STARTED OR
C                NEW SPILLETS APPEAR.
C   NR     - INPUT FILE FOR STEP CONTROL PARAMETERS.
C   DT     - TIME STEP USED IN FOLLOWING THE SPILL (SECS).
C   SCALE  - # OF METERS PER DEGREE LATITUDE.
C   TIME   - TIME SINCE THE RUN BEGAN (SECS).
C   TIMMAX - TIME AT WHICH THIS RUN IS TO END (SECS)
C   MAXSPL - MAXIMUM NUMBER OF POSSIBLE SPILLETS
C   XMSPAR - AMOUNT OF MASS TO BE REPRESENTED BY EACH PARTICLE
C   NUMCL  - NUMBER OF PARTICLE CLASSES
C   NSDUM  - INTERVAL CONTROL PARAMETER FOR WRITING TO
C            RESTART DATA SET
C   NRUN   -  1 THIS INDICATES A SHORT PREVIEW RUN
C             0 THIS INDICATES A FULL MODEL RUN
C   NSTRT  - 0 THIS IS A RESTARTED RUN AND NEW DATA SETS
C                ARE TO BE USED FOR INPUT AND OUTPUT.
C              1 THIS RESTARTED RUN WILL CONTINUE WRITING TO THE
C                SAME OUTPUT DATA SETS AS THE PREVIOUS RUN.
C
C       OUTPUT FILE NUMBERS
C
C . NOSP  - SPILLET OUTPUT FILE
C   NORS  - RESTART OUTPUT FILE
C   NOCN  - CONCENTRATION PARAMETERS OUTPUT FILE.
C   NOPT  - PARTICLE PARAMETERS OUTPUT FILE.
C   NOVL  - FLOATING GRID VELOCITIES OUTPUT FILE.
C   NOMS  - MASS BALANCE OUTPUT FILE.
C   NODP  - PARTICLES DEPOSITED ON BOTTOM OUTPUT FILE.
C   NOLT  - PARTICLES LOST THROUGH OPEN BOUNDARIES
C           OUTPUT FILE.
C
C               DESCRIPTION OF INPUT VARIABLES
C
C         I N T E G E R S
C
C  NMAX         - MAXIMUM NUMBER OF PARTICLES
C  NEXTN         - 1  EXPAND AND TRANSLATE FLOATING GRID
C                - 0  DO NOT EXPAND
C       PRINT INTERVAL PARAMETERS
C  KPRTP         - PRINT PARTICLE POSITION


C  KPRTC         - PRINT CONCENTRATION
C  KPRTV         - PRINT VELOCITY MATRIX
C  NCRIT         - NUMBER OF PARTICLES NEEDED BEFORE
C                 CALCULATING  CONCENTRATION
C  NDIFF         - 0 CONSTANT DIFFUSION COEFFICIENTS
C                - 1 SCALE DEPENDENT DIFFUSION COEFFICIENTS
C  NPRD          - PRINT INTERVAL CONTROL FOR DISK
C  NPRP          - PRINT PARTICLE PARAMETERS
C  NPRC          - PRINT CONCENTRATION PARAMETERS
C  NPRV          - PRINT VELOCITY MATRIX
C  NSUB          - 0 PARTICLE DIFFUSION WITH EXPANDING TRANSLATING GRID
C                - 1 ANALYTIC DIFFUSION UNTIL STANDARD DEVIATION OF
C                   WASTE CLOUD IS COMPARABLE TO GRID MESH
C  NTRANS        - 0 NO Z TRANSPORMATION
C                - 1    Z TRANSPORMATION
C  NPRTMS        - INTERVAL PRINT CONTROL FOR MASS BALANCE OUTPUT
C  NPTSUB        - INTERVAL PRINT CONTROL FOR SUBSURFACE INFORMATION
C                  PRINTOUT (FLOATING GRID AND VARIABLE DIFFUSION)
C
C     R E A L   V A R I A B L E S
C
C  DT .          - TIME STEP (SECS)
C  DX,DY,DZ      - GRID SPACING OF FLOATING GRID (FT)
C  DXX,DYY,DZZ - TURBULENT DIFFUSION COEFFICIENTS (FT**2/SEC)
C  EXX,EYY       - COEFFICIENT USED IN SCALE DEPENDENT DIFFUSION
C  POWX,POWY     - POWER USED IN SCALE DEPENDENT DIFFUSION
C  RADIUS        - RADIUS OF INITIAL UNIFORM PARTICLE DISTRIBUTION
C                  AVERAGED OVER ONE TIDAL CYCLE
C  XC,YC         - CENTER OF UNIFORM DISTRIBUTION IN THE FIXED
C                  SYSTEM (GRID UNITS)
C  XORIG,YORIG - ORIGIN OF FLOATING SYSTEM IN FIXED SYSTEM (GRID UNITS)
C  ZORIG         - ORIGIN OF FLOATING GRID IN GRID UNITS FROM BOTTOM
C  DEPC          - VERTICAL ORIGIN OF INITIAL PARTICLE DISTRIBUTION
C  MDISP         - MINIMUM DURATION OF ENTRAINMENT
C  MENT          - MAXIMUM DURATION OF ENTRAINMENT
C  TMASS         - MASS ENTRAINED PER STEP
C  AFRAC         - DETERMINES THE FRACTION OF PARTICLES WITHIN RO
C  RIFRAC        - DETERMINES RADIUS WHERE PARTICLE DENSITY IS
C                - UNIFORM (RO=RSPILL/RIFRAC)
C  ROFRAC        - FACTOR WHICH DETERMINES RATE AT WHICH
C                  PARTICLE DISTRIBUTION FALLS OFF
C                  RMAX=(RSPILL*(1.0+((MENT/5.0)/(ROFRAC*TIME*TIME+1.0))))
C  COMB          - RATIO OF DISTANCE BETWEEN SPILLETS WHICH WILL
C                - CAUSE THEM TO COMBINE
C  DDIAMT        - DIAMETER OF PARTICLES
C  DVELIT        - SETTLING VELOCITY OF PARTICLES
C                  PARTICLES WHICH ARE TREATED.
C
C     MASS BALANCE: MASS
C
C   XMATM  - MASS OF OIL LOST TO THE ATMOSPHERE (TONS).
C   XMBIO  - MASS OF OIL BIOLOGICALLY CONSUMED (TONS)
C   XMCLN  - MASS OF OIL CLEANED UP (TONS).
C   XMBOT  - MASS OF OIL WHICH HAS SETTLED TO THE BOTTOM (TONS).
C   XMDMP  - MASS OF OIL SPILLED THUS FAR (TONS).
C   XMLOS  - MASS OF OIL WHICH LEAVES THE STUDY AREA (TONS).
C   XMSHR  - MASS OF OIL DEPOSITED ON THE SHORELINE (TONS).
C   XMSUR  - MASS OF OIL IN SPILLETS ON THE SURFACE (TONS).
C   XMSUS  - MASS OF OIL SUSPENDED IN THE WATER COLUMN (TONS).
C
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Figure VII.-3. MAIN

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C        SEA STATE GRID: SEAS
C
C     NAISX   - # OF GRID ELEMENTS IN X FOR THE SEA STATE GRID.
C     NAISY   - # OF GRID ELEMENTS IN Y FOR THE SEA STATE GRID.
C     NSD     - UNIT FROM WHICH SEA STATE DATA SHALL BE READ.
C     NSU     - FORMAT CONTROL (SEE NCU).
C     NS      - 1 IF SEA STATE VALUES ARE TO BE UPDATED THIS STEP
C                 0 OTHERWISE.
C     AS      - ANGLE BETWEEN THE X AXIS OF THE SEA STATE GRID AND
C                 LINES OF CONSTANT LATITUDE (DEGREES).
C     WAVHGT -NAISX,NAISY- WAVE AMPLITUDE (METERS).
C     WAVPRD -NAISX,NAISY- WAVE PERIOD (SEC).
C     XSL     - LONGITUDE OF THE ORIGIN OF THE SEA STATE GRID.
C     YSL     - LATITUDE OF THE ORIGIN OF THE SEA STATE GRID.
C     XSS     - GRID SPACING IN X OF THE SEA STATE GRID (METERS).
C     YSS     - GRID SPACING IN Y OF THE SEA STATE GRID (METERS).
C
C        SHORELINE DEFINITION: SHOR
C
C     NSHD    - UNIT FROM WHICH SHORELINE DATA SHALL BE READ.
C     NSHOR   - # OF POINTS USED TO DEFINE THE SHORELINE
C     XSHOR  -NSHOR- SHORELINE POINT (LONGITUDE).
C     YSHOR  -NSHOR- SHORELINE POINT (LATITUDE).
C
C        SPILL DEFINITION: SPIL
C
C     LSPIL   - # OF SPILLETS ADDED EXTERNALLY THIS STEP.
C     MSPIL   - # OF CLASSES OF OIL TO BE CONSIDERED.
C     NSPD    - UNIT FROM WHICH SPILLET DATA SHALL BE READ.
C     NSPIL   - # OF ACTIVE SPILLETS AFTER ADDING LSPIL.
C     ASPIL  -NSPIL- AREA OF SPILLET TREATED THUS FAR (METERS**2),
C                      THIS PARAMETER IS NEGATIVE IF TREATMENT
C                      OF THIS SPILLET IS COMPLETE.
C     BSPIL  -NSPIL- TIME SINCE THE SPILLET FIRST APPEARED .
C                    - ENTERED IN HOURS,CONVERTED TO SECONDS(SEC)
C     DSPIL  -NSPIL- DENSITY OF OIL (GM/CC).
C     FSPIL  -NSPIL- FRACTION BY VOLUME OF SPILL TREATED.
C     GSPIL  -NSPIL,MSPIL- FRACTION BY MASS OF EACH CLASS OF OIL.
C     RSPIL  -NSPIL- RADIUS OF SPILLET (METERS).
C     SSPIL  -NSPIL- INTERFACIAL TENSION OF THE OIL (DYNES/CM).
C     SSPILT -NSPIL- INTERFACIAL TENSION OF THE TREATED FRACTION OF
C                      THE SPILLET (DYNES/CM).
C     TSPIL  -NSPIL- DENSITY OF OIL AT TIME T=0.
C     TSPILT -NSPIL- TOXICITY OF THE TREATED FRACTION OF THE SPILLET.
C     USPIL  -NSPIL- KINEMATIC VISCOSITY OF THE OIL (CENTISTOKES).
C     WSPIL  -NSPIL- MASS OF THE OIL IN THE SPILLET (TONS).
C     XSPIL  -NSPIL- CENTER OF THE SPILLET (LONGITUDE).
C     YSPIL  -NSPIL- CENTER OF THE SPILLET (LATITUDE).
C
C        TIDAL CURRENT 2-D FIXED GRID: TIDE
C
C   THERE ARE TWO TIDAL GRIDS. IT IS ASSUMED THAT THEY HAVE THE
C   SAME SPACING AND ORIENTATION.  THE ORIGINS ARE DIFFERENT SO
C   THAT THEY CAN BE OFFSET IF A SPACE STAGGERED NUMERICAL TIDAL
C   IS USED
C
C     NAITX   - # OF GRID ELEMENTS IN X FOR THE TIDAL CURRENT GRID.
C     NAITY   - # OF GRID ELEMENTS IN Y FOR THE TIDAL CURRENT GRID.
C     NSD     - UNIT FROM WHICH THE TIDAL CURRENT SHALL BE READ.
C     NSU     - FORMAT CONTROL (SEE NCU).


C     NS      - 1 IF TIDAL VELOCITY VALUES ARE TO BE UPDATED THIS STEP
C                 0 OTHERWISE
C     AT      - ANGLE BETWEEN THE X AXIS OF THE TIDAL CURRENT
C                 GRID AND LINES OF CONSTANT LATITUDE (DEGREES).
C     UT     -NAITX,NAITY- U COMPONENT OF THE TIDAL CURRENT (M/SEC).
C     VT     -NAITX,NAITY- V COMPONENT OF THE TIDAL CURRENT (M/SEC).
C     XTLU    - LONGITUDE OF THE ORIGIN OF THE X-DIR TIDAL CURRENT GRID.
C     XTLV    - LONGITUDE OF THE ORIGIN OF THE Y-DIR TIDAL CURRENT GRID.
C     YTLU    - LATITUDE OF THE ORIGIN OF THE X-DIR TIDAL CURRENT GRID.
C     YTLV    - LATITUDE OF THE ORIGIN OF THE Y-DIR TIDAL CURRENT GRID.
C     XTS     - GRID SPACING IN X IN THE TIDAL CURRENT GRID (METERS).
C     YTS     - GRID SPACING IN Y IN THE TIDAL CURRENT GRID (METERS).
C
C        TEMPERATURE GRID: TMPC
C
C     NAIKX   - # OF GRID ELEMENTS IN X FOR THE TEMP. GRID.
C     NAIKY   - # OF GRID ELEMENTS IN Y FOR THE TEMP. GRID.
C     NKD     - UNIT FROM WHICH TEMPERATURE SHALL BE READ.
C     NKU     - FORMAT CONTROL (SEE NCU).
C     NK      - 1 IF TEMPERATURE VALUES ARE TO BE UPDATED THIS STEP,
C                 0 OTHERWISE.
C     AK      - ANGLE BETWEEN THE X AXIS OF THE TEMP. GRID AND
C                 LINES OF CONSTANT LATITUDE (DEGREES).
C     TEMP   -NAIKX,NAIKY- TEMP VALUES IN THE GRID (CENTIGRADE).
C     XKL     - LONGITUDE OF THE ORIGIN OF THE TEMPERATURE GRID.
C     YKL     - LATITUDE OF THE ORIGIN OF THE TEMPERATURE GRID.
C     XKS     - GRID SPACING IN X OF THE TEMP. GRID (METERS).
C     YKS     - GRID SPACING IN Y OF THE TEMP. GRID (METERS).
C
C        WIND GRID: WIND
C
C     NAIWX   - # OF GRID ELEMENTS IN X FOR THE WIND GRID.
C     NAIWY   - # OF GRID ELEMENTS IN Y FOR THE WIND GRID.
C     NWD     - UNIT FROM WHICH WIND DATA SHALL BE READ
C     NWU     - FORMAT CONTROL (SEE NCU).
C     NW      - 1 IF WIND VALUES ARE TO BE UPDATED THIS STEP,
C                 0 OTHERWISE.
C     AW      - ANGLE BETWEEN THE X AXIS OF THE WIND GRID AND LINES
C                 OF CONSTANT LATITUDE (DEGREES).
C     UW     -NAIWX,NAIWY- U COMPONENT OF THE WIND (M/SEC).
C     VW     -NAIWX,NAIWY- V COMPONENT OF THE WIND (M/SEC).
C     XWL     - LONGITUDE OF THE ORIGIN OF THE WIND VELOCITY GRID
C     YWL     - LATITUDE OF THE ORIGIN OF THE WIND VELOCITY GRID.
C     XWS     - GRID SPACING IN X IN THE WIND GRID (METERS).
C     YWS     - GRID SPACING IN Y IN THE WIND GRID (METERS).
C
C        NOTE 1: IN THE CALL TO ARAYIN THE FLOATING POINT ARRAY IS
C                EQUIVALENCED TO A FIXED POINT ARRAY THUS ALLOWING
C                THE SUBROUTINE TO READ IN EITHER A FLOATING POINT
C                OR A FIXED POINT ARRAY DEPENDING ON THE  VALUE OF
C                THE FORMAT CONTROL PARAMETER.
C
C.......................................................................
C
C                    COMMON STATEMENTS
C
      COMMON /CHEM/ NCHEM, ACHEM(10), BCHEM(10), KCHEM(10),
     1     SCHEM(10), TCHEM(10), VCHEM(10), WCHEM(10), XCHEM(10),
     2     YCHEM(10), PCHEM(10)
      COMMON /CLEN/ NCLN, ACLN(10), BCLN(10), KCLN(10), MCLN(10),
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     1     VCLN(10), XCLN(10), YCLN(10)
      COMMON /DENS/ DEN(8)
      COMMON /DEPOS/ NLOST, NDEP
      COMMON /COMP/ NAICX, NAICY, AC, NCOMP(30,30), XCL, YCL,
     1     XCS, YCS
      COMMON /DPTH/ NAIDX, NAIDY, AD, DEPTH(30,30), XDL, YDL,
     1     XDS, YDS
      COMMON /ELVN/ NAIEX, NAIEY, AE, NGHT(30,30), XEL, YEL,
     1     XES, YES
      COMMON /PLOT/ NAIPX, NAIPY, NAIPZ, AP, DPLT(15,15,10),
     1     VPLT(15,15,10), UPLT(15,15,10), XPL, YPL, ZPL, XPS, YPS, ZPS
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPATH,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ XMATM, XMBIO, XMBOT, XMCLN, XMDBF, XMLOS,
     1     XMSRF, XMSOP, XMSDS
      COMMON /OUTP/ NOSF, NOAS, NOCN, NOPX, NOBS, NOLT,
     1     NODP, NOVL
      COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDPAT(200),
     1     DMASS(200), DVELZ(200), DCOMP(200,6), NTCLAS, NORCL
      COMMON /SEAS/ NAISX, NAISY, AS, WAVHGT(30,30), WAVPRD(30,30),
     1     XSL, YSL, XSS, YSS
      COMMON /SHOR/ NSHOR, XSHOR(1500), YSHOR(1500)
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), BSPIL(99), DSPIL(99),
     1     FSPIL(99), GSPIL(99,8), RSPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), USPIL(99), WSPIL(99), XSPIL(99),
     3     YSPIL(99), SSPILT(99), NAISPL
      COMMON /SOBS/ NTRANS, NSOB, NRITE, NMAX, NMAY, DX, DY, DZ,
     1       XORIG,YORIG,ZORIG
      COMMON /TIDE/ NAITX, NAITY, AT, UT(30,30), VT(30,30),
     1     XTLU, YTLU, XTS, YTS, XTLV, YTLV
      COMMON /TMPC/ NAIKX, NAIKY, AK, TEMP(30,30),
     1     XKL, YKL, XKS, YKS
      COMMON /WIND/ NAIWX, NAIWY, AW, UW(30,30), VW(30,30),
     1     XWL, YWL, XWS, YWS
C
C                  DIMENSION STATEMENTS
C
      DIMENSION NPLT(15,15), DPLT(15,15), CC(15,15)
      DIMENSION AIO(30), AJO(30)
      DIMENSION COMFF(30,30), NDT(30,30), NST(30,30), MST(30,30)
      DIMENSION NKT(30,30), NWT(30,30), NWU(30,30), NZT(30,30)
      DIMENSION NTV(30,30), NTU(30,30)
      DIMENSION NTT(30,30), NET(30,30)
      DIMENSION X(2100), Y(2100), Z(2100)
      DIMENSION C(15,15,10)
      INTEGER N(15,15,10)
      INTEGER*2 NORDR(2100)
C
C                  EQUIVALENCE STATEMENTS
C
      EQUIVALENCE (NCOMP(1,1), COMPP(1,1))
      EQUIVALENCE (NDT(1,1), DEPTH(1,1))
      EQUIVALENCE (NKT(1,1), TEMP(1,1))
      EQUIVALENCE (NST(1,1), WAVHGT(1,1)), (MST(1,1), WAVPRD(1,1))
      EQUIVALENCE (NTT(1,1), UT(1,1)), (NTV(1,1),VT(1,1))
      EQUIVALENCE (NWT(1,1), UW(1,1)), (NWU(1,1), VW(1,1))
      EQUIVALENCE (NET(1,1), NGHT(1,1))
C
C                  DATA STATEMENTS
C


      DATA  NW/ 6/
C
C                  S T A R T   H E R E
C
C
C   READ IN MODEL CONTROL PARAMETERS.
C
       WRITE(NW,800)
 800   FORMAT('1', T10, 'INPUT CONTROL PARAMETERS ',/)
      CALL READI( NSTAT, 'NSTAT    ', 0, 1)
      CALL READI( NSTPN, 'NSTPN    ', 0, 1)
      CALL READI( NSORM, 'NSORM    ', 0, 100)
      CALL READI(  NRUN, 'NRUN     ', 0, 1)
      CALL READI( IDAY, 'IDAY      ', 0, 365)
      CALL READI( NEVT, 'NEVT      ', 0, 100)
      CALL READF( DT, 'DT         ')
      DT = DT * 3600.0
      CALL READF( TIMMAX, 'TIMMAX  ')
      TIMMAX = TIMMAX * 3600.0
      CALL READI( ISCAL, 'ISCAL    ', 1, 3)
      CALL READI( NPRTA, 'NPRTA    ', -1, 1)
      CALL READI( NPRTC, 'NPRTC    ', 0, 1)
      CALL READI( NR, 'NR          ', 1, 19)
      CALL READI( NCD, 'NCD       ', 1, 19)
      CALL READI( NCU, 'NCU       ', 1, 4)
      CALL READI( NDD, 'NDD       ', 1, 19)
      CALL READI( NDU, 'NDU       ', 1, 4)
      CALL READI( NED, 'NED       ', 1, 19)
      CALL READI( NEU, 'NEU       ', 1, 4)
      CALL READI( NKD, 'NKD       ', 1, 19)
      CALL READI( NKU, 'NKU       ', 1, 4)
      CALL READI( NSD, 'NSD       ', 1, 19)
      CALL READI( NSU, 'NSU       ', 1, 4)
      CALL READI( NTDU, 'NTDU      ', 1, 19)
      CALL READI( NTDV, 'NTDV      ', 1, 19)
      CALL READI( NTUU, 'NTUU      ', 1, 4)
      CALL READI( NTUV, 'NTUV      ', 1, 4)
      CALL READI( NWD, 'NWD       ', 1, 19)
      CALL READI( NWU, 'NWU       ', 1, 4)
      CALL READI( NCHD, 'NCHD      ', 1, 19)
      CALL READI( NCLD, 'NCLD      ', 1, 19)
      CALL READI( NSHD, 'NSHD      ', 1, 19)
      CALL READI( NSPD, 'NSPD      ', 1, 19)
C
C   READ IN SURFACE AND PRINT CONTROL PARAMETERS
C
      CALL READI( NMAX, 'NMAX      ', 1, 2000)
      CALL READI( NTCLAS, 'NTCLAS   ', 1, 200)
      CALL READI( NORCL, 'NORCL    ', 1, 200)
      CALL READF( XMSPAR, 'XMSPAR   ')
      CALL READI( NAISPL, 'NAISPL   ', 1, 99)
      CALL READF( CORR, 'CORR      ')
      CALL READI( MSPIL, 'MSPIL     ', 1, 9)
      CALL READI(  NSPPRD, 'NSPPRD  ',-1, 100)
      CALL READI(  NSPPAP, 'NSPPAP  ',-1, 100)
C
C        READ IN OUTPUT FILE NUMBERS
C
      CALL READI( NUSP, 'NUSP      ', 1, 19)
      CALL READI( NOBS, 'NOBS      ', 1, 19)
```

Figure VII.-3. MAIN

```
      CALL READI( NUCN, 'NUCN     ', 1, 19)
      CALL READI( NUPT, 'NUPT     ', 1, 19)
      CALL READI( NUVL, 'NUVL     ', 1, 19)
      CALL READI( NUMS, 'NUMS     ', 1, 19)
      CALL READI( NUDP, 'NUDP     ', 1, 19)
      CALL READI( NULT, 'NULT     ', 1, 19)
C
C    READ IN THE SHORELINE CONFIGURATION.
C
      CALL READI( NSHOR, 'NSHOR    ', 0,1500)
      CALL SHORE(NSHO)
C
C    INITIALIZE THE SUBSURFACE DRIFT/DIFFUSION MODEL HERE.
C
      CALL INITSS (NPRTSS, FORIN)
C
C    INITIALIZE MODEL MASS VARIABLES.
C
      EMATM = 0.0
      EMBIO = 0.0
      EMBOT = 0.0
      EMCLN = 0.0
      EMDRF = 0.0
      EMLOS = 0.0
      EMSHR = 0.0
      EMSUR = 0.0
      EMSUS = 0.0
C
C  INITIALIZE NUMBER OF PARTICLES
C
      NORDR(1) = 0
      NCHEM = 0
      NCLN = 0
      NSPIL = 0
      INN = 0
      NDEF = 0
      NLOST = 0
C
C   THE FIRST TIME STEP IS REFERRED AS STEP 0.
C
      TIME = 0.0
      NSTEP = 0
      IF(NSTRT.NE.1)WRITE(1) IDAT
      IF(NSTRT.NE.1)WRITE(10) IDAT
      IF(NSTRT.NE.1)WRITE(11) IDAT
      NMAI = 0
C
C  DEFINE THE DENSITIES OF THE OIL COMPONENTS
C
      DEN(1) = 0.715
      DEN(2) = 0.775
      DEN(3) = 0.825
      DEN(4) = 0.95
      DEN(5) = 0.99
      DEN(6) = 1.15
      DEN(7) = 1.085
      DEN(8) = 1.05
C
C             HERE IF THIS IS A RESTART
C


C     THIS SECTION IS ONLY USED FOR THE RESTART OPTION. IT
C     READS THROUGH ALL OF THE PREVIOUS DATA SETS IN ORDER
C     TO REACH THE END OF THEM  IT DOES THIS IN ORDER TO
C     BE ABLE TO WRITE TO THEM WITHOUT WRITING OVER
C     PREVIOUS DATA. THIS SECTION ALSO INITIALIZES ALL OF
C     VARIABLES TO THE VALUES THEY HAD WHEN THE PREVIOUS RUN
C     WAS TERMINATED. THE PARAMETER IN IS USED TO CONTROL
C     THE READING OF THE ENVIRONMENTAL DATA SETS AND.BRING THEM
C     UP TO THIS TIME STEP
C
      IF(NSTRT.EQ.0) GO TO 111
      WRITE(NW,72)
 72   FORMAT('1')
      WRITE(NW,73)
 73   FORMAT(2X,' *** THIS IS A RESTARTED RUN *** ')
C
C   READ IN RESTART PARAMETERS
C
      READ (NURS) NPTRST, NSTT, NSPT, NPRVT, NPRCT, NPRPT
C
C  IF NSTPN = 0, NEW DATA SETS ARE USED
C
       IF(NSTPN.EQ.0) GO TO 708
      NSTEP = NSTT + 1
      NSTT = NSTT + 1
C
C  DETERMINE THE NUMBER OF DATA SETS WHICH HAVE TO
C  TO BE READ IN ORDER TO CONTINUE THE RUN.
C
       IF(NPRVT.NE.0)  NPRVT = NSTT/NPRVT
       IF(NPRCT.NE.0)  NPRCT = NSTT/NPRCT
       IF(NPRPT.NE.0)  NPRPT = NSTT/NPRPT
       IF(NPTRST.NE.0) NPTRST = NSTT/NPTRST
       IF(NSPT.NE.0)   NSPT = NSTT/NSPT
       WRITE(NW,324) NPRVT,NPRCT,NPRPT,NSPT,NPTRST,NSTT
 324   FORMAT(2X,' READ',I4,'VELOCITY ',I4,' CONCENTRATION ',
    1      I4,' PARTICLE',I4,' SPILLET AND',I4, ' MASS DATA SETS FOR',
    2    I4,' STEPS')
      IF(NPRPT.GT.0) READ (NUPT) IDAT11
      IF(NSPT.GT.0)  READ (NUSP) IDAT1
      IF(NPRCT.GT.0) READ (NUCN) IDAT10
C
C   READ IN SPILL PARAMETERS
C
      IF(NSPT.EQ.0) GO TO 951
       DO 700 KK=1,NSPT
        READ (NUSP,END=901) TIME,NSPIL
        WRITE(NW,776) TIME,NSPIL
 776    FORMAT(2X,F15.5,2X,I4,'SPILLETS')
        DO 101  I=1,NSPIL
         IF(I.GT.1) READ (NUSP) TIME, NNSPIL
         READ (NUSP,END=901) II,BSPIL(I),XSPIL(I),YSPIL(I),ZSPIL(I),
    1     USPIL(I),DSPIL(I),SSPIL(I),OSPIL(I),(GSPIL(I,J),J=1,6)
 101     CONTINUE
 700  CONTINUE
      GO TO 951
C
C   HERE IF AN EOF WAS ENCOUNTERED ON UNIT 1
C
 901  CONTINUE
```

```
      WRITE(NW,801)
 801  FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 1'/)
 951  CONTINUE
C
C   READ IN CONCENTRATION PARAMETERS
C
      IF(NPRCT.LE.0) GO TO 960
       DO 701 JJ=1,NPRCT
        READ (NUCN,END=910)IMSUB,JMSUB,KMSUB,NMAI,NCLASS,NFLG,NSTP,
     1  NLOST,NDEP,TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDS,YDS
        WRITE(NW,775) TIME
 775    FORMAT(2X,' CONCENTRATION AT TIME ',F20.3,' READ IN')
        READ (NUCN,END=910) (RIO(I),I=1,IMSUB)
        READ (NUCN,END=910) (RJO(J),J=1,JMSUB)
        DO 99 K=1,KMSUB
          READ (NUCN,END=910) ((C(I,J,K),I=1,IMSUB),J=1,JMSUB)
 99     CONTINUE
 701   CONTINUE
      GO TO 960
C
C   HERE IF AN EOF WAS ENCOUNTERED ON UNIT 10.
C
 910  CONTINUE
      WRITE(NW,810)
 810  FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 10'/)
 960  CONTINUE
C
C   READ IN PARTICLE PARAMETERS
C
      IF(NPRPT.LE.0) GO TO 961
      NPRPT = NPRPT
       DO 702 KK=1,NPRPT
        READ (NUPT,END=911) IMSUB,JMSUB,KMSUB,NMAI,NCLASS,NFLG,NSTP,
     1  NLOST,NDEP,TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDS,YDS
        WRITE(NW,774)  TIME
 774    FORMAT(2X,' PARTICLE POSITIONS AT TIME ',F20.3,' READ IN')
        READ (NUPT,END=911) (RIO(I),I=1,IMSUB)
        READ (NUPT,END=911) (RJO(J),J=1,JMSUB)
        DO 650 II=1,NCLASS
         READ (NUPT,END=911) N,NUMBD(II),DDIAM(II),DDENS(II),DMASS(II),
     1     DVELZ(II),(DCOMP(II,JJ),JJ=1,8)
650     CONTINUE
C
C  READ IN PARTICLE POSITIONS
C
        DO 66 K=1,NMAI
         READ (NUPT,END=911)NORDR(K),X(K),Y(K),Z(K),ZT
 66     CONTINUE
 702    CONTINUE
      GO TO 961
C
C   HERE IF AN EOF WAS ENCOUNTERED ON UNIT 11.
C
 911  CONTINUE
      PRINT 811
 811  FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 11'/)
 961  CONTINUE
C
C       READ THROUGH THE MASS DATA SET
C


      IF(NPTRST.EQ.0) GO TO 706
       DO 703 KJ=1,NPTRST
        READ (NUMS,END=912) TMMT,EMATM,EMBIO,EMBOT,EMCLN,EMDRF,
     1    EMLOS,EMSHR,EMSUR,EMSUS
        WRITE(NW,773)  TMMT
 773    FORMAT(2X,' MASS AT TIME ',F20.3,' READ IN')
 703   CONTINUE
      GO TO 708
C
C    HERE IF AN END OF FILE FOUND ON UNIT 15
C
 912   WRITE(NW,812)
 812   FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 15'/)
 708   IF(NSTT.EQ.-1) NSTEP = 0
C
C    THIS SECTION READS THE RESTART DATA SET ON UNIT 3
C
C
C     READ IN THE VALUES OF THE FOLLOWING VARIABLES WHICH
C     WERE PRESENT AT THE TERMINATION OF THE LAST RUN  THESE
C     ARE WRITTEN OUT AT CERTAIN STEPS AS DETERMINED BY NSUBR
C     IN THE SUBROUTINE  SUBRUF
C
      READ (NURS) IMSUB, JMSUB, KMSUB, NPRTT,
     1  NPRTCT, DTT, TIME, TIMAX, ISCAL, NSAV(99)
      TIME = TIME + DT
      READ (NURS) EMATM, EMBIO, EMBOT, EMCLN, EMDRF, EMLOS,
     1  EMSHR, EMSUR, EMSUS
      READ (NURS) NSPIL, NSPIL
       DO 55 NS=1,NSPIL
        READ (NURS)  ASPIL(NS),BSPIL(NS),DSPIL(NS),
     1    FSPIL(NS),(GSPIL(NS,JJ),JJ=1,6),RSPIL(NS),SSPIL(NS),
     2    SSPILT(NS),TSPIL(NS),TSPILT(NS),USPIL(NS),
     3    VSPIL(NS),XSPIL(NS),YSPIL(NS)
 55    CONTINUE
C
C     REINITIALIZE NSPIL
C
       NSPIL = 0
C
C      SKIP PART OF THIS IF THIS IS A PREVIEW RUN
C
       IF(NRUN.EQ.1) GO TO 332
       READ (NURS) NCLASS
       DO 789 II=1,NCLASS
       READ (NURS) NUMBD(II),DDIAM(II),DDENS(II),DMASS(II),
     1   DVELZ(II),(DCOMP(II,JJ),JJ=1,8)
 789   CONTINUE
       READ (NDAS)NTRRST, NSDNT, NRITRT, NMAIT, NMAI, DX, DY, DZ,
     1    XORIG, YORIG, ZORIG
          DO 405 I=1,NMAI
            READ (NURS) X(I), Y(I), Z(I), NORDR(I)
 405      CONTINUE
 332      CONTINUE
      READ (NURS) NCHEM
      IF(NCHEM.EQ.0) GO TO 65
      DO 540 I=1,NCHEM
      READ (NURS) ACHEM(I), DCHEM(I), ECHEM(I), SCHEM(I), TCHEM(I),
     1     VCHEM(I), WCHEM(I), XCHEM(I), YCHEM(I), PCHEM(I)
540   CONTINUE
```

Figure VII.-3. MAIN

```
      NCHEM = 0
 65   READ (NUNS) NCLN
      IF(NCLN.EQ.0) GO TO 111
      DO 501 I = 1,NCLN
      READ (NUNS) MCLN(I), DCLN(I), XCLN(I), RCLN(I), VCLN(I),
     1     ECLN(I), TCLN(I)
 501  CONTINUE
      NCLN = 0
C
C         FINISH THE RESTART SECTION HERE.
C
 111  CONTINUE
C
C   READ IN THE DEPTH GRID.
C   NOTE: BECAUSE THE FLOATING GRID IS REFERENCED BUT THE DEPTH GRID
C         THE DEPTH GRID SHOULD NEVER BE CHANGED IN THE MIDDLE OF A
C         RUN, IE., DO NOT MOVE THIS CALL.
C
      CALL ARAYIN( NDU, NDD, 1, 'BATHYMETRY  ' ,DEPTH, DEPTH,
     1        MAXDX, MAXDY, AD, XDL, YDL, XDS, YDS, NDX, NDY)
C
C   READ IN THE COMPUTATIONAL CELL GRID
C
      CALL ARAYIN( NCU, NCD, 1, 'COMP CELL   ', CONFI, CONFP,
     1        MAXCX, MAXCY, AC, XCL, YCL, XCS, YCS, NCONF, NCONP)
C
C                 B E G I N   I T E R A T I N G   H E R E
C
  1    CONTINUE
C
C   THIS CONTROL PARAMETER CHECK IS FOR RESTARTING ONLY
C
        INR = INR + 1
        NPRTAT = NPRTA
        IF((NSTRT.EQ.1).AND.(INR LE.NSTEP)) NPRTA = -1
        IF((NSTRT.EQ.1).AND.(INR GT.NSTEP)) NPRTA = NPRTAT
C
C   INCREASE TIME STEP AS SPILL SPREADS AND DISPERSES
C
C READ IN THE STEP CONTROL PARAMETERS AND PRINT OUT VARIBLES READ IN.
C
      READ (NR,100) NP, NV, NT, NK, NS, LSPIL, LCLN, LCHEM
 100  FORMAT(8I5)
      NPAGE = NP + NV + NK + NS + NT
      PRIT = TIME /3600.0
      NPRIT = AMOD( FLOAT(NSTEP), FLOAT(NPRT))
      IF((NSTRT.EQ.1).AND.(INR.LE.NSTEP)) GO TO 10
      IF(NPRIT.NE.0) GO TO 247
      WRITE(NW,240) PRIT
 240  FORMAT('1',120('*')//T27,'SPILL CONTROL PARAMETERS',F8.3,
     1 ' HOURS AFTER THE BEGINNING OF THE SPILL'/'+',T27,72('_')//
     2 '    ENVIRONMENTAL DATA READ THIS STEP:')
      IF(NP.NE.0) WRITE(6,241)
 241                 FORMAT('+',T40,'WIND')
      IF(NV.NE.0) WRITE(NW,242)
 242                 FORMAT('+',T52,'CURRENT')
      IF(NK.NE.0) WRITE(NW,243)
 243                 FORMAT('+',T69,'TEMPERATURE')
      IF(NS.NE.0) WRITE(NW,244)
 244                 FORMAT('+',T92,'SEA STATE')


      IF(NT.NE.0) WRITE(NW,239)
 239                 FORMAT('+',T105,'TIDAL HEIGHTS')
      IF(NPAGE.LE.0) WRITE(NW,245)
 245                   FORMAT('+',T60,'NONE')
      WRITE(6,246) LSPIL, LCLN, LCHEM
 246  FORMAT('0   ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS',
     1  ' THIS STEP:',I3,' SPILLETS:',I5,' CLEANUP EFFORTS:',
     2   I5,' TREATMENT EFFORTS.'//' ',120('*')/)
      NPAGE = NPAGE * NPRTA
 247  CONTINUE
      IF(TIME.GT.0.0) GO TO 10
C
C   IF THIS IS THE FIRST STEP MAKE SURE THAT ALL REQUIRED DATA
C   HAS BEEN READ IN.
C
      NTEST = NP * NV * LSPIL * NT
      IF(NTEST.NE.0) GO TO 10
      WRITE (NW,200)
 200  FORMAT(4X,'MISSING INPUT DATA FOR THE FIRST STEP     EXIT')
      IF(NV.EQ.0) WRITE (NW,210) NV
 210  FORMAT(4X,'NV=',I3)
      IF(NP.EQ.0) WRITE (NW,220) NP
 220  FORMAT(4X,'NP=',I3)
      IF(LSPIL.EQ.0) WRITE (NW,230) LSPIL
 230  FORMAT(4X,'LSPIL=',I3)
      IF(NT.EQ.0)     WRITE (NW,231) NT
 231  FORMAT(4X,' NT =', I3)
      CALL EXIT
 10   CONTINUE
C
C   IF WIND VELOCITY FLAG IS SET READ IN NEW WIND ARRAY.
C
      IF(NP.EQ.1) CALL ARAYIN( NWU, NWD, 2, 'WIND VEL    ', UW, VW,
     1        MAXWX, MAXWY, AW, XWL, YWL, XWS, YWS, NWX, NWY)
C
C   IF TEMPERATURE FLAG IS SET READ IN NEW TEMPERATURE ARRAY.
C
      IF(NK.EQ.1) CALL ARAYIN( NKU, NKD, 1, 'TEMPERATURE ', TEMP,
     1        TEMP, MAXKX, MAXKY, AK, XKL, YKL, XKS, YKS, NKX,.NKY)
C
C   IF SEASTATE FLAG IS SET READ IN NEW SEASTATE ARRAY.
C
      IF(NS.EQ.1) CALL ARAYIN( NSU, NSD, 2, 'SEA STATE   ', WAVHGT,
     1        WAVPRD, MAXSX, MAXSY, AS, XSL, YSL, XSS, YSS, NSX, NSY)
C
C   IF TIDAL VELOCITY FLAG IS SET READ IN NEW TIDAL CURRENT ARRAY.
C
      IF(NV.NE.1) GO TO 109
      CALL ARAYIN( NTUU, NTDU, 1, 'UTID CURRENT', UT, UT, MAXTX,
     1        MAXTY, AT, XTLU, YTLU, XTS, YTS, NTX, NTY)
      CALL ARAYIN( NTUV, NTDV, 1, 'VTID CURRENT', VT, VT, MAXTX,
     1        MAXTY, AT, XTLV, YTLV, XTS, YTS, NTX, NTY)
 109  IF(NT.NE.1) GO TO 110
      CALL ARAYIN( NEU, NED, 1, 'TIDE LEVEL  ', HGHT,.HGHT, MAXEX,
     1        MAXEY, AE, XEL, YEL, XES, YES, NEX, NEY)
 110  CONTINUE
C
C   IF ONE OR MORE ADDITIONAL CLEANUP EFFORTS THIS STEP READ IN.
C
      IF((LCLN.GT.0) .OR. (NPRTC.EQ.1))
```

```
     1   CALL CLNIN( LCLN, NCLD, NPAGE, NSTRT, INR, NSTEP)
C
C   IF ONE OR MORE ADDITIONAL TREATMENT EFFORT THIS STEP READ IN.
C
      IF((LCHEM.GT.0) .OR. (NPRTC.EQ.1))
     1   CALL CHEMIN( LCHEM, NCHD, NPAGE, NSTRT, INR, NSTEP)
C
C   IF ONE OR MORE ADDITIONAL SPILLETS THIS STEP READ THEM IN.
C
      IF((LSPIL.GT.0) .OR. (NPRTC.EQ.1))
     1   CALL SPILIN( LSPIL, NSPD, NPAGE, NSTEP, INR, NSTRT,
     2   NSPPRD, NSPPEP)
C
C    GO BACK TO THE START IF THIS IS A RESTART AND ALL
C     OF THE DATA SETS ARE NOT UP TO THE CORRECT STEP.
C
         IF((NSTRT.EQ.1).AND.(INR.LE.NSTEP)) GO TO 1
C
C   REMOVE OIL BIOLOGICALLY CONSUMED.
C
      CALL CONSUM
C
C   EVAPORATE, DISSOLVE, DRIFT AND SPREAD OIL SPILLETS.
C
      CALL SURFES( X, Y, Z, NORDA, RNSPAR, PORIN, NRUN)
C
C   CONVERT PARTICLE POSITION TO TRANSFORMED SYSTEM IF NECESSARY.
C
      IF( (NTRANS.EQ.1) .AND. (NMAX.GT.0) )
     1     CALL CNVRT2( 1, X, Y, Z, UPLT, DPLT,NORDA)
C
C   MOVE SUSPENDED OIL DROPLETS
C
      CALL SUBSUR( X, Y, Z, NORDA, C, M, NSTEP, UPLT, DPLT)
C
C   MOVE OIL DEPOSITED ON THE  SEA FLOOR.
C
      CALL BOTDFT
C
C   ADD RESURFACED OIL TO EXISTING SPILLETS OR CREATE NEW SPILLETS.
C
      CALL RESRFS
      CALL ADD(COMM)
C
C    LOCATE ALL THE MASS
C
      CALL MASSC( C, M, X, Y, Z, NORDR, NSTEP, NPRTMS)
C
C   CONVERT PARTICLE POSITION FROM TRANSFORMED SYSTEM IF NECESSARY.
C
      IF( (NTRANS.EQ.1) .AND. (NMAX.GT.0) )
     1 CALL CNVRT2( -1, X, Y, Z, UPLT, DPLT,NORDR)
C
C  IF STEP IS MULTIPLE OF NSUMM WRITE OUT TO RESTART DATA SET
C
      NCM = AMOD(FLOAT(NSTEP),FLOAT(NSUMM))
      IF((NCM.EQ.0).AND.(NRUN.E..0))
     1   CALL SUMMUP(X, Y, Z, NORDR, NSTEP, NPRTMS, NSPPRD,
     1    NRUN)
 C


C   INCREMENT TIME
C
       TIME = TIME + DT
       NSTEP = NSTEP + 1
C
C     IF TIME LIMIT IS EXCEEDED, TERMINATE THE RUN
C
      IF(TIME.LT.TIMMAX) GO TO 1
C
C   SUMMUP THE END OF THE RUN
C
      NSTEP = NSTEP - 1
      TIME = TIME - DT
      CALL SUMMUP(X, Y, Z, NORDR, NSTEP, NPRTMS,NSPPRD,NRUN)
C
C              E N D   H E R E
C
      STOP
      END
       SUBROUTINE DIST(X1, Y1, X2, Y2, NO, ANG, D, XSP, YSP)
C
C  THIS SUBROUTINE CALCULATES DISTANCES
C  IF NO = 1  IT ASSUMESTHAT THE TWO POINTS ARE
C             GIVEN IN LONGITUDE AND LATITUDE AND
C             IT CALCULATES THE GREAT CIRCLE DISTANCE
C             BETWEEN THEM IN METERS.
C  IF NO = 2  IT CALCULATES THE X AND Y SPACING BETWEEN
C             TWO POINTS GIVEN IN LONGITUDE AND LATITUDE.
C  IF NO = 5  IT CALCULATES THE DIFFERENCE BETWEEN THE NUMBERS.
C             THIS IS USED WHEN FINDING THE DIFFERENCE BETWEEN
C             TWO POINTS WHICH HAVE  DIMENSIONS IN DEGREES
C             SO NO CONVERSION IS NECESSARY.
C  IF ANG = 0  THEN NO ROTATION
C  IF ANG > 0  THEN ROTATE COUNTER-CLOCKWISE
C  IF ANG < 0  THEN ROTATE CLOCKWISE
C
C...........................................................
      PI=3.14159
      R=6371.0
      SCAL = R*1000.0*PI/180.0
      RAD = PI/180.0
      IF(NO.EQ 2) GO TO 100
      IF(NO.EQ.5) GO TO 400
      B1=SIN(Y1*RAD)*SIN(Y2*RAD)
      XD=ABS(X2-X1)
      B2=COS(Y1*RAD)*COS(Y2*RAD)*COS(XD*RAD)
      S=ARCOS(B1+B2)
      D=R*S*1000.0
      RETURN
 100  CONTINUE
      YSP= (Y2-Y1)*SCAL
      XSP= (X1-X2)*SCAL*COS(Y2*RAD)
      IF(ANG.EQ.0.0) RETURN
      GO TO 500
 400  CONTINUE
      XSP=X1-X2
      YSP=Y2-Y1
      IF(ANG.EQ.0.0) RETURN
 500  CONTINUE
      XSP=XSP*COS(ANG)+YSP*SIN(ANG)
```

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```
      YSP=-XSP*SIN(ANG)+YSP*COS(ANG)
      RETURN
      END
       SUBROUTINE MASSC( C, N, X, Y, Z, NORDR, NST, NPRTMS)
C                 SUBROUTINE DESCRIPTION
C
C     IN THIS SUBROUTINE THE MASS OF THOSE PARTICLES LOST
C  THROUGH AN OPEN BOUNDARY OR DEPOSITED IS CALCULATED ALONG
C  WITH THE REMAINING MASS.
C
C...............................................................
C
C                 COMMON STATEMENTS
C
      COMMON /DEPOS/ NLOST, NDEP
      COMMON /CNTL/ INSUB, JNSUB, NNSUB, NPRTA,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ XMATM, XMBIO, XMBOT, XMCLN, XMDMP, XMLCS,
     1     XMSHR, XMSUR, XMSUS
      COMMON /OUTP/ NOSP, NORS, NOCN, NOPT, NOMS, NOLT,
     1     NODP, NUTL
      COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1     DMASS(200), DVELZ(200), DCONF(200, 8), NTCLAS, NDSCL
      COMMON /SUBS/ NTRANS, NSUB, NRITE, NMAX, MMAX, DX, DY, DZ,
     1     XORIG, YORIG, ZORIG
C
C                 DIMENSION STATEMENTS
C
       DIMENSION C(15,15,10)
       DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
       INTEGER N(15,15,10)
       INTEGER*2 NORDR(NMAX)
C
       DATA NW / 6/
C
C                 S T A R T   H E R E
C
C    PRINTOUT MASS BALANCE THIS STEP ONLY ONCE PER DAY.
C
      NPRIT = AMOD( FLOAT(NST), FLOAT(NPRTMS))
      IF(NPRIT.NE.0)    RETURN
        WRITE (NOMS) TIME, XMATM, XMBIO, XMBOT, XMCLN, XMDMP, XMLOS,
     1     XMSHR, XMSUR, XMSUS
C
      WRITE(NW,50)
 50   FORMAT(/' ',120('*')///T56, 'MASS BALANCE'/'+', T56,12('_'))
C
C
C    PRINT OUT TOTAL AMOUNT OF MASS
C
      WRITE(NW,5) XMDMP
 5    FORMAT(/, 25X, 'TOTAL MASS OF OIL SPILLED', 5X, F13.5,
     1  2X, 'METRIC TONS', //)
      WRITE(NW,21)
 21   FORMAT(7X, 'LOCATION OF OIL', 47X, 'AMOUNT (METRIC TONS)',
     1   14X, 'PERCENT OF TOTAL')
C
C  PRINT OUT TOTAL AMOUNT IN ATMOSPHERE
C
      PRT  = 100.0 * XMATM / XMDMP



      WRITE(NW,80) XMATM, PRT
 80   FORMAT(10X, 'IN ATMOSPHERE', T74, F13.5, T110, F6.2)
C
C  PRINT OUT TOTAL AMOUNT ON SURFACE
C
      PRT  = 100.0 * XMSUR / XMDMP
      WRITE(NW,55) XMSUR, PRT
 55   FORMAT(10X, 'ON SURFACE', T74, F13.5, T110, F6.2)
C
C  PRINT OUT REMAINING MASS IN WATER COLUMN
C
      PRT=100.0 * XMSUS/XMDMP
      WRITE(NW,20) NMAX, XMSUS, PRT
 20   FORMAT(10X, 'IN WATER COLUMN', T35, I5, ' MARKED PARTICLES', T74,
     1   F13.5, T110, F6.2)
C
C  PRINT OUT AMOUNT ON BOTTOM
C
      PRT = 100.0 *XMBOT/XMDMP
      WRITE(NW,40) NDEP, XMBOT, PRT
 40   FORMAT(10X,'ON BOTTOM        ',T35,I5,' DEPOSITED PARTICLES',T74,
     1   F13.5, T110, F6.2)
C
C  PRINT OUT AMOUNT ON THE SHORE
C
      PRT= 100.0 * XMSHR/XMDMP
      WRITE(NW,62) XMSHR, PRT
 62   FORMAT(10X, 'ON SHORE', T74, F13.5, T110, F6.2)
      WRITE(NW,63)
63    FORMAT(7X, 'REMOVAL MECHANISMS')
C
C PRINT OUT AMOUNT BIOLOGICALLY CONSUMED
C
      PRT = 100.0 * XMBIO/XMDMP
      WRITE(NW,70) XMBIO, PRT
 70   FORMAT(10X, 'BIOLOGICALLY CONSUMED', T74, F13.5, T110; F6.2)
C
C  PRINT OUT AMOUNT PHYSICALLY CLEANED UP
C
      PRT = 100.0 *XMCLN/XMDMP
      WRITE(NW,44) XMCLN, PRT
 44   FORMAT(10X, 'PHYSICALLY CLEANED UP', T74, F13.5, T110, F6.2)
C
C  AMOUNT LOST THRU BOUNDARIES
C
      PRT = 100.0 * XMLOS/XMDMP
      WRITE(NW,60) NLOST, XMLOS, PRT
 60   FORMAT(10X, 'LOST THRU OPEN BOUNDARY', T35, I5, ' LOST PARTICLES',
     1  T74, F13.5, T110, F6.2//2(' ',120('*')/))
C                 R E T U R N   H E R E
C
       RETURN
       END
      SUBROUTINE ROTAT(XL, YL, XD, YD, ANG, XO, YO, XG, YG)
C
C  THIS SUBROUTINE CONVERTS THE POSITIONS XO, YO, WHICH ARE
C         WITH RESPECT TO THE DEPTH GRID
C          TO POSITION WITH RESPECT TO A NEW GRID
C        AS DEFINED BY XL, YL, XD, YD, ANG,
C        WHERE XL AND YL ARE THE LONGITUDE AND LATITUDE
```

```
C        OF THE NEW GRID, XD AND YD ARE THE GRID SEPARATIONS,
C        AND ANG IS THE ANGLE WITH RESPECT TO LINES OF CONSTANT
C        LATITUDE.
C
C.. .............................. .................
      COMMON /SUBS/ NTRANS, NSUB, NRITE, NMAX, MMAX, DX, DY, DZ,
     1       XORIG, YORIG, ZORIG
      COMMON /CNTL/ INSUB, JNSUB, NNSUB, NPRTA,
     1     NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30, 30), XDL, YDL,
     1     XDS, YDS
C
      NO = 2
      IF(ISCAL.EQ.2) NO = 5
      AND = ANG - AD
      XN = XO*COS(AND)+YO*SIN(AND)
      YN =-XO*SIN(AND)+YO*COS(AND)
C
C CALCULATE DISTANCE BETWEEN ORIGINS
C
      CALL DIST(XDL, YDL, XL, YL, NO, ANG, D, XSP, YSP)
      XDP = XN - XSP
      YDP = YN - YSP
      XG = XDP/XD + 1.0
      YG = YDP/YD + 1.0
      RETURN
      END
C
      SUBROUTINE ARAYIN( NO, ND, NO, NAME, ARRAY1, ARRAY2, IMAX,
     1              JMAX, ANGLE, XL, YL, XS, YS, MARAY1, MARAY2)
C
C                 SUBROUTINE DESCRIPTION
C
C       THIS SUBROUTINE READS IN ONE OR TWO ARRAYS FOR THE VARIOUS
C    GRIDS USED IN THE PROGRAM, SPECIFICALLY THE DEPTH GRID, THE
C    WIND VELOCITY GRID, THE TEMPERATURE GRID AND THE SEA STATE
C    GRID.
C
C                 VARIABLE DESCRIPTION
C
C      SUBROUTINE ARGUMENTS
C
C    (1) NO      - FORMAT CONTROL: 1 - UNFORMATTED REAL;
C                                  2 - UNFORMATTED INTEGER;
C                                  3 - FORMATTED REAL;
C                                  4 - FORMATTED INTEGER.
C    (2) ND      - UNIT # DATA IS TO BE READ FROM.
C    (3) NO      - # OF ARRAYS TO BE READ IN.
C    (4) NAME    - DESCRIPTOR FOR VARIABLE TO BE READ IN
C    (5) ARRAY1 - FIRST ARRAY READ IN.
C    (6) ARRAY2 - SECOND ARRAY READ IN.
C    (7) IMAX    - # OF ELEMENTS IN X IN THE INPUT ARRAYS.
C    (8) JMAX    - # OF ELEMENTS IN Y IN THE INPUT ARRAYS.
C    (9) ANGLE   - ANGLE BETWEEN THE X AXIS FOR THE INPUT VARIABLES
C                  AND LINES OF CONSTANT LATITUDE.
C    (10) XL      - LONGITUDE OF THE ORIGIN OF THE FLOATING GRID.
C    (11) YL      - LATITUDE OF THE ORIGIN OF THE FLOATING GRID.
C    (12) XS      - GRID SPACING IN X.
C    (13) YS      - GRID SPACING IN Y.
C    (14) MARAY1 - EQUIVALENCED TO ARRAY1 IN THE CALLING PROGRAM


C    (15) MARAY2 - EQUIVALENCED TO ARRAY2 IN THE CALLING PROGRAM
C
C      OTHER VARIABLES USED IN THE SUBROUTINE
C
C    NAM     - THE DESCRIPTOR OF THE INPUT VARIABLE STORED
C              WITH THE DATA.
C    VAR1    -2- NAME OF ARRAY1 TO BE USED IN PRINTOUT HEADER.
C    VAR2    -2- NAME OF ARRAY2 TO BE USED IN PRINTOUT HEADER.
C    UNITS1 -3- UNITS OF ARRAY1 TO BE USED IN PRINTOUT HEADER
C    UNITS2 -3- UNITS OF ARRAY2 TO BE USED IN PRINTOUT HEADER
C
C      NOTE 1: THE ARRAYS ARRAY1 AND ARRAY2 ARE EQUIVALENCED IN THE
C              MAIN PROGRAM TO THE ARRAYS MARAY1 AND MARAY2. THE
C              PARAMETER NO DETERMINES IF AN INTEGER OR A FLOATING
C              POINT VALUE IS TO BE READ IN.
C
C...............................................................
C
C                 COMMON STATEMENTS
C
      COMMON /CNTL/ INSUB, JNSUB, NNSUB, NPRTA,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /UNIT/ UNITS3(2)
C                 DIMENSION STATEMENTS
C
      DIMENSION ARRAY1( 30, 30), ARRAY2( 30, 30), NAM(3), NAME(3)
      DIMENSION VAR1(2), VAR2(2), UNITS1(3), UNITS2(3)
      DIMENSION NI(15), MARAY1( 30, 30), MARAY2( 30, 30)
      DIMENSION ARAY1T( 30, 30), ARAY2T( 30, 30)
C
C                 DATA STATEMENTS
C
      DATA PI, NW/ 3.14159, 6/
      DATA NI/ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15/
      DATA NAM1, NAM2/ 'UWID', 'VWID'/
C
C                 S T A R T   H E R E
C
C  DETERMINE DIMENSIONS OF GRIDS
C
C
C   READ IN GRID DEFINITION VARIABLES (FORMATTED).
C
      IF(NO.LE.2) GO TO 20
      READ (ND,100) NAM, VAR1, UNITS1, VAR2, UNITS2
 100  FORMAT(13A4)
      READ (ND,105) IMAX, JMAX, ANGLE, XL, YL, XS, YS, UNITS3
 105  FORMAT(2I5,3F10.6,2F10.4,2A4)
      GO TO 25
C
C   READ IN GRID DEFINITION VARIABLES (UNFORMATTED).
C
 20   CONTINUE
      READ (ND) NAM, VAR1, UNITS1, VAR2, UNITS2
      READ (ND) IMAX, JMAX, ANGLE, XL, YL, XS, YS, UNITS3
C
C   CHECK THAT THIS IS THE DATA REQUESTED.
C
 25   CONTINUE
      DO 900 I=1,3
```

Figure VII.-3. MAIN

```
         IF(NAB(I).NE.NAME(I)) GO TO 999
 900  CONTINUE
C
C  TEST IF THE DIMENSIONS ARE RIGHT
C
      IF((ISCAL EQ.1).AND.(XS.GT 5.0))  GO TO 41
      IF((ISCAL.EQ.1).AND.(YS.GT.5.0))  GO TO 41
      IF((ISCAL EQ.2).AND.(XS.LT 5.0))  GO TO 41
      IF((ISCAL.EQ.2).AND.(YS.LT.5.0))  GO TO 41
      WRITE (NW,67) ISCAL,XS,YS
 67   FORMAT(100('*'),/2X,'DIMENSIONS DO NOT MATCH',
     1'ISCAL = ',I3,6X,'XS =',F10.3,6X,'YS =',F10.3)
      STOP
  41  CONTINUE
      IF(ISCAL.EQ.1) GO TO 42
      IF(ISCAL.EQ.2.AND ANGLE.EQ 0.0) GO TO 42
      WRITE (NW,63) ANGLE
 63   FORMAT(100('*'),/2X,'ISCAL = 2 AND ANGLE =',F10.3)
      STOP
 42   CONTINUE
      IF(NPRTA) 10,11,12
C
C   WRITE GRID DEFINITION VARIABLES AND HEADER IF OUTPUT REQUESTED.
C
 12   CONTINUE
      PRIT = TIME / 3600.0
      WRITE (NW,200) NAB, PRIT, NAR, IMAX, XS, UNITS3, JMAX, YS, UNITS3
 200  FORMAT('1',40X,3A4,' INPUT DATA ',F10.2,'  HOURS  AFTER',
     1         ' THE BEGINNING OF THE SPILL'//4X,'THE ',3A4,
     2         ' GRID HAS ',I5,' DIVISIONS IN X SPACED ',F12.4,
     3         1X,2A4,' APART'/26X,'AND ',I5,
     4         ' DIVISIONS IN Y SPACED ',F12.4,1X,2A4,' APART.'/)
      WRITE (NW,210) NAR, XL, YL
 210  FORMAT(4X,'THE (1,1) GRID LOCATION OF THE ',3A4,
     1         ' COORDINATE SYSTEM IS AT ',
     1         F10.6,' DEGREES LONGITUDE AND ',F10.6,
     2         ' DEGREES LATITUDE '/)
      IF(ANGLE.NE.0.0) WRITE (NW,215) NAR, ANGLE
 215  FORMAT(4X,'FINALLY THE X AXIS OF THE ',3A4,
     1         ' GRID MAKES AN ANGLE (COUNTERCLOCKWISE) OF',F10.6,
     2         ' DEGREES WITH LINES OF'/4X,'CONSTANT LATITUDE.')
      ANGLE = ANGLE * PI / 180.0
      GO TO 10
C
C   HERE ONLY IF THE SHORT DIAGNOSTIC FORM IS DESIRED.
C
 11   CONTINUE
      TNT = TIME / 3600.0
      WRITE (NW,230) NAR, TNT
 230  FORMAT(4X,'NEW ',3A4,' INFORMATION IS BEING READ IN',F10.4,
     1         ' HOURS INTO THE SPILL')
C
C   HERE TO READ IN THE DATA.
C
 10   CONTINUE
C
C   BRANCH TO READ DIFFERENT FORMAT TYPES.
C
       GO TO (40,50,60,70), NO
C


C   HERE TO READ UNFORMATTED REAL VARIABLES
C
 40   CONTINUE
      READ (ND)  ((ARRAY1(I,J),I=1,IMAX),J=1,JMAX)
      IF(NO.EQ.1) GO TO 80
      READ (ND)  ((ARRAY2(I,J),I=1,IMAX),J=1,JMAX)
      GO TO 80
C
C   HERE TO READ UNFORMATTED INTEGER VARIABLES.
C
 50   CONTINUE
      READ (ND)  ((NARAY1(I,J),I=1,IMAX),J=1,JMAX)
      IF(NO.EQ.1) GO TO 90
      READ (ND)  ((NARAY2(I,J),I=1,IMAX),J=1,JMAX)
      GO TO 90
C
C   HERE TO READ FORMATTED REAL VARIABLES.
C
 60   CONTINUE
      DO 62 J=1,JMAX
         READ (ND,110)  (ARRAY1(I,J),I=1,IMAX)
 110     FORMAT(10F6.2)
 62   CONTINUE
      IF(NO.EQ.1) GO TO 80
      DO 64 J=1,JMAX
         READ (ND,110)  (ARRAY2(I,J),I=1,IMAX)
 64   CONTINUE
      GO TO 80
C
C   HERE TO READ FORMATTED INTEGER VARIABLES.
C
 70   CONTINUE
      DO 72 J=1,JMAX
         READ (ND,120)  (NARAY1(I,J),I=1,IMAX)
 120     FORMAT(15I4)
 72   CONTINUE
      IF(NO.EQ.1) GO TO 90
      DO 74 J=1,JMAX
         READ (ND,120)  (NARAY2(I,J),I=1,IMAX)
 74   CONTINUE
      GO TO 90
C
C   HERE TO PRINT REAL ARRAYS.
C
 80   CONTINUE
      IF(NPRTA.LE.0) RETURN
      DO 96 I = 1,IMAX
      DO 96 J = 1,JMAX
      ARAY1T(I,J) = ARRAY1(I,J)
 96   ARAY2T(I,J) = ARRAY2(I,J)
      NFT = 0
C
C  THIS FIXES THE REAL ARRAYS IF ISCAL = 2
C
      IF(ISCAL.EQ.1) GO TO 56
      IF(NAB(1).EQ.NAB1) GO TO 55
      IF(NAB(1).NE.NAB2) GO TO 56
  55  NFT = 1
      WRITE (NW,24)
 24   FORMAT(1X,' ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED',
    1  ' BY 10 ** -6')
 56   CONTINUE
      IMAXX = IMAX
      IF(IMAXX.GT.15) IMAXX = 15
      WRITE (NW,220) VAR1, UNITS1, (KX(II),II=1,IMAXX)
 220  FORMAT(//50X,2A4,' VALUES IN UNITS OF ',3A4//4X,'Y',55X,
    1     'X ELEMENTS'/1X,'ELEMENTS',3X,15(I2,6X)//)
       IF(NFT.NE.1) GO TO 77
       DO 71 I=1,IMAX
       DO 71 J=1,JMAX
 71    ARAY1T(I,J) = ARAY1T(I,J)*(10**6.0)
 77    CONTINUE
      J = JMAX + 1
      DO 82 K=1,JMAX
         J = J - 1
         WRITE (NW,240) J, (ARAY1T(I,J),I=1,IMAX)
 240     FORMAT('0',I4,5X,15(1X,F7.3)/(8X,15(1X,F7.3)))
 82   CONTINUE
      IF(NO.EQ.1) RETURN
      IF(NFT.NE.1) GO TO 79
      DO 76 I=1,IMAX
      DO 76 J=1,JMAX
 76   ARAY2T(I,J) = ARAY2T(I,J) * (10**6.0)
 79   CONTINUE
      WRITE (NW,220) VAR2, UNITS2, (KX(II),II=1,IMAXX)
      J = JMAX + 1
      DO 84 K=1,JMAX
         J = J - 1
         WRITE (NW,240) J, (ARAY2T(I,J),I=1,IMAX)
 84   CONTINUE
      RETURN
C
C   HERE TO PRINT INTEGER ARRAYS
C
 90   CONTINUE
      IF(NPRTA.LE.0) RETURN
      IMAXX = IMAX
      IF(IMAXX.GT.15) IMAXX = 15
      WRITE (NW,220) VAR1, UNITS1, (KX(II),II=1,IMAXX)
      J = JMAX + 1
      DO 92 K=1,JMAX
         J = J - 1
         WRITE (NW,250) J, (NARAY1(I,J),I=1,IMAX)
 250     FORMAT(1X,I5,2X,15(2X,I4,2X))
 92   CONTINUE
      IF(NO.EQ.1) RETURN
      WRITE (NW,220) VAR2, UNITS2, (KX(II),II=1,IMAXX)
      J = JMAX + 1
      DO 94 K=1,JMAX
         J = J - 1
         WRITE (NW,250) J, (NARAY2(I,J),I=1,IMAX)
 94   CONTINUE
      RETURN
C
C   HERE IF THERE IS PROBLEM WITH THE VARIABLE NAME.
C
 999  CONTINUE
      WRITE (NW,260) NAME, NAR
 260  FORMAT(10X,'FATAL ERROR'/10X,3A4,' REQUESTED ',
    1        3A4,' READ IN.   ACTION TAKEN - SNNUF AND EXIT.')


C
C                E N D   M A I N
C
      STOP
      END
      SUBROUTINE CLNIN( LCLN, NC, NPAGE, NSTRT, INR, NSTEP)
C
C     THIS SUBROUTINE READS IN INFORMATION FOR ADDITIONAL
C   CLEANUP EFFORTS.
C
C.................................................................
C
C                COMMON STATEMENTS
C
      COMMON /CLEN/ NCLN, BCLN(10), DCLN(10), ECLN(10), RCLN(10),
     1     VCLN(10), ZCLN(10), YCLN(10)
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPNTA,
     1     NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(95)
C
C                DATA STATEMENTS
C
      DATA NW/6/
C
C                S T A R T   H E R E
C
C   PRINT OUT HEADER FOR THIS PAGE OF OUTPUT
C
      JCLN = NCLN + LCLN
      IF(JCLN.LE.0) RETURN
C
C    GO TO ANOTHER SECTION IF THIS IS A RESTART
C
      IF((NSTRT.EQ.1).AND.(INR.LE.NSTEP)) GO TO 28
      IF(NPAGE.GE.1) WRITE (NW,201)
 201                 FORMAT('1')
      PRIT = TIME / 3600.0
      WRITE (NW,200) PRIT
 200  FORMAT('0',T15,'PHYSICAL CLEANUP EFFORTS IN PROGRESS ',F10.5,
    1 ' HOURS AFTER THE BEGINNING OF THIS RUN'/'+',T15,85('_')/)
C
C   DO LOOP OVER ALL CURRENT CLEANUP EFFORTS.
C
      IF(NCLN.GT.0) WRITE (NW,210)
 210  FORMAT(30X,'CONTINUING SPILL CLEANUP EFFORTS THIS STEP'/)
      DO 10 I=1,JCLN
C
C   DETERMINE IF THESE ARE NEW CLEANUP EFFORTS THIS STEP OR NOT
C
         IF(I-NCLN-1) 20, 21, 22
 21      CONTINUE
         WRITE (NW,220)
 220     FORMAT(30X,'NEW CLEANUP EFFORTS THIS TIME STEP'/)
 22      CONTINUE
         READ (ND,100) BCLN(I), DCLN(I), ECLN(I), RCLN(I),
    1                  VCLN(I), ZCLN(I), YCLN(I)
 100        FORMAT(7F10.3)
 20   CONTINUE
C
C   WRITE OUT ALL DATA ASSOCIATED WITH THIS CLEANUP EFFORT.
C
```

Figure VII.-3. MAIN

```
      WRITE (NW,230) I, XCLN(I), YCLN(I), RCLN(I)
 230  FORMAT(4X,'THE',I4,' CLEANUP EFFORT CURRENTLY UNDERWAY',
     1     ' IS CENTERED AT LONGITUDE ',F10.6,' AND LATITUDE ',
     2     F10.6/4X,'THE RADIUS OF COVERAGE OF THIS EFFORT IS ',
     3     F10.3,' METERS')
      WRITE (NW,240) VCLN(I), ECLN(I)
 240  FORMAT(4X,'THE MAXIMUM RATE OF RECOVERY IS ',F10.6,
     1          ' TONS/HOUR WITH AN EFFICIENCY OF ',F10.6,'%')
      WRITE (NW,250) BCLN(I), DCLN(I)
 250  FORMAT(4X,'THIS CLEANUP STARTS ',F10.6,' HOURS AFTER THE'
     1     ,' BEGINNING OF THE SPILL AND LASTS',F10.6,' HOURS'/)
 10   CONTINUE
C
C  UPDATE THE CLEANUP COUNTER.
C
      NCLN = JCLN
      RETURN
 20   CONTINUE
      IF(LCLN.EQ.0) RETURN
      READ(ND,100) XCL, DCL, RCL, ACL, VCL, ECL, YCL
      WRITE (NW,31) IBN
 31   FORMAT(2X,' AT STEP ',I4,' OLD CLEANUP INFORMATION READ IN')
      NCLN = JCLN
      TNT = (BCL+DCL)*3600.0
      IF(TIME.GT.TNT) NCLN=NCLN-1
C
C              E N D   H E R E
C
      RETURN
      END
      SUBROUTINE CHEMIN( LCHEM, ND, NPAGE, NSTRT, IBN, NSTEP)
C
C     THIS SUBROUTINE READS IN THE CHEMICAL TREATMENT INPUT
C   PROPERTIES AND PRINTS THEM OUT.
C
C.................................................................
C
C              COMMON STATEMENTS
C
      COMMON /CHEM/ NCHEM, BCHEM(10), DCHEM(10), RCHEM(10),
     1     SCHEM(10), YCHEM(10), VCHEM(10), UCHEM(10), XCHEM(10),
     2     TCHEM(10), PCHEM(10)
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPNTA,
     1     NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
C
C              DATA STATEMENTS
C
      DATA NW/6/
C
C              S T A R T   H E R E
C
C   WRITE OUT HEADER AND TIME FOR THIS STEP.
C
      JCHEM = NCHEM + LCHEM
      IF(JCHEM.LE.0) RETURN
C
C  GO TO ANOTHER SECTION IF THIS IS A RESTART
C
      IF((NSTRT.EQ.1).AND.(IBN.LE.NSTEP)) GO TO 28
      IF(NPAGE.GE.1) WRITE (NW,201)



 201                 FORMAT('1')
      PRIT = TIME / 3600.0
      WRITE (NW,200) PRIT
 200  FORMAT('0',T15,'CHEMICAL TREATMENT EFFORTS IN PROGRESS',
     1       F10.6,' HOURS AFTER THE BEGINNING OF THE SPILL'/
     2       '+',T15,87('_')/)
C
C   DO LOOP OVER ALL CURRENT TREATMENT EFFORTS.
C
      IF(NCHEM.GT.0) WRITE (NW,210)
 210  FORMAT(30X,'CONTINUING TREATMENT EFFORTS THIS STEP'/)
      DO 10 I=1,JCHEM
         IF(I-NCHEM-1) 20, 21, 22
 21      CONTINUE
         WRITE (NW,220)
 220     FORMAT(30X,'NEW TREATMENT EFFORTS BEGUN THIS STEP'/)
 22      CONTINUE
         READ (ND,100) BCHEM(I), DCHEM(I), PCHEM(I), RCHEM(I), SCHEM(I),
     1                 YCHEM(I), VCHEM(I), UCHEM(I), XCHEM(I), TCHEM(I)
 100     FORMAT(5F10.3)
 20      CONTINUE
C
C   PRINT OUT ALL TREATMENT DATA FOR CURRENT EFFORTS.
C
         TEMP = VCHEM(I) / UCHEM(I)
         WRITE (NW,230) I, XCHEM(I), YCHEM(I), VCHEM(I), TEMP, PCHEM(I)
 230     FORMAT(4X,'THE ',I4,' CHEMICAL TREATMENT EFFORT',
     1        ' IS CENTERED AT LONGITUDE ',F10.6,' AND LATITUDE ',
     2       F10.6/4X,F10.3,' LITERS OF DISPERSANT PER HOUR',
     3        ' ARE USED ON AN AREA OF ',F10.3,' SQUARE METERS',
     4         'WITH AN EFFICIENCY OF ',F5.2,' % ')
         WRITE (NW,240) RCHEM(I)
 240     FORMAT(4X,'THE RADIUS OVER WHICH SPILLETS TO BE TREATED',
     1        ' ARE SOUGHT IS ',F10.3,' METERS')
         WRITE (NW,250) BCHEM(I), DCHEM(I)
 250     FORMAT(4X,'THIS TREATMENT EFFORT STARTS ',F10.6,' HOURS'
     1        ,' AFTER THE BEGINNING OF THE SPILL AND LASTS ',F10.6,
     2        ' HOURS.')
         WRITE (NW,260) SCHEM(I)
 260     FORMAT(4X,'THIS TREATMENT EFFORT LOWERS THE INTERFACIAL',
     1        ' TENSION TO ',F10.6/)
 10   CONTINUE
C
C   STORE THE NUMBER OF CURRENT TREATMENT EFFORTS.
C
      NCHEM = JCHEM
      RETURN
 28    CONTINUE
       IF(LCHEM.EQ.0) RETURN
       READ(ND,100) BCH, DCH, RCH, SCH,  TCH,
     1    VCH, UCH, XCH, YCH, PCH
       WRITE (NW,31) IBN
 31    FORMAT(2X,'AT STEP ',I4,' OLD TREATMENT INFO READ IN')
       NCHEM = JCHEM
       TNT=(BCH+DCH)*3600.0
       IF(TIME.GT.TNT) NCHEM=NCHEM-1
C
C              E N D   H E R E
C
      RETURN
```

```
      END
      SUBROUTINE INITSS (NPNTNS, POMIN)
C
C              SUBROUTINE DESCRIPTION
C
C     THIS SUBROUTINE IS USED TO INITIALIZE THE SUBSURFACE DRIFT/
C   DIFFUSION MODEL.
C
C..............................  ...................................
C
C              COMMON STATEMENTS
C
      COMMON /DIFU/ NCRIT, NDIFF, DXX, DYY, DZZ, EXX, EYY,
     1     POWX, POWY
      COMMON /DEPOS/ NLOST, NDEP
      COMMON /INJC/ DEPC, AFRAC, BIFRAC, BOFRAC, DDIAMT,DVELZT, NENT
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPNTA,
     1     NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /PRNT/ KPNTY, KPNTC, KPNTP, NPNL, NPNY, NPNC, NPNP,
     1     NPTSUB, NPASUB
      COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1     DMASS(200), DVELZ(200), DCONF(200, 8), NTCLAS, NUMCL
      COMMON /SUBS/ NTRANS, NSUB, NEITA, RMAX, MMAX, DX, DY, DZ,
     1   XORIG, YORIG, ZORIG
C
C            DATA STATEMENTS
       DATA NW / 6/
C
C              S T A R T   H E R E
C
       WRITE(NW,200)
 200  FORMAT('1', T5, 'INPUT STREAM FOR THE SUBSURFACE PORTION',
     1  ' OF THE MODEL'//)
      CALL READF( POWX, 'POWX     ')
      CALL READF( POWY, 'POWY     ')
      CALL READF( EXX, 'EXX      ')
      CALL READF( EYY, 'EYY      ')
      CALL READI( NTRANS, 'NTRANS  ', 0,1)
      CALL READF( DXX, 'DXX      ')
      CALL READF( DYY, 'DYY      ')
      CALL READF( DZZ, 'DZZ      ')
      CALL READF( DX, 'DX      ')
      CALL READF( DY, 'DY      ')
      CALL READF( DZ, 'DZ      ')
C INSUB AND JNSUB MUST BE GREATER THAN THREE BECAUSE OF
C THE RESTRICTIONS IN SUBROUTINE GRIDZI
      CALL READI( INSUB, 'INSUB    ', 4,30)
      CALL READI( JNSUB, 'JNSUB    ', 4,30)
      CALL READI( KNSUB, 'KNSUB    ',1,10)
      IF(NTRANS.EQ.0) GO TO 20
      DZ=(1.0/FLOAT(KNSUB))
      WRITE (NW, 44) DZ
 44   FORMAT(2X, F15.4, 5X, 'CORRECTION TO DZ')
 20   CONTINUE
      CALL READI( NSUB, 'NSUB     ', 0,1)
      CALL READI( NDIFF, 'NDIFF    ', 0,1)
      CALL READI( NCRIT, 'NCRIT    ', 0,1000)
      CALL READI( NEITA, 'NEITA    ', 0,1)
      CALL READF( DEPC, 'DEPC     ')
      CALL READF( POMIN, 'POMIN    ')



      CALL READF( AFRAC, 'AFRAC    ')
      CALL READF( BIFRAC, 'BIFRAC   ')
      CALL READF( BOFRAC, 'BOFRAC   ')
      CALL READF( NENT, 'NENT     ')
      CALL READF( DDIAMT, 'DDIAMT   ')
      CALL READF( DVELZT, 'DVELZT   ')
      CALL READI( NPTSUB, 'NPTSUB   ',-1,100)
      CALL READI( NPNTNS, 'NPNTNS   ',-1,100)
      CALL READI( KPNTY, 'KPNTY    ',0,100)
      CALL READI( KPNTC, 'KPNTC    ',0,100)
      CALL READI( KPNTP, 'KPNTP    ', 0,100)
      CALL READI( NPNL, 'NPNL     ',0,100)
      CALL READI( NPNY, 'NPNY     ',0,100)
      CALL READI( NPNC, 'NPNC     ',0,100)
      CALL READI( NPNP, 'NPNP     ',0,100)
C
C   ZERO SUBSURFACE COUNTERS.
C
      DO 30 I=1, NTCLAS
         NUMBD(I) = 0
         DDENS(I) =0.0
         DMASS(I) = 0.0
         DDIAM(I) = 0.0
         DVELZ(I)=0.0
 30   CONTINUE
      NCLASS = 0
C
C              R E T U R N   H E R E
C
      RETURN
      END
      SUBROUTINE READI(I,INAME,NL,NU)
      REAL*8 INAME, IPNAME
      DATA NR,NW/5,6/
      READ (NR,10) I,IPNAME
  10  FORMAT(I15,5X,A8)
      IF(IPNAME.EQ.INAME) GO TO 100
      WRITE (NW,20) IPNAME, INAME
  20  FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
      STOP
 100  CONTINUE
      IF(NL.EQ.NU) GO TO 200
      IF( (I.GE.NL) .AND. (I.LE.NU) ) GO TO 200
      WRITE (NW,40) INAME, NL, NU, INAME, I
  40  FORMAT(16H0 THE LIMITS ON ,A8,5H ARE ,I5,4H TO ,I5,
     1  6H  BUT ,A8,16H WAS READ IN AS  ,I5)
      STOP
 200  CONTINUE
      WRITE (NW,30) I, INAME
  30  FORMAT(2X,I15,5X,A8)
      RETURN
      END
      SUBROUTINE READF( X, INAME)
      REAL*8 INAME, IPNAME
      DATA NR,NW/5,6/
      READ (NR,10) X, IPNAME
  10  FORMAT(F15.5,5X,A8)
      IF(INAME.EQ.IPNAME) GO TO 100
      WRITE (NW,20) IPNAME, INAME
  20  FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
```

Figure VII.-3. MAIN

```
      STOP
 100  WRITE (NW,30) X, NAME
  30  FORMAT(2X,F15.5,5X,A8)
      RETURN
      END
      SUBROUTINE SHORE(ND)
C
C     THIS SUBROUTINE READS IN THE LONGITUDE AND LATITUDE OF
C   SHORELINE POINTS.
C
C.. ...........................................................
C
C                 COMMON STATEMENTS
C
      COMMON /SHOR/ NSHOR, XSHOR(1500), YSHOR(1500)
C
C               DATA STATEMENTS
      DATA NW / 6/
C                 S T A R T   H E R E
C
       IF(NSHOR.EQ.0) RETURN
       WRITE (NW,75) NSHOR
 75    FORMAT(2X,/,'   THERE ARE ',I4,' SHORELINE POINTS')
C
      READ (ND) XSHOR
      READ (ND) YSHOR
C
C                 E N D   H E R E
C
      RETURN
      END
      SUBROUTINE SPILIN(LSPIL, ND, NPAGE, NSTEP, INR, NSTRT,
     1      NSPPRD, NSPPRP)
C
C     THIS SUBROUTINE READS IN ALL NEW SPILLETS THIS STEP AND
C   PRINTS OUT THE APPROPRIATE DATA ON ALL CURRENT SPILLETS.
C   SOME VARIABLES
C    NSPPRP - INTERVAL PRINT CONTROL FOR OUTPUT TO PAPER
C    NSPPRD - INTERVAL PRINT CONTROL FOR OUTPUT TO DISK
C
C.............................................................
C
C                 COMMON STATEMENTS
C
      COMMON /CNTL/ IRSUB, JRSUB, KRSUB, NPRTA,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ XMATM, XMBIO, XMBOT, XMCLN, XMDSP, XMLOS,
     1     XMSHR, XMSUR, XMSUS
      COMMON /OUTP/ NOSF, NOMS, NOCN, NOPT, NOBS, NOLT,
     1     NODP, NOVL
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), BSPIL(99), DSPIL(99),
     1     FSPIL(99), GSPIL(99,8), RSPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), USPIL(99), WSPIL(99), XSPIL(99),
     3    YSPIL(99), SSPILT(99), MAXSPL
       DIMENSION GSPT(10)
C
C                 DATA STATEMENTS
C
      DATA NW/6/
C


C                 S T A R T   H E R E
C
C   PRINT OUT HEADER AND TIME OF THIS STEP.
C
      NPRIT2=0
      NPRIT = 0
      JSPIL = NSPIL + LSPIL
C
C   FOR RESTARTING, SKIP TO END OF THE SUBROUTINE
C
      IF((NSTRT.EQ.1).AND.(INR.LE.NSTEP)) GO TO 28
C
C    DETERMINE THE PRINT CONTROL PARAMETERS FOR THIS STEP
C
      IF(NSPPRP.LT.0) GO TO 79
      IF((NSPPRP.EQ.0).AND.(TIME.EQ.0.0)) NPRIT = 1
      IF(NSPPRP.LE.0.) GO TO 79
      NTEMP = AMOD(FLOAT(NSTEP),FLOAT(NSPPRP))
      IF(NTEMP.EQ.0) NPRIT=1
 79   CONTINUE
       IF(NSPPRD.LT.0) GO TO 80
       IF((NSPPRD.EQ.0).AND.(TIME.EQ.0.0)) NPRIT2=1
       IF(NSPPRD.LE.0) GO TO 80
       NTEMP = AMOD(FLOAT(NSTEP),FLOAT(NSPPRD))
       IF(NTEMP.EQ.0) NPRIT2 = 1
 80    CONTINUE
       PRIT = TIME/3600.0
      IF(NPRIT.EQ.0) GO TO 45
      IF(JSPIL.LE.0) RETURN
      IF(NPAGE.GE.1) WRITE (NW,201)
 201                     FORMAT('1')
      WRITE (NW,200) PRIT
 200  FORMAT('0',T29,'EXISTING SPILLETS ',F8.3,' HOURS AFTER',
     1        ' THE BEGINNING OF THE SPILL'/'+',T29,65('_')/)
C
C   DO LOOP OVER ALL EXISTING SPILLETS.
C
      IF(NSPIL.GT.0) WRITE (NW,210)
 210  FORMAT(30X,'SPILLETS CREATED PRIOR TO THIS STEP'/)
  45     CONTINUE
      IF(JSPIL.LE.0) RETURN
      DO 10 I=1,JSPIL
         IF(I-NSPIL-1) 20, 21, 22
 21      CONTINUE
        IF(NPRIT.EQ 0) GO TO 22
         WRITE (NW,220)
 220     FORMAT('0',30X,'NEW SPILLETS ADDED THIS STEP'/)
 22      CONTINUE
         READ (ND,100) BSPIL(I),DSPIL(I),RSPIL(I),SSPIL(I),TSPIL(I),
     1   USPIL(I),WSPIL(I),XSPIL(I),YSPIL(I)
100      FORMAT(6F8.3,E8.2,2F8.3)
         READ(ND,101) (GSPIL(I,J),J=1,NSPIL)
 101     FORMAT(8F5.2)
C
C   BSPIL(I) IS SET EQUAL TO TIME HERE. THIS IS FOR ENTRAINMENT.
C
         BSPIL(I) = TIME
C
C    ADD MASS TO EXISTING MASS
C
         XMDSP = XMDSP + USPIL(I)
         XMSUR = XMSUR + WSPIL(I)
 20      CONTINUE
C
C   PRINT OUT ALL SPILLET PARAMETERS.
C
         PRIT = BSPIL(I) / 3600.0
       IF(NPRIT.EQ.0) GO TO 23
         WRITE (NW,230) I, PRIT, XSPIL(I), YSPIL(I), RSPIL(I),
     1                   WSPIL(I)
 230     FORMAT(4X,'THE',I4,' SPILLET APPEARED ',F8.2,
     1       '  HOURS  AFTER THE BEGINNING OF THE SPILL'/4X,'IT IS',
     2       ' CENTERED AT LONGITUDE ',F10.6,' AND LATITUDE ',F10.6,
     3       ','/4X,'IS OF RADIUS ',F10.2,
     4       ' METERS AND IS OF WEIGHT ',F10.4,' METRIC TONS.')
         WRITE (NW,240) DSPIL(I), SSPIL(I), USPIL(I)
 240     FORMAT(4X,'SOME PROPERTIES OF THE SPILLED OIL ARE:'/
     1       20X,' DENSITY ',12X,F10.6,' GRAMS/CC'/20X,
     2       ' INTERFACIAL TENSION ',F10.6,' DYNES/CM'/20X,
     3       ' KINEMATIC VISCOSITY ',F10.6,' CENTISTOKES')
         WRITE (NW,250) (GSPIL(I,J),J=1,NSPIL)
 250     FORMAT(4X,'BY WEIGHT THE OIL FRACTIONS ARE:',20X,
     1       'PARAFFIN (C6-C12)',10X,F10.6/56X,
     2       'PARAFFIN (C13-C22)',9X,F10.6/56X,
     3       'CYCLOPARAFFIN (C6-C12)',5X,F10.6/56X,
     4       'CYCLOPARAFFIN (C13-C22)',4X,F10.6/56X,
     5       'AROMATIC (C6-C11)',10X,F10.6/56X,'AROMATIC (C12-C18)',
     6      9X,F10.6/56X,'NAPTHENO-AROMATIC (C9-C25)',
     7       1X,F10.6/56X,'RESIDUAL',19X,F10.6)
 23       CONTINUE
C
C      WRITE SPILLET DEFINITIONS OUT TO DISK
C
      IF(NPRIT2.EQ.0) GO TO 24
      WRITE (1) TIME,JSPIL
      WRITE(1) I,PRIT,XSPIL(I),YSPIL(I),RSPIL(I),WSPIL(I),
     1  DSPIL(I),SSPIL(I),USPIL(I),(GSPIL(I,J),J=1,8)
 24   CONTINUE
C
C
C   INITIALIZE FRACTION OF SPILL TREATED VARIABLE.
C
      FSPIL(I) = 0.0
C
C   INITIALIZE TSPIL TO DENSITY AT BEGINNING OF SPILL.
C               ALSO TREATED PORTION TO ZERO(TSPILT,SSPILT)
C
      TSPIL(I) = DSPIL(I)
      SSPILT(I) = 0.0
      ASPIL(I) =  0.0
      TSPILT(I) = 0.0
 10   CONTINUE
      IF(NPRIT.EQ.0) GO TO 29
      WRITE (NW,260)
 260  FORMAT(/120('-')/)
 29   CONTINUE
C
C   UPDATE THE SPILLET NUMBER COUNTER.
C
      NSPIL = JSPIL


C
C                 E N D   H E R E
      RETURN
C
 28    CONTINUE
       IF(LSPIL.EQ.0) RETURN
C
C    HERE IF THIS IS A RESTART
C     THIS SECTION READS THROUGH THE INPUT SPILLETS WHICH
C     HAVE ALREADY BEEN ENTERED IN THE PREVIOUS RUN.
C
      READ(ND,100) BSPT,DSPT,RSPT,SSPT,TSPT,
     1    USPT,WSPT,XSPT,YSPT
      READ(ND,101)(GSPT(I),I=1,NSPIL)
       WRITE (NW,234) INR
 234   FORMAT(2X,'AT STEP ',I4,' OLD SPILLET INFORMATION READ IN')
       NSPIL = JSPIL
      RETURN
      END
      SUBROUTINE SONBOP(X,Y,Z,NORDR,NST,NPRTBS,NSPPRD,NSUN)
C
C      THIS SUBROUTINE WRITES OUT TO THE DISK THE
C      NECESSARY VARIABLES NEEDED TO RESTART A RUN IF A RUN
C      IS TERMINATED. IT WRITES OUT THE INFORMATION EVERY
C      CERTAIN NUMBER OF STEPS AS DEFINED BY  NSURR. EACH
C      TIME THE OLD VALUES ARE WRITTEN OVER SO THAT ANY
C      RESTART WILL HAVE TO START AT THE LAST STEP WHICH
C      WAS WRITTEN OUT.
C
C . ........................... ......................
C
      COMMON /CHEM/ NCHEM, BCHEM(10), DCHEM(10), ECHEM(10),
     1     SCHEM(10), TCHEM(10), VCHEM(10), WCHEM(10), XCHEM(10),
     2     YCHEM(10), PCHEM(10)
      COMMON /CLEN/ NCLN, BCLN(10), DCLN(10), ECLN(10), RCLN(10),
     1     VCLN(10), XCLN(10), YCLN(10)
      COMMON /SUBS/ NTRANS, NSUB, NRITE, NMAX, MMAX, DX, DY, DZ,
     1       XORIG,YORIG,ZORIG
      COMMON /PRNT/ KPRTV, KPRTC, KPRTP, NPRD, NPRV, NPRC, NPRP,
     1     NPTSUR, NPRSUB
      COMMON /CNTL/ IRSUB, JRSUB, KRSUB, NPRTA,
     1     NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ XMATM, XMBIO, XMBOT, XMCLN, XMDSP, XMLOS,
     1     XMSHR, XMSUR, XMSUS
      COMMON /OUTP/ NOSF, NOMS, NOCN, NOPT, NOBS, NOLT,
     1     NODP, NOVL
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), BSPIL(99), DSPIL(99),
     1     FSPIL(99), GSPIL(99,8), RSPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), USPIL(99), WSPIL(99), XSPIL(99),
     3    YSPIL(99), SSPILT(99), MAXSPL
      COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1     DMASS(200), DVELZ(200), DCOMP(200,8), NTCLAS, NUMCL
C
C                DIMENSION STATEMENTS
C
       DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
       INTEGER*2 NORDR(NMAX)
C
C                S T A R T   H E R E
C
```

Figure VII.-3. MAIN

```
      TNT = TIME + DT
       WRITE(NOUS)    NPNTAS, NST, NSPPRD, NPRT, NPRC, NPRP
       WRITE(NOUS) INSOB, JNSOB, KNSOB, NPATA,
     1      NPNTC, DT, TIME, TIMMAX, ISCAL, NSAV(99)
       WRITE(NOUS) XMATM, XMBIO, XMBOT, XMCLN, XMDSP, XMLOS,
     1      XMSNK, XMSOL, XMSOS
      WRITE(NOUS) MSPIL, NSPIL
      DO 55 I=1,NSPIL
      WRITE(NOUS) ASPIL(I),BSPIL(I),DSPIL(I),
     1  FSPIL(I),(GSPIL(I,J),J=1,8),RSPIL(I),SSPIL(I),
     2  SSPILT(I),TSPIL(I),TSPILT(I),USPIL(I),
     3 WSPIL(I),XSPIL(I),YSPIL(I)
55    CONTINUE
      IF(NRUN.EQ.1) GO TO 332
      WRITE(NOUS) NCLASS
      DO 789 JJ=1,NCLASS
      WRITE(NOUS) NUMBD(JJ),DDIAM(JJ),DDENS(JJ),DMASS(JJ),
     1  DVELZ(JJ),(DCOMP(JJ,II),II=1,8)
789   CONTINUE
       WRITE(NOUS) NTRANS, NSUB, NEXTR, NMAX, MMAX, DX, DY, DZ,
     1 XORIG, YORIG, ZORIG
       DO 100 I=1,MMAX
       WRITE(NOUS) X(I), Y(I), Z(I), NORDS(I)
100    CONTINUE
332    CONTINUE
      WRITE(NOUS) NCHEM
      IF(NCHEM.EQ.0) GO TO 65
      DO 101 I=1,NCHEM
      WRITE(NOUS) ACHEM(I), DCHEM(I), ECHEM(I), SCHEM(I), TCHEM(I),
     1       VCHEM(I), WCHEM(I), XCHEM(I), YCHEM(I), PCHEM(I)
101   CONTINUE
 65   CONTINUE
      WRITE(NOUS) NCLN
      IF(NCLN.EQ.0) RETURN
      DO 102 I=1,NCLN
      WRITE(NOUS) ACLN(I), DCLN(I), ECLN(I), RCLN(I), VCLN(I),
     1             XCLN(I), YCLN(I)
102   CONTINUE
      REWIND NOUS
     RETURN
     END
     SUBROUTINE SURFES(X, Y, Z, NORDS, XMSPAR, PORIN, NRUN)
C
C     THIS SUBROUTINE HANDLES THE CALL TO ALL SUBROUTINES
C   RELATED TO THE SURFACE PHYSICS OF THE SPILLED OIL.
C   SOME VARIABLES
C      MDLSPL  - THIS IS PASSED FROM THE SUBROUTINE LOCN
C                1 SPILLET IS WITHIN FIXED GRIDS
C                0 SPILLET IS OUT OF FIXED GRID
C      NDLSPL  - SAVED AFTER BEING CHECKED WITH MDLSPL
C                0 SPILLET IS WITHIN FIXED GRIDS
C                1 SPILLET IS OUTSIDE OF FIXED GRIDS
C   IF SPILLET IS OUTSIDE OR TOO NEAR EDGE OF ANY OF THE
C   ENVIRONMENTAL GRIDS, NO MORE OPERATIONS ARE PERFORMED
C    TO IT.
C
C.............................................................
C
C              COMMON STATEMENTS
C


      COMMON /CHEM/ NCHEM, ACHEM(10), DCHEM(10), ECHEM(10),
     1     SCHEM(10), TCHEM(10), VCHEM(10), WCHEM(10), XCHEM(10),
     2     YCHEM(10), PCHEM(10)
      COMMON /CLEN/ NCLN, ACLN(10), DCLN(10), ECLN(10), RCLN(10),
     1     VCLN(10), XCLN(10), YCLN(10)
      COMMON /CNTL/ INSOB, JNSOB, KNSOB, NPATA,
     1     NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ XMATM, XMBIO, XMBOT, XMCLN, XMDSP, XMLOS,
     1     XMSNK, XMSOL, XMSOS
      COMMON /SEAS/ MAXSX, MAXSY, AS, WAVHGT(30, 30), WAVPRD(30, 30),
     1     XSL, YSL, XSS, YSS
      COMMON /SHOR/ NSHOR, XSHOR(1500), YSHOR(1500)
      COMMON /SPIL/ MSPIL, NSPIL, ASPIL(99), BSPIL(99), DSPIL(99),
     1     FSPIL(99), GSPIL(99, 8), RSPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), USPIL(99), WSPIL(99), XSPIL(99),
     3    YSPIL(99), SSPILT(99), MAXSPL
      COMMON /SUBS/ NTRANS, NSUB, NEXTR, NMAX, MMAX, DX, DY, DZ,
     1      XORIG, YORIG, ZORIG
      COMMON /TMPC/ MAXKX, MAXKY, AK, TEMP(30, 30),
     1     XKL, YKL, XKS, YKS
      COMMON /WIND/ MAXWX, MAXWY, AW, UW(30, 30), VW(30, 30),
     1     XWL, YWL, XWS, YWS
      COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30, 30), XDL, YDL, XDS, YDS
      COMMON /ELVN/ MAXEX, MAXEY, AE, HGHT(30, 30), XEL, YEL, XES, YES
      COMMON /COMP/ MAXCX, MAXCY, AC, HCOMP(30, 30), XCL, YCL, XCS, YCS
      COMMON /TIDE/ MAXTX, MAXTY, AT, UT(30, 30), VT(30, 30),
     1XTLD, YTLD, XTS, YTS, XTLV, YTLV
C
C              DIMENSION STATEMENTS
C
      DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
      DIMENSION NDLSPL(99)
      INTEGER*2 NORDS(NMAX)
C
C              DATA STATEMENTS
C
      DATA NDLSPL/ 99*0/
      SUMAS = 0.0
C
C   .          S T A R T   H E R E
C
C   DO LOOP OVER ALL SPILLETS.
C
C
      DO 10 ISPIL=1, NSPIL
      IF(NDLSPL(ISPIL).EQ.1) GO TO 10
      SUMAS = 0.0
C
C  PERFORM ALL CLEANUP AND TREATMENT EFFORTS
C
      IF(NCLN.GT.0) CALL CLNUP( ISPIL )
C
      IF(NCHEM.GT.0) CALL TREAT( ISPIL, SUMAS)
C
C   AVERAGE THE CURRENT OVER THE SPILLET. OBTAIN THE DIRECTION
C   OF THE CURRENT RELATIVE TO THE CURRENT GRID.
C
        CALL LOCN(1, MAXTX, MAXTY, AT, XTLD, YTLD, XTS, YTS, UT, UT,
     1      XSPIL(ISPIL), YSPIL(ISPIL), RSPIL(ISPIL), UCRNT, UDUM,
     2      MDLSPL, ISPIL)
        CALL LOCN(1, MAXTX, MAXTY, AT, XTLV, YTLV, XTS, YTS, VT, VT,
     1      XSPIL(ISPIL), YSPIL(ISPIL), RSPIL(ISPIL), VCRNT, VDUM,
     2      MDLSPL, ISPIL)
      IF(MDLSPL.EQ.0) GO TO 20
      NDLSPL(ISPIL) = 1
      GO TO 10
 20   CONTINUE
C
C   AVERAGE THE WIND OVER THE SPILLET. OBTAIN THE WIND DIRECTION
C   RELATIVE TO THE WIND GRID.
C
        CALL LOCN(2, MAXWX, MAXWY, AW, XWL, YWL, XWS, YWS, UW, VW,
     1      XSPIL(ISPIL), YSPIL(ISPIL), RSPIL(ISPIL), UWIND, VWIND,
     2   MDLSPL, ISPIL)
        WVEL = SQRT(UWIND * UWIND + VWIND * VWIND)
      IF(MDLSPL.EQ.0) GO TO 30
      NDLSPL(ISPIL) = 1
      GO TO 10
 30   CONTINUE
C
C   AVERAGE THE WATER DEPTH FROM MEAN LOW WATER OVER THE SPILLET.
C
        CALL LOCN(1, MAXDX, MAXDY, AD, XDL, YDL, XDS, YDS,
     1      DEPTH, DEPTH, XSPIL(ISPIL), YSPIL(ISPIL), RSPIL(ISPIL),
     2      DEPLOC, DEPDUM, MDLSPL, ISPIL)
        IF(MDLSPL.EQ.0) GO TO 40
        NDLSPL(ISPIL) = 1
        GO TO 10
 40     CONTINUE
C
C   AVERAGE THE TIDAL ELEVATION OVER THE SPILLET.
C
        CALL LOCN(1, MAXEX, MAXEY, AE, XEL, YEL, XES, YES,
     1      HGHT, HGHT, XSPIL(ISPIL), YSPIL(ISPIL), RSPIL(ISPIL),
     2      HTLOC, HTDUM, MDLSPL, ISPIL)
      IF(MDLSPL.EQ.0) GO TO 50
      NDLSPL(ISPIL) = 1
       GO TO 10
 50   CONTINUE
C
C   AVERAGE THE TEMPERATURE OVER THE SPILLET.
C
        CALL LOCN(1, MAXKX, MAXKY, AK, XKL, YKL, XKS, YKS, TEMP,
     1      TEMP, XSPIL(ISPIL), YSPIL(ISPIL), RSPIL(ISPIL), DAGRES,
     2      DUMY, MDLSPL, ISPIL)
      IF(MDLSPL.EQ.0) GO TO 60
      NDLSPL(ISPIL) = 1
      GO TO 10
 60    CONTINUE
C
C   CALCULATE THE AMOUNT OF OIL ENTRAINED.
C
         CALL ENTMAS(SUMAS, WSPIL(ISPIL), WVEL, ISPIL, NMAX,
     1        RSPIL(ISPIL), ENMAS, NRUN)
         CALL ENTRN(ISPIL, X, Y, Z, NORDS, SUMAS, XMSPAR, PORIN, NRUN)
C
C   SPREAD THE SPILLET.
C
         OLDRAD = RSPIL(ISPIL)
         CALL SPREAD(ISPIL)


C
C   EVAPORATION
C
         CALL EVPORN(ISPIL, OLDRAD, DAGRES, WVEL)
C
C   MOVE THE SPILL ALONG THE SURFACE
C
         CALL SURDFT(XSPIL(ISPIL), YSPIL(ISPIL), UWIND, VWIND,
     1        UCRNT, VCRNT)
 10   CONTINUE
C
C   HAS THE SPILLET REACHED SHORE.
C
         CALL ASHOR
C
C               E N D   H E R E
C
      RETURN
      END
      SUBROUTINE ADD(COMB)
C
C     THIS SUBROUTINE COMBINES OIL SPILLETS WHICH TOUCH
C
C.    .............................................................
C
C              COMMON STATEMENTS
C
      COMMON /CHEM/ NCHEM, ACHEM(10), DCHEM(10), ECHEM(10),
     1     SCHEM(10), TCHEM(10), VCHEM(10), WCHEM(10), XCHEM(10),
     2     YCHEM(10), PCHEM(10)
      COMMON /CLEN/ NCLN, ACLN(10), DCLN(10), ECLN(10), RCLN(10),
     1     VCLN(10), XCLN(10), YCLN(10)
      COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30, 30), XDL, YDL,
     1     XDS, YDS
      COMMON /CNTL/ INSOB, JNSOB, KNSOB, NPATA,
     1     NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ XMATM, XMBIO, XMBOT, XMCLN, XMDSP, XMLOS,
     1     XMSNK, XMSOL, XMSOS
      COMMON /SEAS/ MAXSX, MAXSY, AS, WAVHGT(30, 30), WAVPRD(30, 30),
     1     XSL, YSL, XSS, YSS
      COMMON /SHOR/ NSHOR, XSHOR(1500), YSHOR(1500)
      COMMON /SPIL/ MSPIL, NSPIL, ASPIL(99), BSPIL(99), DSPIL(99),
     1     FSPIL(99), GSPIL(99, 8), RSPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), USPIL(99), WSPIL(99), XSPIL(99),
     3    YSPIL(99), SSPILT(99), MAXSPL
      COMMON /TMPC/ MAXKX, MAXKY, AK, TEMP(30, 30),
     1     XKL, YKL, XKS, YKS
      COMMON /WIND/ MAXWX, MAXWY, AW, UW(30, 30), VW(30, 30),
     1     XWL, YWL, XWS, YWS
C
C              DIMENSION STATEMENTS
C
      DIMENSION DUM(99, 21)
C
C              EQUIVALENCE STATEMENTS
C
      EQUIVALENCE (DUM(1, 1), ASPIL(1))
C
C              DATA STATEMENTS
C
```

Figure VII.-3. MAIN

```
      DATA  NVAR/  21/
C
C                 S T A R T   H E R E
C
C    RETURN IF THERE IS ONLY ONE SPILLET.
      IF(NSPIL.LE.1) RETURN
C
C    FIND TOUCHING SPILLETS.
C
      NTEMP = NSPIL - 1
      NSAV = 0
      DO 10 ISP=1, NTEMP
         ITEMP = ISP + 1
         DO 20 JSP=ITEMP, NSPIL
C
C    FIND THE SUM OF THE RADII TO COMPARE WITH
C    THE SEPARATION OF THE SPILLET CENTERS.
C
            DISTA = RSPIL(ISP) + RSPIL(JSP)
C
C    FIND THE DISTANCE BETWEEN THE SPILLET CENTERS.
C
             CALL DIST(XSPIL(ISP), YSPIL(ISP), XSPIL(JSP),
     1                 YSPIL(JSP), 1, 0.0, DIS, XSP, YSP)
C
C    ARE THE SPILLETS TOUCHING OR OVERLAPING IF NOT GET NEXT SPILLET.
C
            RMIN = RSPIL(ISP)
            IF(RSPIL(JSP).LT.RSPIL(ISP)) RMIN=RSPIL(JSP)
            DISTA = DISTA - DIS
            IF(DISTA.LT.COMB*RMIN) GO TO 20
            WRITE(NW, 24) ISP, JSP
 24         FORMAT(2X, ' SPILLETS ', I4, 'AND', I4, 'ARE BEING
     1            ADDED TOGETHER')
C
C    HERE IF THE SPILLETS ARE TOUCHING.
C
            FRACJ = MSPIL(JSP) / (MSPIL(ISP) + MSPIL(JSP))
            FRACI = 1.0 - FRACJ
C
C    COMBINE SPILLETS.
C
            IF((ASPIL(ISP).LT.0.0) .AND. (ASPIL(JSP).LT.0.0))
     1         GO TO 30
            ASPIL(ISP) = ABS(ASPIL(ISP))
            ASPIL(JSP) = ABS(ASPIL(JSP))
 30         CONTINUE
            ASPIL(JSP) = ASPIL(ISP) + ASPIL(JSP)
            RSPIL(JSP) = SQRT(RSPIL(ISP)**2 + RSPIL(JSP)**2)
            SSPIL(JSP) = SSPIL(ISP) * FRACI * (1.0-PSPIL(ISP))
     1                 + SSPIL(JSP) * FRACJ * (1.0-PSPIL(JSP))
            TSPIL(JSP) = TSPIL(ISP) * FRACI * (1.0-PSPIL(ISP))
     1                 + TSPIL(JSP) * FRACJ * (1.0-PSPIL(JSP))
            SSPILT(JSP) = SSPILT(ISP) * FRACI * PSPIL(ISP)
     1                  + SSPILT(JSP) * FRACJ * PSPIL(JSP)
            TSPILT(JSP) = TSPILT(ISP) * FRACI * PSPIL(ISP)
     1                  + TSPILT(JSP) * FRACJ * PSPIL(JSP)
            USPIL(JSP) = USPIL(ISP) * FRACI + USPIL(JSP) * FRACJ
            MSPIL(JSP) = MSPIL(ISP) + MSPIL(JSP)
            XSPIL(JSP) = XSPIL(ISP) +


     1                   (XSPIL(JSP) - XSPIL(ISP)) * FRACJ
            YSPIL(JSP) = YSPIL(ISP) +
     1                   (YSPIL(JSP) - YSPIL(ISP)) * FRACJ
C
C    COMBINE ALL VARIABLES BY FRACTION WEIGHT OF SPILLET.
C
            DO 40 I=2, 12
               DOM(JSP, I) = DOM(ISP, I) * FRACI + DOM(JSP, I) * FRACJ
 40         CONTINUE
C
C    SAVE THE NUMBER OF THE SPILLET WHICH IS TO BE REMOVED.
C
            NSAV = NSAV + 1
            NSAV(NSAV) = ISP
 20      CONTINUE
 10   CONTINUE
C
C    REPLACE SPILLETS  WHICH HAVE BEEN ABSORBED BY OTHERS
C
      IF(NSAV.LE.0) RETURN
C
C    BY OTHERS FROM THE END OF THE LIST.
C
      MSPIL = NSPIL + 1
      NSUB = NSAV + 1
      DO 50 I=1, NSAV
         NSUB = NSUB - 1
         ISPIL = NSAV(NSUB)
         MSPIL = MSPIL - 1
         IF(ISPIL.EQ.MSPIL) GO TO 50
         DO 60 J=1, NVAR
            DOM(ISPIL, J) = DOM(MSPIL, J)
 60      CONTINUE
 50   CONTINUE
C
C    REMOVE SPILLETS WHICH HAVE BEEN ABSORBED.
C
      NSPIL = MSPIL - 1
C
C                 E N D   H E R E
C
      RETURN
      END
      SUBROUTINE CLNUP( ISP )
C
C     THIS SUBROUTINE HANDLES THE PHYSICAL CLEANUP OF THE OIL.
C
C...............................................................
C
C                 COMMON STATEMENTS
C
      COMMON /CLEN/ NCLN, RCLN(10), DCLN(10), ECLN(10), MCLN(10),
     1     VCLN(10), XCLN(10), YCLN(10)
      COMMON /CNTL/ NNSUB, JNSUB, KNSUB, NPRTA,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ XMATM, XMBIO, XMBOT, XMCLN, XMDSP, XMLOS,
     1     XMSUR, XMSUB, XMSOS
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), BSPIL(99), DSPIL(99),
     1     PSPIL(99), GSPIL(99,8), RSPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), USPIL(99), MSPIL(99), XSPIL(99),
     3     YSPIL(99), SSPILT(99), MAXSPL
C
C                 DIMENSION STATEMENTS
C
      DIMENSION DUM(10,7)
C
C                 EQUIVALENCE STATEMENTS
C
      EQUIVALENCE (DUM(1,1),RCLN(1))
C
C                 DATA STATEMENTS
C
      DATA NW/ 6/
C
C                 S T A R T   H E R E
C
      IF(NCLN.GT.0) GO TO 50
      TNT = TIME / 3600.0
      WRITE (NW,210) TNT
 210  FORMAT('0 NO AREAS BEING CLEANED UP AT TIME ',F10.2,
     1   ' HOURS'/)
      RETURN
 50   CONTINUE
C
C    REMOVE EXPIRED CLEANUP EFFORTS FROM THE CLEANUP LIST.
C
      CALL REMOV( DUM, NCLN, DCLN, NCLN, 7)
      IF(NCLN.GT.0) GO TO 51
      TNT = TIME / 3600.0
      WRITE (NW,210) TNT
      RETURN
 51   CONTINUE
C
C
C    DO LOOP OVER THE CLEANUP EFFORTS.
C
      SMCLN = 0.0
      DO 10 ICLN=1,NCLN
         RC = RCLN(ICLN)
C
C    DETERMINE THE AMOUNT OF OIL WHICH MAY BE CLEANED UP THIS STEP
C
         AMNT = VCLN(ICLN) * DT / 3600.0
         EFF = ECLN(ICLN) / 100.0
C
C    FIND ALL SPILLETS WITHIN RANGE OF THE CLEANUP EQUIPMENT.
C
            CALL DIST(XSPIL(ISP),YSPIL(ISP),XCLN(ICLN),
     1                YCLN(ICLN), 1, 0.0,DIS,XSP,YSP)
            IF(DIS.GT.RC) GO TO 20
C
C    CLEANUP THIS  SPILLET.
C
         IF(AMNT/EFF.LE.MSPIL(ISP)) GO TO 40
         MCLN = MSPIL(ISP) * EFF
         AMNT = AMNT - MCLN
         SMCLN = SMCLN + MCLN
         GO TO 10
C
C    HERE WHEN ONLY A FRACTION  OF A SPILLET MAY BE CLEANED UP.


C
 40      CONTINUE
         MSPIL(ISP) = MSPIL(ISP) - AMNT
         SMCLN = SMCLN + AMNT
 10   CONTINUE
C
C  KEEP TRACK OF MASS
C
      XMCLN = XMCLN + SMCLN
      XMSUR = XMSUR - SMCLN
C
C   PRINT OUT MASS OF OIL PHYSICALLY REMOVED.
C
      TNT = TIME / 3600.0
      WRITE (NW,200) TNT, SMCLN, ISP
 200  FORMAT(4X,'DURING THE TIME STEP WHICH BEGAN AT ',F10.4,
     1       ' HOURS ',F10.4,' TONS OF OIL WERE PHYSICALLY',
     2       ' REMOVED FROM THE',I3,' SPILLET')
 20   CONTINUE
C
C                 E N D   H E R E
C
      RETURN
      END
      SUBROUTINE CONSUM
      RETURN
      END
       SUBROUTINE ENTMAS(SUMAS, NSP, WVEL, ISPIL, NMAX,
     1    MSP, ENMAS, NAUM)
C
C THIS SUBROUTINE THE AMOUNT OF MASS ENTRAINED AS A
C  FUNCTION OF WIND SPEED FOR NATURAL DISPERSION.
C . .. ........................... ..................... . .
      COMMON /MASS/ XMATM, XMBIC, XMBOT, XMCLN, XMDSP, XMLOS,
     1     XMSUR, XMSUB, XMSOS
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), BSPIL(99), DSPIL(99),
     1     PSPIL(99), GSPIL(99, 8), RSPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), USPIL(99), MSPIL(99), XSPIL(99),
     3     YSPIL(99), SSPILT(99), MAXSPL
      COMMON /CNTL/ NNSUB, JNSUB, KNSUB, NPRTA,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      DATA DCY, SEC/ 172800.0, 86400.0/
      DATA AO, WO, E/ 0.1, 8.5, 2.71828/
      DATA  NW /  6/
        IF(XMSUR.LE.0.0)  RETURN
C
C  CALCULATE NATURAL DISPERSION- AMOUNT PER TIME STEP.
C
        AMT = AO *(WVEL**2)/(WO**2)
C
C  CONVERT FROM /DAY TO /SEC
C
        AMT = AMT/SEC
C
C  AMOUNT DECAYS BY 1/E EVERY 2 DAYS.
C
        EXP = -(TIME-MSP)/DCY
        DCT = E**EXP
        PERENT = AMT*DCT*DT
C
```

Figure VII.-3. MAIN

```
C  CALCULATE AMOUNT OF MASS LOST BY SPILLET
C
         SUMAS = PERCNT*WSP
         IF(SUMAS.GT.XMSUR) SUMAS=XMSUR
         WSP = WSP - SUMAS
         XMMAS = XMMAS + SUMAS
         XMSOS = XMSOS + SUMAS
         XMSUR = XMSUR - SUMAS
C
C       THIS SECTION  COMPUTES THE APPROXIMATE AMOUNT
C       OF MASS TO BE REPRESENTED BY EACH PARTICLE
C       DURING EACH STEP OF THE PREVIEW RUN .
C       THIS VALUE IS THEN USED IN THE LONGER RUN.
         IF(NRUN.EQ.0) GO TO 90
        IF(ISPIL.NE.NSPIL) GO TO 90
         XMSPAR = XMSOS/FLOAT(NMAX)
         THT = TIME / 3600.0
         WRITE(NW, 100) THT, XMSOS, XMSPAR, NMAX
 100     FORMAT(2X, /, 5X, 'AT TIME EQUALS', F10.3, 'HOURS',
     1     'THE TOTAL MASS ENTRAINED IS', F13.6, 'METRIC TONS',
     2     /, 5X, 'THIS RESULTS IN', F12.5, 'TONS PER DROPLET SPREAD
     3     OUT OVER', I5, 'PARTICLES')
  90     CONTINUE
        RETURN
        END
        SUBROUTINE ENTRN(ISPIL, X, Y, Z, NORDR, SUMAS, XMSPAR,
     1                 POSIN, NRUN)
C
C                SUBROUTINE DESCRIPTION
C
C      THIS SUBROUTINE INJECTS OIL DROPLETS INTO THE WATER COLUMN.
C
C.. .. ......................... ..............................
C
C                COMMON STATEMENTS
C
       COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30, 30), XDL, YDL,
     1      XDS, YDS
       COMMON /INJC/ DEPC, AFRAC, RIFRAC, ROFRAC, DDIAMT, DVELZT, NINT
       COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1      NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(99)
       COMMON /MASS/ XMATM, XMMIC, XMBOT, XMCLN, XMDMF, XMLOS,
     1      XMSHR, XMSUR, XMSOS
       COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1      DMASS(200), DVELZ(200), DCOMP(200, 8), NTCLAS, NUMCL
       COMMON /SPIL/ MSPIL, NSPIL, ASPIL(99), RSPIL(99), DSPIL(99),
     1      FSPIL(99), GSPIL(99, 8), MSPIL(99), SSPIL(99),
     2      TSPIL(99), TSPILT(99), OSPIL(99), WSPIL(99), XSPIL(99),
     3     YSPIL(99), SSPILT(99), MAXSPL
       COMMON /SUBS/ NTMBRS, NSUB, NEXTA, NMAX, MMAX, DX, DY, DZ,
     1       XORIG, YORIG, ZORIG
C
C                DIMENSION STATEMENTS
C
       DIMENSION DCOMPT(8)
       DIMENSION X(MMAX), Y(MMAX), Z(MMAX)
       INTEGER*2 NORDR(MMAX)
C
C               DATA STATEMENTS
C


        DATA  NDIS, NO, NW/  0, 2, 6/
C
C   DO NOT CREATE PARTICLES IF THIS IS A SHORT RUN
C
       IF(NRUN.EQ.1) RETURN
C
C  THE AMOUNT OF MASS PER PARTICLE HAS BEEN DETERMINED
C  IN A PREVIOUS SHORTER RUN
C
        IF(XMSUR.LE.0.0) RETURN
       IF(ISCAL.EQ.2) NO = 5
C
C  DETERMINE THE NUMBER OF PARTICLES
C
       PART = SUMAS /XMSPAR
       NPART = PART + 0.5
C
C                S T A R T . H E R E
C
C  RETURN IF NO ENTRAINMENT
C
       IF(NPART LE.0) RETURN
C
C   DETERMINE THE PARTICLE PROPERTIES FOR THIS SPILLET
C
       DDENST = DSPIL(ISPIL)
       DO 10 IFRAC = 1, 8
          DCOMPT(IFRAC) = GSPIL(ISPIL, IFRAC)
  10   CONTINUE
C
C   DOES A CLASS ALREADY EXIST WITH THESE PROPERTIES.
C
       IF(NCLASS.EQ.0) GO TO 50
       DO 20 ICLASS=1, NCLASS
          IF(DDENST.NE.DDENS(ICLASS)) GO TO 20
          IF(DDIAMT.NE.DDIAM(ICLASS)) GO TO 20
          IF(DVELZT.NE.DVELZ(ICLASS)) GO TO 20
          DO 25 IFRAC=1, 8
             IF(DCOMPT(IFRAC).NE DCOMP(ICLASS, IFRAC)) GO TO 20
  25      CONTINUE
C
C    IS THERE ANY ROOM IN THIS CLASS FOR MORE PARTICLES?
C
          NPT = NUMBD(ICLASS) + NPART
          IF(NPT.GE.NUMCL) GO  TO 20
          JCLASS = ICLASS
          GO TO 30
  20   CONTINUE
C
C   CONTROL COMES HERE IF A NEW CLASS IS TO BE CREATED  CHECK THAT
C   NONE OF THE EXISTING CLASSES ARE EMPTY.
C
       DO 40 ICLASS=1, NCLASS
          IF(NUMBD(ICLASS).GT.0) GO TO 40
          JCLASS = ICLASS
          GO TO 55
  40   CONTINUE
C
C   CHECK THAT THERE IS ROOM FOR A NEW CLASS. IF NOT COMMENT AND PUT
C    ALL NEW PARTICLES TO BE INJECTED INTO THE LAST CLASS: NCLASS.
```

```
C
       JCLASS = NCLASS
       IF(NCLASS.LT.NTCLAS) GO TO 50
        IF(NDIS.EQ.1) GO TO 30
       NDIS = 1
       WRITE(NW,100) NCLASS
 100   FORMAT(2X, 5('*'), ' NO ROOM FOR A NEW CLASS. ALL NEW ',
     1 ' PARTICLES WILL BE PUT INTO CLASS:', I5/)
       GO TO 30
 50    CONTINUE
       NCLASS = NCLASS + 1
       JCLASS = NCLASS
C
C   HERE TO SAV PARTICLE PROPERTIES FOR JCLASS.
C
 55    CONTINUE
       DDENS(JCLASS) = DDENST
       DDIAM(JCLASS) = DDIAMT
       DVELZ(JCLASS) = DVELZT
       DO 60 IFRAC=1, 8
          DCOMP(JCLASS, IFRAC) = DCOMPT(IFRAC)
 60    CONTINUE
C
C   THE CLASS HAS BEEN DETERMINED AND THE DROPLET PARAMETERS SAVED
C
 30    CONTINUE
C
C   DO THESE ADDITIONAL PARTICLES EXCEED THE TOTAL PARTICLE COUNTER
C
       NTEMP = NMAX + NPART
       IF(NTEMP.LE.MMAX) GO TO 90
       NPART = MMAX - NMAX
C
C   CHECK THAT THE MAXIMUM # OF PARTICLES HAS NOT BEEN EXCEEDED
C
       IF(NPART.GT.0) GO TO 90
       WRITE(NW,120) MMAX
 120   FORMAT(2X, 5('*'), ' NO NEW PARTICLES MAY BE ADDED',
     1 ' THIS STEP.', I5, ' PARTICLES HAVE ALREADY BEEN CREATED.'/)
       RETURN
 90    CONTINUE
       NLOW = NMAX + 1
       NUPR = NMAX + NPART
C
C   CALCULATE THE RADIUS RESTRICTIONS ON PARTICLE INJECTION .
C
       RO = RSPIL(ISPIL) / RIFRAC
       A = RO / (AFRAC * AFRAC)
       RMAX = (RSPIL(ISPIL) * (1.0 + ((NINT * (3600.0**2) / 5.0) /
     1         (ROFRAC*((TIME*TIME)-(RSPIL(ISPIL)*RSPIL(ISPIL)))+1))))
       D = SQRT(RO/A)
       B = (RMAX - RO) / (1.0 - D)
       C = (RO - RMAX * D) / (1.0 - D)
C
C   OBTAIN THE CENTER OF THE PARTICLE DISTRIBUTION IN X AND Y.
C
        CALL DIST(XDL, YDL, XSPIL(ISPIL), YSPIL(ISPIL),
     1            RO, AD, D, XC, YC)
        XC = XC/XDS + 1.0
        YC = YC/YDS + 1.0


C
C   IF THIS IS THE FIRST PASS THROUGH ENTRN DEFINE THE ORIGIN
C   NOTE: THE SUBSURFACE PROGRAMS HAVE NOT BEEN CALLED SO A FLOATING
C         GRID HAS NOT BEEN DEFINED. DEFINE THE ORIGIN OF THE FLOATING
C         GRID HERE. THIS ORIGIN WILL BE MOVED BY GRIDER WHEN THE
C         SUBSURFACE PROGRAMS ARE CALLED.
C
       IF(NLOW.NE.1) GO TO 210
       XORIG = XC - DX * FLOAT(IMSUB) / (2.0 * XDS)
       YORIG = YC - DY * FLOAT(JMSUB) / (2.0 * YDS)
       ZORIG = 0.0
 210   CONTINUE
C
C   INJECT PARTICLES.
C
        CALL INJECT(XC, YC, RO, A, B, C, X, Y, Z, NORDR,
     1    NLOW, NUPR, JCLASS, POSIN)
C
C       MASS BALANCE THIS STEP.
C
        DMASS(JCLASS) = SUMAS/FLOAT(NPART)
       NUMBD(JCLASS) = NUMBD(JCLASS) + NPART
       NMAX = NUPR
C
C              R E T U R N   H E R E
C
       RETURN
       END
       SUBROUTINE EVPORN(ISP, OLDRAD, DAGRES, WVEL)
C
C       THIS SUBROUTINE WILL PREDICT EVAPORATION LOSS FROM THIS
C   SPILLET FOR ONE TIME STEP. TO ACCOMPLISH THIS THE OIL IS
C   BROKEN UP INTO EIGHT FRACTIONS AND THE LOSS DUE TO EVAPORATION
C   IS CALCULATED FOR EACH FRACTION AND THEN SUMMED FOR THE OIL
C   AS A WHOLE. SINCE THE DECAY "CONSTANT" IS NOT CONSTANT WITH
C   TIME THE TIME STEP IS DIVIDED INTO SEVERAL SUB TIME STEPS.
C   THE "CONSTANT IS THEN ASSUMED TO BE CONSTANT FOR THESE SUBSTEPS
C   AND THE EVAPORATIVE LOSS CALCULATED FOR THE SUBSTEP. THE LOSS
C   IS THEN ACCUMULATED FOR THE ENTIRE TIME STEP.
C
C                VARIABLE DESCRIPTION
C
C   ABSZRO - ABSOLUTE ZERO (DEGREES CENTIGRADE).
C   AREA   - OF SPILLET (METERS**2).
C   CON1     - ARRAY OF CONSTANTS.
C   CON2     - ARRAY OF CONSTANTS.
C   CON3   - ARRAY OF CONSTANTS.
C   DAGRES - TEMPERATURE (DEGREES CENTIGRADE).
C   RAD    - RADIUS OF SPILLET AT SUBSTEP TIME (METERS).
C   DELTA  - TIME OF SUBSTEP IN THE INTEGRATION PROCEDURE (SEC).
C   DT     - TIME STEP IN THE MAIN PROGRAM (SEC).
C   NINT   - # OF STEPS IN THE INTEGRATION PROCEDURE.
C   OLDRAD - RADIUS OF SPILLET AT LAST TIME STEP (METERS).
C   P      - VAPOR PRESSURE.
C   Q      - CONSTANT.
C   R      - CONSTANT.
C   RC     - GAS CONSTANT.
C   WVEL   - WIND VELOCITY (M/SEC).
C
    ............................. ..............................
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Figure VII.-3. MAIN

```
C
C               COMMON STATEMENTS
C
      COMMON /DENS/ DEN(8)
      COMMON /CNTL/ IMSUB, JMSUB, NMSUB, NPNTA,
     1      NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ ZMATM, ZMBIO, ZMBOT, ZMCLN, ZMDNS, ZMLOS,
     1      ZMSNK, ZMSUR, ZMSUS
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), RSPIL(99), DSPIL(99),
     1      PSPIL(99), GSPIL(99, 8), HSPIL(99), SSPIL(99),
     2      TSPIL(99), TSPILT(99), OSPIL(99), WSPIL(99), XSPIL(99),
     3     YSPIL(99), ZSPILT(99), MAXSPL
C
C               DIMENSION STATEMENTS
C
      DIMENSION CON1(7), CON2(7), CON3(7)
C
C               DATA STATEMENTS
C
      DATA CON1/ 1417.61, 1825.03, 1441.79, 1893.78, 1407.34,
     1              1801.00, 1789.85/
      DATA CON2/ 202.174, 149.757, 204.697, 151.822, 206.479,
     1              162.771, 164.560/
      DATA CON3/ 6.9357, 7.0107, 6.9111, 6.9871, 6.9059,
     1              6.9698, 6.9696/
      DATA CONST, Q, B, RC/ 69.0, 0.42, -0.055, 8.31399/
      DATA ABSZRO, PI/ 273.0, 3.14159/
      DATA NINT/ 10/
C
C               S T A R T   H E R E
C
       IF(ZMSUR LE.0.0) RETURN
      NPF = 7
      NFRAC = NPF + 1
      BEGIN = DSPIL(ISP) / TSPIL(ISP)
      DELTA = DT / (FLOAT(NINT) * 3600.0)
      DSPIL(ISP) = 0.0
      DR = (RSPIL(ISP) - OLDRAD) / FLOAT(NINT)
      GSUM = 0.0
      GDSUM = 0.0
      TMAS=GSPIL(ISP, 8)
      DO 10 IFRAC=1, NPF
      TMAS = TMAS + GSPIL(ISP, IFRAC)
         COEFS = 0.0
         RAD = OLDRAD - DR / 2.0
         DO 20 J=1, NINT
            RAD = RAD + DR
            AREA = PI * RAD * RAD
            P = 10.0**(CON3(IFRAC) - CON1(IFRAC)/ (CON2(IFRAC)
     1         + DAGRES))
            COEF = CONST * EXP(Q*WVEL) * (1.0 / (AREA**(-B)))
            COEF = COEF * P / (RC * (ABSZRO + DAGRES))
            COEFS = COEFS + COEF
 20      CONTINUE
         IF(BEGIN.GT.2.0078) COEFS = COEFS / 5.0
         EXPON = COEFS * DELTA
         IF((EXPON.LT.20) .AND. (GSPIL(ISP, IFRAC).GT.10.0E-6) )
     1        GO TO 30
         GSPIL(ISP, IFRAC) = 0.0
         GO TO 40


 30      CONTINUE
         GSPIL(ISP, IFRAC) = GSPIL(ISP, IFRAC) * EXP(-EXPON)
 40      CONTINUE
         GSUM = GSUM + GSPIL(ISP, IFRAC)
         GDSUM = GDSUM + GSPIL(ISP, IFRAC) / DEN(IFRAC)
 10   CONTINUE
      GSUM = GSUM + GSPIL(ISP, 8)
      GDSUM = GDSUM + GSPIL(ISP, 8) / DEN(8)
C
C   CALCULATE THE DENSITY OF THE OIL IN THIS SPILLET.
C   GSUM IS THE MASS OF SOME QUANTITY OF OIL.
C   GDSUM IS THE VOLUME OF THE SAME QUANTITY OF THIS OIL.
C
      DSPIL(ISP) = GSUM / GDSUM
C
C   MASS OF OIL EVAPORATED FROM THIS SPILLET
C
      EMAS = WSPIL(ISP)*((TMAS-GSUM)/TMAS)
      IF(EMAS GT WSPIL(ISP)) EMAS=WSPIL(ISP)
      ZMATM = ZMATM + EMAS
      ZMSUR = ZMSUR - EMAS
      WSPIL(ISP) = WSPIL(ISP) - EMAS
C
C               E N D   H E R E
C
      RETURN
      END
      SUBROUTINE INJECT(XC, YC, RO, A, B, C, X, Y, Z,
     1  NORDS, NLOW, NUPS, JCLASS, POSIN)
C
C               SUBROUTINE DESCRIPTION
C
C
C   THIS SUBROUTINE IS USED TO DETERMINE THE LOCATION OF THE
C   ENTRAINED PARTICLES. THE DISTRIBUTION WILL BE UNIFORM
C   IN X AND Y WITHIN RC OF THE CENTER AND THEN FALL OFF LINEARLY
C   FROM RO TO RMAX. AT RMAX THE DISTRIBUTION GOES TO ZERO.
C   THE DISTRIBUTION IS UNIFORM IN Z BETWEEN ZL AND ZU
C
C.. ..........................................................
C
C               COMMON STATEMENTS
C
      COMMON /COMP/ MAXCX, MAXCY, AC, NCOMP(30, 30), XCL, YCL,
     1     XCS, YCS
      COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30, 30), XDL, YDL,
     1     XDS, YDS
      COMMON /INJC/ DEPC, AFRAC, EIFRAC, NOFRAC, DDIANT, DVELIT, NENT
      COMMON /SUBS/ STEADS, NSUB, DELTA, NMAX, RMAX, DX, DY, DZ,
     1       XORIG, YORIG, ZORIG
      COMMON /CNTL/  IMSUB, JMSUB, NMSUB, NPNTA,
     1     NPNTC, DT, TIME, TIMMAX, ISCAL, NSAV(99)
C
C               DIMENSION STATEMENTS
C
       DIMENSION RAN(3)
       REAL*4 X(NMAX), Y(NMAX), Z(NMAX)
       INTEGER*2 NORDS(NMAX)
C
C               DATA STATEMENTS
C
      DATA TWOPI, NPASS/ 6.28319, 0/
      DATA FIVE, NW/  5.0, 6/
C
C               S T A R T   H E R E
C
C   INITIALIZE THE SEED FOR THE RANDOM NUMBER GENERATOR
C
       IF(NPASS.EQ.1) GO TO 10
       NPASS = 1
       IX=5**15
       IU=7830666
       IU=2*IU+1
       P = 2.0**32
 10    CONTINUE
C
C   CALCULATE THE RANGE OF RANDOM NUMBERS CORRESPONDING
C   TO PARTICLES WITHIN RO.
C
      RLIM = SQRT(RC / A)
C
C   DO LOOP OVER PARTICLES TO BE CREATED.
C
       DO 1 N=NLOW, NUPS
       JJ = 0
 2     CONTINUE
C
C   OBTAIN RANDOM NUMBERS.
C
       CALL RAND(IX, IU, P, RX)
       CALL RAND(IX, IU, P, RY)
       CALL RAND(IX, IU, P, RZ)
C
C   CALCULATE PARTICLE DISTANCE AND ANGLE FROM SPHERE CENTER
C
       IF(RX.LE RLIM) RADIUS = A * RX * RX
       IF(RX.GT.RLIM) RADIUS = B * RX + C
       THETA = TWOPI * RY
       DUM1 = RADIUS * SIN(THETA)
       DUM2 = RADIUS * COS(THETA)
C
C    IF LARGE SCALE MODE IS USED, POSITIONS ARE CONVERTED TO DEGREES
C
        IF(NLOW EQ.0) DUM1 = 0.0
        IF(NLOW.EQ.0) DUM2 = 0.0
       IF(ISCAL.EQ.1) GO TO 79
       SCAL =6371.0*1000.0*3.14159/180.0
       RAD = 3.14159/180.0
       DUM2 = DUM2/SCAL
       YLAT = (YC*YDS)+(YDL+YDS)+DUM2
       DUM1 = DUM1/(SCAL*COS(YLAT*RAD))
 79    CONTINUE
C
C   CALCULATE THE PARTICLE POSITION IN X AND Y.
C
       X(N) = (XC - XORIG) * XDS + DUM1
       Y(N) = (YC - YORIG) * YDS + DUM2
C
C   CHECK THAT THE PARTICLE FALLS IN THE FIXED GRID.
C
        X1 = X(N) / XDS + XORIG


        ML = X1
        MU = ML + 1
        Y1 = Y(N) / YDS + YORIG
        NL = Y1
        NU = NL + 1
        JJ = JJ + 1
        IF(JJ.LT 100) GO TO 800
        WRITE(NW,801)
 801    FORMAT(2X,' NEW PARTICLE POSITIONS ARE OUT OF FIXED GRID')
        STOP
 800    CONTINUE
        IF((MU.GT.MAXCX) .OR. (NU GT.MAXCY)) GO TO 2
        IF((ML.LT.1) .OR. (NL.LT 1)) GO TO 2
        IF((NCOMP(MU, NU).EQ.0) .OR. (NCOMP(MU, NL).EQ.0)) GO TO 2
        IF((NCOMP(ML, NU).EQ.0) .OR. (NCOMP(ML, NL).EQ 0)) GO TO 2
C
C  IS THE SPACING BETWEEN THE FIRST PARTICLES ENOUGH ?
C
        IF(N.NE 2) GO TO 790
        XDIF = ABS(X(1)-X(2))
        YDIF = ABS(Y(1)-Y(2))
        IF(ISCAL.EQ.1) GO TO 791
        YDIF = YDIF*SCAL
        XDIF = XDIF*SCAL*COS(YLAT*RAD)
 791    CONTINUE
        IF((YDIF.LT.POSIN) .OR. (XDIF.LT POSIN)) GO TO 2
 790    CONTINUE
C
C   CALCULATE THE Z POSITION OF THE PARTICLE.
C
        Z(N) = DEPC + FIVE * (RZ - 0.5)
C
C   SAVE THE CLASS TO WHICH THIS PARTICLE BELONGS.
C
       NORDS(N) = JCLASS
C
C   PRINT OUT THE PARTICLE POSITION.
C
   1    CONTINUE
C
C               R E T U R N
C
        RETURN
        END
       SUBROUTINE LOCN(NGRD, NX, NY, ANG, XL, YL, XS, YS, VAR1,
     1   VAR2, XC, YC, R, VAL1, VAL2, MDLSPL, ISPIL)
C
C     THIS SUBROUTINE FINDS THE SEPARATION IN METERS IN LONGITUDE
C   AND IN LATITUDE BETWEEN THE ORIGIN OF THE GIVEN COORDINATE
C   SYSTEM AND THE GIVEN POINT. THIS LINE IS THEN ROTATED INTO
C   THE GIVEN COORDINATE SYSTEM, IE., THE SEPARATION PARALLEL
C   TO THE COORDINATE SYSTEM X AXIS AND THE SEPARATION PARALLEL
C   TO THE COORDINATE SYSTEM Y AXIS. FINALLY ALL GRID ELEMENTS
C   WHICH COVER THE CIRCLE OF RADIUS R CENTERED ON THE GIVEN POINT
C   ARE AVERAGED AND THE AVERAGES ARE RETURNED.
C
C..............................................................
C
C               COMMON STATEMENTS
C
```

Figure VII.-3. MAIN

```
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPNTA,
     1     NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
C
C                DIMENSION STATEMENTS
C
      DIMENSION VAR1(30, 30), VAR2(30, 30)
C
C                DATA STATEMENTS
C
      DATA PI, NN, NO/ 3.14159, 6, 2/
      IF(ISCAL.EQ.2) NO = 5
      NDLSPL = 0
C
C                S T A R T   H E R E
C
C   IF ONLY ONE GRID ELEMENT SAVE THE VALUE AND RETURN.
C
      IF((NX.GT 1) .OR  (NY.GT 1)) GO TO 10
      VAL1 = VAR1(1, 1)
      IF(NGRD.EQ.2) VAL2 = VAR2(1, 1)
      RETURN
 10   CONTINUE
C
C   FIND THE LOCATION OF THE SPILLET CENTER IN THE GRID
C    IF NECESSARY ROTATE THE DISTANCE
C
      CALL DIST(XL, YL, XC, YC, NO, ANG, D, XDT, YDT)
C
C   FIND THE SPILLET LIMITS IN THE GRID
C
      RX = R
      RY = R
      IF(ISCAL EQ.1) GO TO 85
   28 SCAL = 6371.0*1000.0*PI/180.0
      RX = R/(SCAL*COS(YC/57.296))
      RY = R/SCAL
 85   CONTINUE
      XDL = XDT - RX
      XDU = XDT + RX
      YDL = YDT - RY
      YDU = YDT + RY
C
C   OBTAIN ALL OF THE GRID ELEMENTS IMMEDIATELY ADJACENT TO THE
C   SPILLET OR IN IT.
C
      NXL = XDL / XS + 1.0
      NXU = XDU / XS + 2.0
      NYL = YDL / YS + 1.0
      NYU = YDU / YS + 2.0
      VAL1 = 0.0
      VAL2 = 0.0
C
C   CHECK THAT THE SPILLET LIES WITHIN THE STUDY AREA.
C
      IF(NXL.GT.0) GO TO 40
      IF(NXU.GT.0) GO TO 41
 45   CONTINUE
      NDLSPL = 1
      WRITE(NN, 200) ISPIL
 200  FORMAT(2X, ' SPILLET ', I4, ' IS COMPLETELY OUT OF RANGE')


      RETURN
 41   CONTINUE
      NXL = 1
 40   CONTINUE
      IF(NXU.LE NX) GO TO 50
      IF(NXL.GT.NX) GO TO 45
      NXU = NX
 50   CONTINUE
      IF(NYL.GT.0) GO TO 60
      IF(NYU.LE.0) GO TO 45
      NYL = 1
 60   CONTINUE
      IF(NYU.LE.NY) GO TO 70
      IF(NYL.GT.NY) GO TO 45
      NYU = NY
 70   CONTINUE
C
C   AVERAGE VARIABLES OVER THE APPROPRIATE GRID ELEMENTS.
C
      DO 20 MX=NXL, NXU
         DO 30 MY=NYL, NYU
            VAL1 = VAL1 + VAR1(MX, MY)
            IF(NGRD.EQ.2) VAL2 = VAL2 + VAR2(MX, MY)
 30      CONTINUE
 20   CONTINUE
      DENOM = FLOAT((NXU-NXL+1) * (NYU-NYL+1) )
      VAL1 = VAL1 / DENOM
      IF(NGRD.EQ.2) VAL2 = VAL2 / DENOM
C
C                E N D   H E R E
C
      RETURN
      END
      SUBROUTINE RAND(IX, IU, P, FIU)
      IU=IX*IU
      FIU=IU/P+ 0.5
      RETURN
      END
      SUBROUTINE REMOV( DUM, BEG, DUR, NEF, NVAR)
C
C      THIS SUBROUTINE IDENTIFIES THOSE EFFORTS TO CLEANUP
C   OR TO TREAT THE SPILLETS WHICH HAVE EXPIRED. THE LIST OF
C   EFFORTS IS THEN COMPRESSED REMOVING EXPIRED ONES.
C
C.. ............................ ..................................
C
C                COMMON STATEMENTS
C
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPNTA,
     1     NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
C
C                DIMENSION STATEMENTS
        DIMENSION DUM(10,NVAR), BEG(10), DUR(10)
C
C
C                S T A R T   H E R E
C
C   FIND ALL EXPIRED EFFORTS.
C
       JTEMP = 0
```

```
      DO 50 ITEMP=1,NEF
         BEGT = BEG(ITEMP)* 3600 0
         DURT = DUR(ITEMP) *3600 0
         END = BEGT + DURT
         IF(END.GT.TIME) GO TO 50
         JTEMP = JTEMP + 1
         NSAV(JTEMP) = ITEMP
 50   CONTINUE
C
C   REORDER THE CLEANUP LIST SO THAT EXPIRED EFFORTS ARE AT THE END
C
      IF(JTEMP.EQ.0) RETURN
      MTEMP = NEF + 1
      KTEMP = JTEMP + 1
      DO 70 ITEMP=1,JTEMP
         MTEMP = MTEMP - 1
         KTEMP = KTEMP - 1
         LTEMP = NSAV(KTEMP)
         IF(LTEMP.EQ.MTEMP) GO TO 70
         DO 80 I=1,NVAR
            DUM(LTEMP,I) = DUM(MTEMP,I)
 80      CONTINUE
 70   CONTINUE
C
C   REMOVE EXPIRED EFFORTS AND RETURN.
C
      NEF = MTEMP - 1
C
C                E N D   H E R E
C
      RETURN
      END
      SUBROUTINE SPREAD(ISPIL)
C
C     THIS SUBROUTINE SPREADS A SPILLET FOR ONE TIME STEP. THE
C   SPREADING PROCEDURE USED IS THAT DEVELOPED BY FAY  FIRST HOWEVER
C   THE "STARTING TIME" OF THE SPILLET MUST BE DETERMINED FROM
C   ITS RADIUS AND ITS VOLUME . THEN THE REGIME IS DETERMINED
C   AND FINALLY THE NEW RADIUS AFTER ONE TIME STEP. THIS APPROACH
C   MUST BE TAKEN AS THE VOLUME CHANGES FROM STEP TO STEP.
C
C                VARAIBLE DESCRIPTION
C
C   COEF1  - SPREADING COEFFICIENT FOR FIRST REGIME.
C   COEF2  - SPREADING COEFFICIENT FOR SECOND REGIME.
C   COEF3  - SPREADING COEFFICIENT FOR THIRD REGIME.
C   DELTA  - (WATER DENSITY - OIL DENSITY) / WATER DENSITY.
C   GRAV   - GRAVITATIONAL ACCELERATION (CM/SEC**2).
C   RAD    - RADIUS OF SPILLET (CM).
C   RHOW   - DENSITY OF SEA WATER (GM/CC).
C   RMAX   - MAX RADIUS TO WHICH A SPILLET OF THIS VOL WILL SPREAD.
C   SIG    - SPREADING TENSION (DYNES/CM*GM/SEC**2).
C   TIJ    - TIME AT WHICH THE SPILLET GOES FROM REGIME I TO
C            REGIME J.
C   VISW20 - VISCOSITY OF SEA WATER (STOKES*CM**2/SEC).
C   VISRT2 - SQRT(VISW20).
C   VMIN   - MAXIMUM VOLUME FOR WHICH FAYS REGIME 2 IS SKIPPED.
C   VOL    - VOLUME OF SPILLED OIL (CC).
C
C..................................................................


C
C                COMMON STATEMENTS
C
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPNTA,
     1     NPNTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), RSPIL(99), DSPIL(99),
     1     FSPIL(99), GSPIL(99, 8), ESPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), USPIL(99), WSPIL(99), XSPIL(99),
     3    YSPIL(99), SSPILT(99), NATSPL
C
C                DATA STATEMENTS
C
      DATA PI/ 3.14/
      DATA RHOW/ 1.024/
      DATA VISW20/ 0.012077/
      DATA COEF1, COEF2, COEF3/ 1.14, 1.45, 2.30/
      DATA GRAV/ 980.5416/
C
C                S T A R T   H E R E
C
      FRAC = 0.0
      VISRT2 = SQRT(VISW20)
      T3 = DT
C
C   CALCULATE TEMPORARY VARIABLES.
C
      DELTA = (RHOW - DSPIL(ISPIL)) / RHOW
      VOL = WSPIL(ISPIL) * 1.0E6 / DSPIL(ISPIL)
      RAD = RSPIL(ISPIL) * 100.0
C
C   IF THE SPILLET HAS REACHED ITS MAXIMUM SIZE:  MAKE
C   THE RADIUS THE MAXIMUM SIZE AND RETURN
C
      AREA = 1.0E5 * (VOL / 1.0E6)**.75
      RMAX = SQRT(AREA / PI) * 100.0
      IF(RMAX.GT RAD) GO TO 79
      RAD = RMAX
      RETURN
C
C   FIND THE FRACTION OF THIS SPILLET WHICH HAS BEEN CHEMICALLY
C   TREATED AND WEIGHT THE INTERFACIAL TENSION ACCORDINGLY.
C
 79   IF(FSPIL(ISPIL).GE.1.0) GO TO 10
      IF(FSPIL(ISPIL).LE.0.0) GO TO 11
      FRAC = FSPIL(ISPIL)
      SIG = SSPIL(ISPIL) * (1.0 - FRAC) + SSPILT(ISPIL) * FRAC
      GO TO 20
 11   CONTINUE
      SIG = SSPIL(ISPIL)
      GO TO 20
 10   CONTINUE
      SIG = SSPILT(ISPIL)
 20   CONTINUE
C
C   IF THE SPILLET IS TOO SMALL THE SECOND REGIME WILL BE SKIPPED
C   DETERMINE IF THIS IS THE CASE FOR THIS SPILLET.
C
      VMIN = (COEF2 * COEF3)**6 / (COEF1**12)
      TEMP = VISW20 * DELTA * GRAV
      VMIN = VMIN * (SIG / RHOW)**3 / (TEMP**2)
```

Figure VII.-3. MAIN

```
      IF(VOL.GT.VMIN) GO TO 60
C
C    DETERMINE THE TIME SINCE THE START OF THE SPILLET
C    ASSUMING THAT IT IS IN THE FIRST REGIME.
C
      T1 = ((RAD / COEF1)**2) / SQRT(DELTA * GRAV * VOL)
      T1 = T1 + DT
C
C    DETERMINE THE TIME AT WHICH THE SPILLET GOES FROM THE FIRST
C    REGIME TO THE THIRD REGIME.
C
      T13 = DELTA * GRAV * VOL * VISH2O
      T13 = T13 * ((RHOW / SIG)**2)
      T13 = ((COEF1 / COEF3)**4) * T13
C
C    IS THE SPILLET IN THE FIRST REGIME?
C
      IF(T1.LE.T13) GO TO 30
C
C    GO DIRECTLY TO 50 IF THIS IS THE FIRST TIME STEP.
C
      IF(RAD.LE.0.0) GO TO 50
C
C    DETERMINE THE TIME SINCE THE START OF THE SPILLET
C    ASSUMING THAT IT IS IN THE THIRD REGIME.
C
      T3 = ((SIG / RHOW)**2) / VISH2O
      T3 = (((RAD / COEF3)**4) / T3)**(1.0/3.0)
      T3 = T3 + DT
      GO TO 50
C
C    DETERMINE THE TIME SINCE THE START OF THE SPILLET
C    ASSUMING THAT IT IS IN THE FIRST REGIME.
C
 60   CONTINUE
      T1 = ((RAD / COEF1)**2) / SQRT(DELTA * GRAV * VOL)
      T1 = T1 + DT
C
C    DETERMINE THE TIME AT WHICH THE SPILLET GOES FROM THE FIRST
C    REGIME TO THE SECOND REGIME
C
      T12 = VOL / (DELTA * GRAV * VISH2O)
      T12 = ((COEF2 / COEF1)**8) * (T12**(1.0/3.0))
C
C    IS THE SPILLET IN THE FIRST REGIME?
C
      IF(T1.LE.T12) GO TO 30
C
C    DETERMINE THE TIME SINCE THE START OF THE SPILLET
C    ASSUMING THAT IT IS IN THE SECOND REGIME.
C
      T2 = (DELTA * GRAV * (VOL**2) / VISRT2)**(2.0/3.0)
      T2 = ((RAD / COEF2)**4) / T2
      T2 = T2 + DT
C
C    DETERMINE THE TIME AT WHICH THE SPILLET GOES FROM THE SECOND
C    REGIME TO THE THIRD REGIME.
C
      T23 = DELTA * GRAV * VOL * VOL * VISH2O
      T23 = ((COEF2 / COEF3)**2) * (T23**(1.0/3.0)) * (RHOW / SIG)


C
C    IS THE SPILLET IN THE SECOND REGIME?
C
      IF(T2.LE.T23) GO TO 40
C
C    GO DIRECTLY TO 50 IF THIS IS THE FIRST TIME STEP
C
      IF(RAD.LE.0.0) GO TO 50
C
C    DETERMINE THE TIME SINCE THE START OF THE SPILLET
C    ASSUMING THAT IT IS IN THE THIRD REGIME.
C
      T3 = ((SIG / RHOW)**2) / VISH2O
      T3 = (((RAD / COEF3)**4) / T3)**(1.0 / 3.0)
      T3 = T3 + DT
C
C    CALCULATE THE SPILLET RADIUS IF IT IS IN THE THIRD REGIME.
C
 50   CONTINUE
      TEMP = ((SIG / RHOW)**2) * (T3**3) / VISH2O
      RAD = COEF3 * (TEMP**0.25)
      GO TO 70
C
C    CALCULATE THE SPILLET RADIUS IF IT IS IN THE SECOND REGIME.
C
 40   CONTINUE
      TEMP = DELTA * GRAV * (VOL**2) * (T2**1.5) / VISRT2
      RAD = COEF2 * (TEMP**(1.0/6.0))
      GO TO 70
C
C    CALCULATE THE SPILLET RADIUS IF IT IS IN THE FIRST REGIME.
C
 30   CONTINUE
      TEMP = DELTA * GRAV * VOL * (T1**2)
      RAD = COEF1 * (TEMP**0.25)
C
C    HERE TO RECALCULATE THE AREA OF THE TREATED SPILLET ASSUMING
C    THAT THE TREATED FRACTION SPREADS WITH THE REST OF THE SPILLET.
C
 70   CONTINUE
      ASPIL(ISPIL) = FRAC * PI * (RAD**2) * 1.0E4
      IF(RAD.GT.RMAX) RAD = RMAX
      RSPIL(ISPIL) = RAD / 100.0
C
C                 E N D   H E R E
C
      RETURN
      END
      SUBROUTINE SUBDFT(XC, YC, UWIND, VWIND, UCRNT, VCRNT)
C
C     THIS SUBROUTINE MOVES THE CENTER OF MASS OF THE GIVEN SPILLET
C    FOR ONE TIME STEP. THE CURRENT VERSION OF THE SUBROUTINE
C    WILL MOVE THE SPILLET AT 3.5% OF THE WIND SPEED IN THE DIRECTION
C    OF THE WIND.
C
C.....................................................................
C
C                 COMMON STATEMENTS
C
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
```

```
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), RSPIL(99), DSPIL(99),
     1     FSPIL(99), CSPIL(99, 8), ESPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), OSPIL(99), VSPIL(99), XSPIL(99),
     3    YSPIL(99), SSPILT(99), MAXSPL
C
C                 DATA STATEMENTS
C
      DATA PI, WINPC/ 3.14159, 0.035/
C
C                 S T A R T   H E R E
C
      SCALE=PI*1000.0*6371.0/180.0
      IF(ISCAL.EQ.1) GO TO 43
C
C    IF ON A LARGE SCALE, CONVERT DEGREES/SEC  TO M/SEC.
C
      VCRNT=VCRNT*SCALE
      UCRNT=UCRNT*SCALE*COS(YC/57.296)
 43   CONTINUE
C
C    CALCULATE THE DISTANCE MOVED IN X AND IN Y.
C
      XDIST = DT * (UWIND * WINPC + UCRNT )
      YDIST = DT * (VWIND * WINPC + VCRNT )
C
C    CALCULATE THE LONGITUDE AND LATITUDE OF THE SPILL CENTER.
C
      YC = YC + YDIST / SCALE
      XC = XC - XDIST / (SCALE*COS(YC/57.296))
C
C                 E N D   H E R E
C
      RETURN
      END
      SUBROUTINE TREAT( ISP , SUMAS )
C
C     THIS SUBROUTINE HANDLES THE CHEMICAL TREATMENT OF THE
C    OIL SPILLS.
C
C............................. ..............................
C
C                 COMMON STATEMENTS
C
      COMMON /CHEM/ NCHEM, ICHEM(10), DCHEM(10), RCHEM(10),
     1     XCHEM(10), YCHEM(10), VCHEM(10), UCHEM(10), ACHEM(10),
     2     TCHEM(10), PCHEM(10)
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(99)
      COMMON /MASS/ XMATM, XMBIO, XMOUT, XMCLN, XMDIS, XMLOS,
     1     XMSHR, XMSUR, XMSOS
      COMMON /SPIL/ NSPIL, MSPIL, ASPIL(99), RSPIL(99), DSPIL(99),
     1     FSPIL(99), CSPIL(99,6), ESPIL(99), SSPIL(99),
     2     TSPIL(99), TSPILT(99), OSPIL(99), VSPIL(99), XSPIL(99),
     3    YSPIL(99), SSPILT(99), MAXSPL
C
C                 DIMENSION STATEMENTS
C
      DIMENSION DUM(10,10)
C


C                 EQUIVALENC STATEMENTS
C
      EQUIVALENCE (DUM(1,1),NCHEM(1))
C
C                 DATA STATEMENTS
C
      DATA PI, NW/ 3.14159, 6/
C
C                 S T A R T   H E R E
C
      IF(NCHEM GT.0) GO TO 50
      TMT = TIME / 3600.0
      WRITE (NW,210) TMT
 210  FORMAT('0 NO AREAS UNDER TREATMENT AT TIME ',F10 2,
     1   ' HOURS'/)
      RETURN
 50   CONTINUE
C
C    REMOVE EXPIRED TREATMENT EFFORTS FROM THE TREATMENT LIST.
C
      CALL REMOV( DUM, NCHEM, DCHEM, NCHEM, 10)
      IF(NCHEM.GT.0) GO TO 51
       TMT = TIME / 3600.0
      WRITE (NW,210) TMT
      RETURN
 51   CONTINUE
C
C
C    DO LOOP OVER ALL TREATMENT EFFORTS.
C
      DO 10 ICHEM=1,NCHEM
         RC = RCHEM(ICHEM)
C
C    DETERMINE AREA WHICH MAY BE TREATED THIS TIME STEP.
C
         TRAREA = (VCHEM(ICHEM) / UCHEM(ICHEM)) * (DT / 3600 0)
C
C    FIND ALL SPILLETS WITHIN RANGE OF TREATMENT EQUIPMENT.
C
            CALL DIST(XSPIL(ISP),YSPIL(ISP),XCHEM(ICHEM),
     1                  YCHEM(ICHEM), 1, 0.0,DIS,XSP,YSP)
C
C  IF THE DISTANCE BETWEEN EFFORT AND SPILLET
C  IS TOO LARGE OR IF THE SPILLET HAS BEEN
C  COMPLETELY TREATED, THEN RETURN.
C
            IF(DIS.GT.RC) RETURN
            IF(ASPIL(ISP).LT.0.0) RETURN
C
C    IF A SPILLET IN THE AREA HAS BEEN PARTIALLY TREATED CONTINUE
C    TREATMENT.
C
            IF(ASPIL(ISP).GT.0.0) GO TO 40
C
C    TREAT THIS SPILLET.
C
         SPAREA = RSPIL(ISP)**2 * PI - ASPIL(ISP)
         IF(TRAREA.LE.SPAREA) GO TO 40
         FSPIL(ISP) = 1.0
         ASPIL(ISP) = (-1.0) * RSPIL(ISP)**2 * PI
```

Figure VII.-3. MAIN

```
          SSPILT(ISP) = SCHEM(ICHEM)
          TSPILT(ISP) = TCHEM(ICHEM)
           PER = PCHEM(ICHEM)
           GO TO 20
C
C    HERE ONLY WHEN A FRACTION OF A SPILLET IS TO BE TREATED.
C
 40       CONTINUE
          SSPILT(ISP) = SCHEM(ICHEM)
          TSPILT(ISP) = TCHEM(ICHEM)
          ASPIL(ISP) = ASPIL(ISP) + TAAREA
          FSPIL(ISP) = ASPIL(ISP) / (PI * RSPIL(ISP)**2)
          PER = TAAREA/SPAREA
 20       CONTINUE
C
C        DISPERSE THE MASS OF THE SPILLET
C
        ZMSDP = PER * MSPIL(ISP)
        IF(ZMSDP GT.MSPIL(ISP)) ZMSDSP = MSPIL(ISP)
        SUMAS = SUMAS + ZMSDP
        ZMSUR = ZMSUR - ZMSDP
        ZMSUS = ZMSUS + ZMSDP
        MSPIL(ISP) = MSPIL(ISP) - SUMAS
          AMNT = WCHEM(ICHEM) * TAAREA
 10     CONTINUE
C
C    PRINT OUT AREA TREATED AND DISPERSANT USED THIS TIME STEP
C
       THR = TIME / 3600.0
       WRITE (NW,200) THR, TAAREA, AMNT
 200   FORMAT(4X,'DURING THE TIME STEP WHICH BEGAN AT ',F10.3,
     1       ' HOURS ',F10.3,' SQUARE METERS OF OIL WERE TREATED',
     2       /,25X,' WITH ',F10.3,' LITERS OF DISPERSANT.')
C
C                E N D   H E R E
C
       RETURN
       END
       SUBROUTINE ASMOS
       RETURN
       END
       SUBROUTINE SUBSUR( X, Y, Z, NORDR, C, N, NST, MPLT, DPLT)
C
C                SUBROUTINE DESCRIPTION
C
C      THIS SUBROUTINE TRACKS ALL MARKER PARTICLES FOR ONE TIME
C    STEP. IT CALLS THE FOLLOWING SUBROUTINES:
C
C             AVGSIG
C             BOUNY
C             CONC
C             COURAN
C             DIFF
C             DISPV
C             GRIDEX
C             PARTV
C             PRINT
C             VELC
C             VELCT
C             VELPRT
C
C
C . ..........................................................
C
C
C                COMMON STATEMENTS
C
        COMMON /DIFD/ NCRIT, NDIFF, DXX, DYY, DZZ, EXX, EYY,
     1        POWX, POWY
       COMMON /ELVN/ MAXEX, MAXEY, AE, HGHT(30,30), XEL, YEL,
     1       XES, YES
       COMMON /PLOT/ MAXPX, MAXPY, MAXPZ, AP, UPLT(15,15,10),
     1       VPLT(15,15,10), WPLT(15,15,10), XPL, YPL, ZPL, XPS, YPS, ZPS
       COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1       NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
       COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1       DMASS(200), DVELZ(200), DCONF(200,8), NTCLAS, NDELL
       COMMON /SUBS/ NTRANS, NSUB, NEXTR, NMAX, MMAX, DX, DY, DZ,
     1   XORIG, YORIG, ZORIG
       COMMON /PRNT/ NPRTV, NPRTC, NPRTP, NPED, NPAT, NPRC, NFFF,
     1       NPTSUR, NPRSUB
       COMMON /TIDE/ MAXTX, MAXTY, AT, UT(30,30), VT(30,30), XTLT, YTLT,
     1       XTS, YTS, XTLV, YTLV
       COMMON /SPIL/ NSPIL, ISPIL, ASPIL(99), BSPIL(99), DSPIL(99),
     1       FSPIL(99), GSPIL(99,8), RSPIL(99), SSPIL(99),
     2       TSPIL(99), TSPILT(99), USPIL(99), MSPIL(99), XSPIL(99),
     3       YSPIL(99), SSPILT(99), MAXSPL
C
C                DIMENSION STATEMENTS
C
         DIMENSION C(15,15,10)
         DIMENSION DPLT(15,15), MPLT(15,15), CC(15,15)
         DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
         INTEGER*2 NORDR(NMAX)
         INTEGER N(15,15,10)
C
C  IF NO PARTICLES ARE CREATED, RETURN
C
        IF(NMAX.LT.2) RETURN
C
C                S T A R T   H E R E
C
C      DETERMINE PRINTOUT PARAMETER
C
       NPRSUB = 0
       IF(NPTSUB.LE.0) GO TO 80
       IF((NPTSUB.EQ.0).AND.(TIME.EQ.0.0)) NPRSUB=1
       IF(NPTSUB LE.0) GO TO 80
       NTP = AMOD(FLOAT(NST), FLOAT(NPTSUB))
       IF(NTP.EQ.0) NPRSUB = 1
 80    CONTINUE
C
C    EXPAND AND MOVE FLOATING GRID IF NOT ALREADY DONE IN SPILL
C
        IF(NEXTR.EQ.0) GO TO 20
        CALL GRIDEX(X, Y, Z, NST)
C
 20     CONTINUE
C
C    CHECK PARTICLES FOR BOUNDARY VIOLATION
C
        CALL BOUNY( N, X, Y, Z, NORDR)
```

```
C
C    OBTAIN THE CONCENTRATION IN EACH GRID ELEMENT
C
       IF(NMAX.GT.NCRIT) CALL CONC( C, X, Y, Z, NORDR)
C
C    OBTAIN DIFFUSION PLUS ADVECTIVE VELOCITY FIELD
C
       CALL VELCT(C, N, X, Y, Z, DPLT, MPLT, NST)
C
C    HAS THE COURANT CONDITION BEEN VIOLATED IN THIS TIME STEP.
C
       CALL COURAN
C
C    MOVE THE PARTICLES
C
       CALL DISPV( N, X, Y, Z, DPLT, MPLT, NORDR)
C
C    PRINTOUT FOR THIS STEP
C
       CALL PRINT(C, N, X, Y, Z, NORDR, NST, DPLT, MPLT, CC)
C
C              R E T U R N   H E R E
C
        RETURN
        END
      SUBROUTINE AVGSIG( X, Y, Z, XAVG, YAVG, ZAVG,
     1                    SIGX, SIGY, SIGZ, NSELCT)
C
C               SUBROUTINE DESCRIPTION
C
C      FOR NSELCT=0 THIS SUBROUTINE CALCULATES THE AVERAGE X, Y, AND
C    Z PARTICLE POSITION. FOR NSELCT=1 THE STANDARD DEVIATION OF THE
C    PARTICLE POSITIONS IS ALS CALCULATED.
C
C . ......................... ....................................
C
C              COMMON STATEMENTS
C
      COMMON /SUBS/ NTRANS, NSUB, NEXTR, NMAX, MMAX, DX, DY, DZ,
     1   XORIG, YORIG, ZORIG
C
C               DIMENSION STATEMENTS
C
      DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
C
C  IF NO PARTICLES ARE PRESENT, RETURN
C
       IF(NMAX.EQ.0)  RETURN
C
C               S T A R T   H E R E
C
       XAVG = 0.0
       YAVG = 0 0
       ZAVG = 0.0
       SIGX = 0.0
       SIGY = 0.0
       SIGZ = 0.0
C
C   DO LOOP OVER MARKER PARTICLES
C


        DO 10 N=1, NMAX
            XAVG = XAVG + X(N)
            YAVG = YAVG + Y(N)
            ZAVG = ZAVG + Z(N)
            IF(NSELCT.EQ.0) GO TO 10
            SIGX = SIGX + X(N) * X(N)
            SIGY = SIGY + Y(N) * Y(N)
            SIGZ = SIGZ + Z(N) * Z(N)
 10     CONTINUE
        XNUM = FLOAT(NMAX)
        IF(NSELCT.EQ.0) GO TO 20
        SIGX = (SIGX - XAVG * XAVG / XNUM) / (XNUM - 1.0)
        SIGY = (SIGY - YAVG * YAVG / XNUM) / (XNUM - 1.0)
        SIGZ = (SIGZ - ZAVG * ZAVG / XNUM) / (XNUM - 1.0)
        SIGX = SQRT(ABS(SIGX))
        SIGY = SQRT(ABS(SIGY))
        SIGZ = SQRT(ABS(SIGZ))
 20     CONTINUE
        XAVG = XAVG / XNUM
        YAVG = YAVG / XNUM
        ZAVG = ZAVG / XNUM
C
C               R E T U R N   H E R E
C
        RETURN
        END
      SUBROUTINE BOTOPT
      RETURN
      END
       SUBROUTINE BOUNY( N, X, Y, Z, NORDR)
C
C               SUBROUTINE DESCRIPTION
C
C      THE POSITION OF EACH MARKER PARTICLE RELATIVE TO THE
C    BOUNDARIES IS CHECKED IN THIS SUBROUTINE  IF THE PARTICLE
C    IS WITHIN A HALF GRID UNIT OF LAND IT IS PUSHED OUT JUST
C    BEYOND THE HALF GRID DISTANCE  IF IT IS WITHIN A HALF OF A
C    GRID UNIT OF THE NON-COMPUTATIONAL EDGE OF A DEPOSITIONAL
C    CELL ITS PARAMETERS ARE WRITTEN TO DISK AND IT IS REMOVED
C    FROM THE PARTICLE LIST. THE SAME ACTION IS TAKEN IF IT MOVES
C    TO WITHIN A HALF OF A GRID UNIT OF AN OPEN BOUNDARY CELL.
C    IF THE PARTICLE MOVES TO WITHIN A HALF OF A GRID UNIT OF THE
C    SURFACE IT IS MOVED BACK TO A POSITION A LITTLE MORE THAN A
C    HALF OF A GRID UNIT FROM THE SURFACE.
C
C.............................. ..................................
C
C               COMMON STATEMENTS
C
      COMMON /COMP/ MAXCX, MAXCY, AC, NCOMP(30,30), XCL, YCL,
     1      XCS, YCS
      COMMON /DEPOS/ NLOST, NDEP
      COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30,30), XDL, YDL,
     1      XDS, YDS
      COMMON /ELVN/ MAXEX, MAXEY, AE, HGHT(30,30), XEL, YEL,
     1      XES, YES
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1      NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
      COMMON /MASS/ ZMATM, ZMBIO, ZMBOT, ZMCLN, ZMDSP, ZMLOS,
     1      ZMSED, ZMSUR, ZMSUS
```

Figure VII.-3. MAIN

```
      COMMON /OUTP/ NUSP, NUNS, NUCL, NUPT, NUBS, NULT,
     1     NUDF, NUVL
      COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1     DMASS(200), DVELS(200), DCOMP(200,8), NTCLAS, NDECL
      COMMON /SUBS/ NTRANS, NSUB, NEXTN, NMAX, MMAX, DX, DY, DZ,
     1     XORIG, YORIG, ZORIG
      COMMON /TIDE/ NAITX, NAITY, AT, UT(30,30), VT(30,30), XTLO, YTLO,
     1     XTS, YTS, XTLV, YTLV
C
C              DIMENSION STATEMENTS
C
       DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
       INTEGER*2 NOBDN(NMAX)
       INTEGER N(15,15,10)
C
C              DATA STATEMENTS
C
      DATA  NW/  6/
C
C              S T A R T   H E R E
C
C
C
C   PART  NEAR A BOUND  ARE MOVED DX/2, DY/2 OR DZ/2 + ER
C
       ER = .01
C
C   INIT VARIABLES USED EXTENSIVELY WHICH DEPEND ON DX, DY OR DZ
C
       DX2 = DX/2.
       DY2 = DY/2.
       DZ2 = DZ/2.
       DXU = INSUB*DX-DX2
       DYU = JNSUB*DY-DY2
       DZU = KNSUB*DZ-DZ2
C
C      DETERMINE BOUNDARY CONDITIONS FOR FLOATING GRID MOVING
C      INSIDE THE FIXED HYDRODYNAMIC GRID
C
C      HORIZONTAL CELLS
C
C      N(I, J, K)=0   A LAND CELL, NON COMPUTATIONAL BOUNDARY
C      N(I, J, K)=1   A WATER CELL , COMPUTATIONAL
C      N(I, J, K)=2   AN OPEN BOUNDARY CELL
C      N(I, J, K)=101 A WATER CELL, COMPUTATIONAL WITH AN
C      ADJACENT CELL WHICH IS NOT A COMPUTATIONAL CELL
C
C      VERTICAL BOUNDARY CELLS
C
C      N(I, J, K)=3   A FREE SURFACE REFLECTION CELL
C      N(I, J, K)=4   A BOTTOM DEPOSITIONAL OR EROSION CELL
C
       XO = XORIG*XDS-0.5*DX-XDS
      KC = 2
       KB=KNSUB-1
       DO 19 I=1, INSUB
       XO = XO + DX
       YO = YORIG*YDS-.5*DY-YDS
       DO 19 J=1, JNSUB
       YO = YO + DY
C


C  FIND THE POSITIONS OF THE FLOATING GRID WITH RESPECT
C   TO THE COMPUTATIONAL GRID
C
       CALL ROTAT(XCL, YCL, XCS, YCS, AC, XO, YO, XG, YG)
C
C   THESE ARE IN GRID UNITS
C
       IXN = XG + 0.5
       IYN = YG + 0.5
       N(I, J, KC) = NCOMP(IXN, IYN)
       N(I, J,1) = 4
       N(I, J, KNSUB) = 3
       DO 19 K=2, KB
 19    N(I, J, K)=N(I, J, KC)
 20    CONTINUE
C
C  DO LOOP OVER ALL MARKER PARTICLES
C
       M=0
 1     CONTINUE
       M = M + 1
       IF(M.GT.NMAX) GO TO 3
C
C   BRANCH OUT OF THIS LOOP IF M>NOPR. THIS CAN OCCUR WHEN A LOT OF
C   PART. ARE LOST OR DEPOSITED AND THE LIST HAS BEEN COMPRESSED
C
       IF(X(M).EQ.0.0.OR.Y(M).EQ.0.0.OR.Z(M).EQ.0.0) GO TO 1
C
C  OBTAIN THE SUBSCRIPTS FOR THE GRID ELEMENT FOR THIS PARTICLE
C
       PI = X(M) / DX
       IP = PI + 1
       PJ = Y(M) / DY
       JP = PJ + 1
       PK = Z(M) / DZ
       KP = PK + 1
C
C  MAKE SURE THAT NONE OF THE P SUBSCRIPTS ARE OUT OF RANGE
C  FIRST CHECK TO SEE IF THE GRID IS AN EXPANDING, TRANSLATING ONE.
C
      IF(NEXTN EQ.1) GO TO 700
      IF( (IP.GT.INSUB) .OR. (IP LT.1) ) GO TO 610
      IF( (JP.GT.JNSUB) .OR  (JP LT.1) ) GO TO 610
      IF(KP.GT.KNSUB) GO TO 620
      IF(KP.LT.1) GO TO 303
 700  CONTINUE
       IF(IP.GT.INSUB) IP = INSUB
       IF(JP.GT.JNSUB) JP = JNSUB
       IF(KP.GT.KNSUB) KP = KNSUB
       IF(IP.LT.1) IP = 1
       IF(JP.LT 1) JP = 1
       IF(KP.LT.1) KP = 1
C
C  IS THIS A COMPUTATIONAL CELL WITH NO ADJACENT BOUNDARY CELLS
C   IN THE HORIZONTAL. NO CHECK ON THE VERTICAL BOUNDARY HERE.
C
       KPP = 2
       IF(N(IP,JP,KP).EQ.0) GO TO 620
       IF(N(IP, JP, 2).EQ.1) GO TO 10
C
C  IF NOT, CHECK FOR BOUNDARY CELL TYPE AND TAKE APPROPRIATE ACTION
C
C  OBTAIN THE XYZ POSITION OF THE MARKER RELATIVE TO CELL CENTER
C
       XP = PI - FLOAT(IP) + 0.5
       YP = PJ - FLOAT(JP) + 0.5
C
C  OBTAIN SUBSCRIPTS OF ADJACENT CELLS TO THE QUAD OCCUPIED
C
       IF(XP) 51, 52, 52
 51    IQ = IP - 1
       XER = - ER
       GO TO 53
 52    IQ = IP + 1
       XER = ER
 53    IF(YP) 54, 55, 55
 54    JQ = JP - 1
       YER = - ER
       GO TO 56
 55    JQ = JP + 1
       YER = ER
 56    CONTINUE
C
C  MAKE SURE THAT NONE OF THE Q SUBSCRIPTS ARE OUT OF RANGE
C
       IF(IQ.GT.INSUB) IQ = INSUB
       IF(IQ.LT.1) IQ = 1
       IF(JQ.GT.JNSUB) JQ = JNSUB
       IF(JQ.LT 1) JQ = 1
C
C  STORE THE BOUNDARY VALUE + 1 OF THE APPROPRIATE ADJACENT CELLS
C
       NBX = N(IQ, JP, KP) + 1
       NBY = N(IP, JQ, KP) + 1
C
C  TAKE APPROPRIATE ACTION DEPENDING ON ADJACENT BOUNDARY CELL
C
       GO TO ( 100,110,102,103,104) , NBX
C
C   IF N(IQ, JP, KP) = 102, IE., A COMPUTATIONAL CELL, GO TO 110
C
      IF(NBX.EQ.102) GO TO 110
 710  WRITE(NW,720) NBX
 720  FORMAT('0 ERROR ', 20('*'), ' NBX=', I5/)
      STOP
C
C  HERE IF N(IQ, JP, KP) = 0, IE , A LAND CELL
C
 100   X(M) = FLOAT(IP) * DX - DX2 + XER
       GO TO 110
C
C  HERE IF N(IQ, JP, KP) = 2, IE , AN OPEN BOUNDARY CELL
C
 102   X(M) = 0.
       GO TO 610
C
C   HERE IF A SURFACE CELL
C
 103   CONTINUE
       GO TO 110


C
C  HERE IF N(IQ, JP, KP) = 4, IE , A DEPOSITION OR AN EROSION CELL
C
 104   IF( (X(M).GE.DXU) .OR. (X(M).LE.DX2) ) GO TO 620
C
C  HERE FOR ALL OTHER CASES
C
 110   CONTINUE
C
C  ALL COMMENTS FOR TEST ON Y BELOW ARE THE SAME AS THOSE FOR X
C
       GO TO ( 200, 210, 202, 203, 204) , NBY
      IF(NBY.EQ.102) GO TO 210
      WRITE(NW,730) NBY
 730  FORMAT('0 ERROR ', 20('*'), ' NBY=', I5/)
      STOP
 200   Y(M) = FLOAT(JP) * DY - DY2 + YER
       GO TO 210
 202   Y(M) = 0
       GO TO 610
 203   CONTINUE
       GO TO 210
 204   IF( (Y(M).GE.DYU) .OR. (Y(M).LE.DY2) ) GO TO 620
 210   CONTINUE
C
C  HAS THE CELL CONTAINING THE MARKER BEEN TESTED YET
C
       NBC = N(IP, JP, KP) + 1
       IF( (NBX.EQ.NBC) .OR. (NBY.EQ.NBC) ) GO TO 10
C
C  IF NOT TEST IT
C
       NBX = NBC
       NBY = NBX
       GO TO ( 100,110,102,103,104) , NBX
      IF(NBX.EQ.102) GO TO 110
      GO TO 710
C
C  HERE IF NO ADJACENT BOUNDARY CELLS TO THE COMPUTATIONAL CELL
C
 10    CONTINUE
C
C  NOW TEST THE Z BOUNDARY CONDITIONS
C
       NBZ = N(IP, JP, KP) + 1
       ZP = PK - FLOAT(KP) + 0.5
C
C  CHECK THE UPPER Z BOUNDARY
C
       IF(KP.LT.KNSUB) GO TO 310
       IF(ZP.LT.0.) GO TO 310
C
C  ALL COMMENTS FOR TEST ON Z BELOW ARE THE SAME AS THOSE FOR X
C
       GO TO ( 310,310,302,303,304) , NBZ
      IF(NBZ.EQ.102) GO TO 310
 740  WRITE(NW,750) NBZ
 750  FORMAT('0 ERROR ', 20('*'), ' NBZ=', I5/)
      STOP
 302  Z(M) = 0.
```

Figure VII.-3. MAIN

```
      GO TO 610
 303   IF(Z(N).GE.DZD) Z(N) = DZD - EE
      GO TO 310
C
C   BE CAREFUL HERE! THE PARTICLE SHOULD BE DEPOSITED A FIXED
C   DISTANCE FROM THE BOTTOM OR THE SURFACE. THE ACTUAL DISTANCE,
C   HOWEVER, VARIES WITH THE TOTAL DEPTH IF Z HAS BEEN TRANSFORMED.
C
 304  IF(Z(N).GE.DZD) GO TO 620
 310  CONTINUE
C
C  CHECK THE LOWER Z BOUNDARY
C
      IF(KP.GT.1) GO TO 410
      IF(EP.GT.0.) GO TO 410
      EP = 1
      GO TO ( 410, 410, 402, 403, 404) , NBZ
     IF(NBZ.EQ 102) GO TO 410
     GO TO 740
 402  Z(N) = 0
      GO TO 610
 403  IF(Z(N).LE.DZ2) Z(N) =  DZ2 + EE
      GO TO 410
 404  IF(Z(N).LE.DZ2) GO TO 620
 410  CONTINUE
      GO TO 1
C
C   PARTICLE LOST THRU AN OPEN BOUNDARY
C
 610  NFILE = NOUT
      NLOST = NLOST + 1
      GO TO 630
C
C   PARTICLE DEPOSITED
C
 620  NFILE = NODP
      NDEP = NDEP + 1
C
C   OBTAIN X, Y AND Z IN THE FIXED SYSTEM FOR PRINTOUT
C
 630  CONTINUE
      XTEMP = X(N) + XORIG * XDS
      YTEMP = Y(N) + YORIG * YDS
      ZTEMP = Z(N)
C
C   UNTRANSFORM Z IF NECESSARY. DEPTH BELOW IS IN METERS
C
      IF(NTRANS.EQ.0) GO TO 640
      X1 = XTEMP / XDS
      Y1 = YTEMP / YDS
      ML = X1
      MU = ML + 1
      NL = Y1
      NU = NL + 1
      IF(ML.LT.1) ML = 1
      IF(NL.LT.1) NL = 1
      IF(MU.GT.MAXDX) MU = MAXDX
      IF(NU.GT.MAXDY) NU = MAXDY
      IF(MU.LT.1) MU = 1
      IF(ML.GT.MAXDX) ML = MAXDX

      IF(NU.LT 1) NU = 1
      IF(NL.GT MAXDY) NL = MAXDY
      H0 = DEPTH(ML, NL)
      H1 = H0 + (X1 - FLOAT(ML)) * (DEPTH(MU, NL) - H0)
      H2 = DEPTH(ML, NU)
      H3 = H2 + (X1 - FLOAT(ML)) * (DEPTH(MU, NU) - H2)
      DEP = H1 + (Y1 - FLOAT(NL)) * (H3 - H1)
      ZTEMP = (1.0 - ZTEMP) * DEP
 640  CONTINUE
      ZTEMP = ZTEMP + ZORIG
C
C   FIND THE PARTICLE CLASS.
C
      ICLASS = NORDR(N)
C
C   OUTPUT EITHER LOST PART (NFILE=NOUT) OR DEPOSITED PART (NFILE=NODP)
C
      WRITE (NFILE) NORDR(N), XTEMP, YTEMP, ZTEMP, DDIAM(ICLASS),
     1   DVELZ(ICLASS), DMASS(ICLASS), DDENS(ICLASS)
C
C   ADD THIS PARTICLE TO EITHER THE LOST OR THE DEPOSITED MASS
C
      II = NORDR(N)
      IF(NFILE.EQ.NOUT) XMLOS = XMLOS + DMASS(II)
      IF(NFILE.EQ.NODP) XMBOT = XMBOT + DMASS(II)
      XMSUS = XMSUS - DMASS(II)
C
C   NOW THE LOST OR DEPOSITED PARTICLE IS REMOVED FROM THE LIST
C   AND THE LIST IS DECREMENTED BY ONE PARTICLE. ALSO DECREMENT
C   THE CLASS COUNTER BY 1.
C
     NUMBD(II) = NUMBD(II) - 1
     X(N) = X(NMAX)
     Y(N) = Y(NMAX)
     Z(N) = Z(NMAX)
     NORDR(N) = NORDR(NMAX)
      NMAX = NMAX - 1
C
C   TRANSFER CONTROL TO BEGINNING OF LOOP BUT DO NOT INCREMENT N
C   THIS PART. HAS BEEN TRANS. FROM THE END OF THE LIST AND
C   THEREFOR NOT CHECKED YET
C
      N = N - 1
      GO TO 1
 3    CONTINUE
C
C                R E T U R N   H E R E
C
      RETURN
      END
     SUBROUTINE CNVRTZ( NCNTRL, X, Y, Z, HPLT, DPLT, NORDR)
C
C   SUBROUTINE DESCRIPTION
C
C   THIS SUBROUTINE CONVERTS THE PARTICLE POSITION IN Z TO OR
C   FROM THE TRANSFORMED COORDINATE SYSTEM
C
C.. ...........................................................
C
C                COMMON STATEMENTS
C
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1     NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
       COMMON /SUBS/ NTRANS, NSUB, NEXTA, NMAX, MMAX, DX, DY, DZ,
     1    XORIG, YORIG, ZORIG
C
C                DIMENSION STATEMENTS
C
      DIMENSION HPLT(15,15), DPLT(15,15)
      DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
      INTEGER*2 NORDR(NMAX)
C
C                DATA STATEMENTS
C
      DATA NFROM, NTO, NU/ -1,1,6/
C
C                S T A R T   H E R E
C
C   DETERMINE THE WATER DEPTH IN THE FLOATING SYSTEM.
C
      CALL VELC( DPLT, HPLT)
C
C   DO OVER PARTICLES.
C
      DO 100 N=1, NMAX
      WRITE(6,789) Z(N)
 789  FORMAT(1X,' FIRST ',F12.5)
C
C   IS THE PARTICLE IN THE COMPUTATIONAL RANGE?
C
      IF( (X(N).LE.0.) .OR. (Y(N).LE.0.) .OR. (Z(N).LE 0.)) GO TO 100
C
C   FIND THE LOWER LHC OF THE GRID SQUARE CONTAINING THIS PARTICLE.
C
      PI = X(N) / DX
      IP = PI + 1
      PJ = Y(N) / DY
      JP = PJ + 1
      PI = (PI - FLOAT(IFIX(PI))) / DX
      PJ = (PJ - FLOAT(IFIX(PJ))) / DY
C
C   CHECK LIMITS ON IP, IQ, JP AND JQ.
C
      IF(IP.GT.IMSUB) IP = IMSUB
      IF(IP.LT.1) IP = 1
      IF(JP.GT.JMSUB) JP = JMSUB
      IF(JP.LT.1) JP = 1
C
C   CHECK THE UPPER RHC OF THE SQ CONTAINING THIS PARTICLE.
C
      IQ = IP + 1
      JQ = JP + 1
      IF(IQ.GT.IMSUB) IQ = IMSUB
      IF(JQ.GT.JMSUB) JQ = JMSUB
C
C   CALCULATE THE DEPTH AT THE PARTICLE LOCATION
C
      Z1 = HPLT(IP, JP) + DPLT(IP, JP)
      Z2 = HPLT(IQ, JP) + DPLT(IQ, JP)
      Z3 = HPLT(IQ, JQ) + DPLT(IQ, JQ)

      Z4 = HPLT(IP, JQ) + DPLT(IP, JQ)
      Z12 = PI * (Z2 - Z1) + Z1
      Z43 = PI * (Z3 - Z4) + Z4
      Z1243 = PJ * ( Z43 - Z12) + Z12
      IF(Z1243.GT.0) GO TO 110
      Z(N) = 0.0
      GO TO 100
 110  CONTINUE
      IF(NCNTRL.EQ.NFROM) GO TO 130
      IF(NCNTRL.EQ.NTO) GO TO 120
      WRITE(NU,200) NCNTRL
 200  FORMAT(' NCNTRL ERROR IN CNVRT. NCNTRL=', A4, ' EXIT')
      STOP
 120  CONTINUE
      Z(N) = Z(N) / Z1243
      IF(Z(N).GT.1.) Z(N) = 1.
      GO TO 101
 130  CONTINUE
      Z(N) = Z(N) * Z1243
 101    CONTINUE
        WRITE(6,765) Z(N), Z1234
 765    FORMAT(2X,' SECOND ',2F12.3)
 100  CONTINUE
C
C                R E T U R N   H E R E
C
      RETURN
      END
       SUBROUTINE CONC( C, X, Y, Z, NORDR)
C
C                SUBROUTINE DESCRIPTION
C
C     IN THIS SUBROUTINE THE CONCENTRATION OF MARKER PARTICLES
C   IS CALCULATED IN EACH OF THE FLOATING GRID CELLS
C
C..............................................................
C
C                COMMON STATEMENTS
C
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1     NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
      COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1     DMASS(200), DVELZ(200), DCONF(200,8), NTCLAS, NUBIL
      COMMON /SUBS/ NTRANS, NSUB, NEXTA, NMAX, MMAX, DX, DY, DZ,
     1    XORIG, YORIG, ZORIG
      COMMON /DPTH/ MAXDX, MAXDY, ND, DEPTH(30,30), XDL, YDL,
     1     XDS, YDS
C
C                DIMENSION STATEMENTS
C
      DIMENSION C(15,15,10)
       DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
        INTEGER*2 NORDR(NMAX)
C
C                S T A R T   H E R E
C
C   INITIALIZE THE CONCENTRATION ARRAY
C
        DO 111 I=1, IMSUB
        DO 111 J=1, JMSUB
```

Figure VII. - 3. MAIN

```
      DO 111 K=1, KMSUB
 111  C(I, J, K)=0.0
C
C   DO LOOP OVER ALL MARKED PARTICLES
C
      DO 100 N=1, NMAX
      IF(X(N).LE.0..OR.Y(N).LE.0..OR.Z(N).LE.0.) GO TO 100
      DXT = DX
      DYT = DY
      IF(ISCAL.EQ.1) GO TO 75
      SCAL = (6371.0*1000.0*3.14159)/180.0
      YPAR = YDS*YORIG+Y(N) + (YDL-YDS)
      DYT = DYT * SCAL
      DXT = DXT*(SCAL*COS(YPAR/57.296))
 75   CONTINUE
C
C   OBTAIN THE VOLUME OF A GRID ELEMENT
C
     DSQ = DXT*DYT*DZ
C
C   OBTAIN THE MASS DENSITY PER UNIT VOLUME. XMD IS IN
C   METRIC TONS PER CUBIC METER OR MILLIGRAMS PER MILLILITER.
C
     II = NORDF(N)
     XMD = DMASS(II) / DSQ
C
C   OBTAIN THE SUBSCRIPTS FOR THE GRID ELEMENT FOR THIS PARTICLE
C
     PI = X(N) / DX
     IP = PI + 1
     PJ = Y(N) / DY
     JP = PJ + 1
     PK = Z(N) / DZ
     KP = PK + 1
C
C   OBTAIN THE XYZ POSITION OF THE MARKED RELATIVE TO CELL CENTER
C
     XP = PI - FLOAT(IP) + 0.5
     YP = PJ - FLOAT(JP) + 0.5
     ZP = PK - FLOAT(KP) + 0.5
C
C   OBTAIN THE SUBSCRIPTS OF THOSE ELEMENTS AFFECTED BY THIS MARKER
C   AXP, AYP AND AZP ARE THE ABSOLUTE VALUES OF XP, YP AND ZP
C
     IF(XP) 1, 2, 2
 1   IQ = IP - 1
     AXP = -XP
     GO TO 3
 2   IQ = IP + 1
     AXP = XP
 3   CONTINUE
     IF(YP) 4, 5, 5
 4   JQ = JP - 1
     AYP = -YP
     GO TO 6
 5   JQ = JP + 1
     AYP = YP
 6   CONTINUE
     IF(ZP) 7,8,8
 7   KQ = KP - 1


     AZP = -ZP
     GO TO 9
 8   KQ = KP + 1
     AZP = ZP
 9   CONTINUE
C
C   CALCULATE THE ABSOLUTE DISTANCE OFFCENTER FOR  THIS MARKER
C
     XQ = 1.0 - AXP
     YQ = 1.0 - AYP
     ZQ = 1.0 - AZP
C
C   MULTIPLY AXP AND XQ BY XMD TO SAVE MULTIPLICATIONS LATER
C
     AXP = XMD * AXP
     XQ = XMD * XQ
C
C   MARK ALL SUBSCRIPTS WHICH ARE OUT OF RANGE
C
     L1 = 0
     L2 = 0
     L3 = 0
     L4 = 0
     L5 = 0
     L6 = 0
     IF( (IP.GT.IMSUB) .OR.  (IP.LT.1) ) L1 = 1
     IF( (IQ.GT.IMSUB) .OR.  (IQ.LT.1) ) L2 = 1
     IF( (JP.GT.JMSUB) .OR.  (JP.LT.1) ) L3 = 1
     IF( (JQ.GT.JMSUB) .OR.  (JQ.LT.1) ) L4 = 1
     IF( (KP.GT.KMSUB) .OR.  (KP.LT.1) ) L5 = 1
     IF( (KQ.GT.KMSUB) .OR.  (KQ.LT.1) ) L6 = 1
C
C   ADD CONCENTRATION DUE TO THIS MARKER
C
     IF((L1.EQ.1) .OR. (L3.EQ.1) .OR. (L5.EQ.1)) GO TO 10
     C(IP, JP, KP) = C(IP, JP, KP) + XQ * YQ * ZQ
 10  IF((L2.EQ.1) .OR. (L3.EQ.1) .OR. (L5.EQ.1)) GO TO 11
     C(IQ, JP, KP) = C(IQ, JP, KP) + AXP * YQ * ZQ
 11  IF((L1.EQ.1) .OR. (L4.EQ.1) .OR. (L5.EQ.1)) GO TO 12
     C(IP, JQ, KP) = C(IP, JQ, KP) + XQ * AYP * ZQ
 12  IF((L1.EQ.1) .OR. (L3.EQ.1) .OR. (L6.EQ.1)) GO TO 13
     C(IP, JP, KQ) = C(IP, JP, KQ) + XQ * YQ * AZP
 13  IF((L2.EQ.1) .OR. (L4.EQ.1) .OR. (L5.EQ.1)) GO TO 14
     C(IQ, JQ, KP) = C(IQ, JQ, KP) + AXP * AYP * ZQ
 14  IF((L2.EQ.1) .OR. (L3.EQ.1) .OR. (L6.EQ.1)) GO TO 15
     C(IQ, JP, KQ) = C(IQ, JP, KQ) + AXP * YQ * AZP
 15  IF((L1.EQ.1) .OR. (L4.EQ.1) .OR. (L6.EQ.1)) GO TO 16
     C(IP, JQ, KQ) = C(IP, JQ, KQ) + XQ * AYP * AZP
 16  IF((L2.EQ.1) .OR. (L4.EQ.1) .OR. (L6.EQ.1)) GO TO 17
     C(IQ, JQ, KQ) = C(IQ, JQ, KQ) + AXP * AYP * AZP
 17  CONTINUE
 100  CONTINUE
C
C              R E T U R N   H E R E
C
      RETURN
      END
      SUBROUTINE COURAN
C
C              SUBROUTINE DESCRIPTION
```

```
C
C     THIS SUBROUTINE CALCULATES THE COURANT NUMBER AND PRINTS IT
C   OUT. IF THE COURANT CONDITION IS VIOLATED A MESSAGE IS PRINTED
C   AND THE PROGRAM CONTINUES OPERATION
C
C.. ............................................................
C
C              COMMON STATEMENTS
C
     COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPSTA,
    1     NPSTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
     COMMON /DIFO/ MCRIT, MDIFF, DXX, DYY, DZZ, EXX, EYY,
    1     POWX, POWY
     COMMON /MAXVEL/ UAMAX, VAMAX, WAMAX, UDMAX, VDMAX, WDMAX
     COMMON /SUBS/ NTRANS, NSUB, NRITE, MMAX, NMAX, DX, DY, DZ,
    1    XORIG, YORIG, ZORIG
C
C              DIMENSION STATEMENTS
C
C
C              DATA STATEMENTS
C
      DATA CAU, CAV, CAW, CDU, CDV, CDW/6*0.0/
      DATA COND, NW/ 1.0, 6/
C
C              S T A R T   H E R E
C
C   CALCULATE AND PRINT THE COURANT # FOR X, Y AND Z ADVECTIVE AND
C   DIFFUSIVE VELOCITIES.
C
     UDMAX = UDMAX * DT
     VDMAX = VDMAX * DT
     WDMAX = WDMAX * DT
     UAMAX = UAMAX * DT
     VAMAX = VAMAX * DT
     WAMAX = WAMAX * DT
C
C   OBTAIN THE MAXIMUM COURANT NUMBER FOR THIS RUN.
C
     IF(UAMAX GT.CAU) CAU = UAMAX
     IF(VAMAX.GT.CAV) CAV = VAMAX
     IF(WAMAX.GT.CAW) CAW = WAMAX
     CDU = 0.0
     CDV = 0.0
     CDW = 0.0
     IF(NMAX.LT.MCRIT) GO TO 20
     IF(UDMAX.GT.CDU) CDU = UDMAX
     IF(VDMAX.GT.CDV) CDV = VDMAX
     IF(WDMAX.GT.CDW) CDW = WDMAX
 20  CONTINUE
C
C   IF THE COURANT CONDITION IS VIOLATED PRINT OUT HERE.
C
     IF(UAMAX.GT.COND) GO TO 10
     IF(VAMAX.GT.COND) GO TO 10
     IF(WAMAX.GT.COND) GO TO 10
     IF(UDMAX.GT.COND) GO TO 10
     IF(VDMAX.GT.COND) GO TO 10
     IF(WDMAX.GT.COND) GO TO 10
     RETURN


 10  CONTINUE
     WRITE(NW,110)
 110 FORMAT('0',100('*')//'  THE COURANT CONDITION HAS BEEN',
    1   ' VIOLATED. THIS RUN SHALL CONTINUE BUT CAUTION SHOULD',
    2   ' BE TAKEN.')
     WRITE(NW,100) UAMAX, VAMAX, WAMAX, UDMAX, VDMAX, WDMAX
 100 FORMAT(/' ADVECTIVE   X', F15.6, '  Y', F15.6, '  Z', F15.6/
    2  ' DIFFUSIVE   X', F15.6, '  Y', F15.6, '  Z', F15.6)
     WRITE(NW,120)
 120 FORMAT(//' ',100('*'))
C
C              E N D   H E R E
C
     RETURN
     END
      SUBROUTINE DIFF( X, Y, Z)
C
C              SUBROUTINE DESCRIPTION
C
C     THIS SUBROUTINE WILL CALCULATE THE DIFFUSION COEFFICIENT IF
C   THE SCALE DEPENDENT DIFFUSION MODE HAS BEEN SELECTED.
C
C.  ............................ ............................ ....
C
C              COMMON STATEMENTS
C
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPSTA,
    1     NPSTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
     COMMON /DIFO/ MCRIT, MDIFF, DXX, DYY, DZZ, EXX, EYY,
    1     POWX, POWY
     COMMON /PRNT/ NPRTY, NPRTC, NPRTP, NPRD, NPRV, NPRC, NPRP,
    1     NPTSUB, NPRSUB
     COMMON /SUBS/ NTRANS, NSUB, NRITE, MMAX, NMAX, DX, DY, DZ,
    1     XORIG, YORIG, ZORIG
     COMMON /DPTH/ MAXDX, MAXDY, ND, DEPTH(30,30), XDL, YDL,
    1     XDS, YDS
C
C              DIMENSION STATEMENTS
C
     DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
     DATA NW, PI / 6, 3.14159/
      SCAL = 6371.0*1000.0*PI/180.0
C
C              S T A R T   H E R E
C
      CALL AVGSIG( X, Y, Z, XAVG, YAVG, ZAVG,
    1               SIGX, SIGY, SIGZ,1)
      RX=SIGX/DX
      RY=SIGY/DY
      EXXT = EXX
      EYYT = EYY
      IF(ISCAL.EQ.1) GO TO 10
      SCAL = 6371.0*1000.0*3.14159/180.0
      YCEN = ((YORIG*YDS)+DY*(FLOAT(JMSUB)/2.0))
      YCEN = YCEN +YDL
      EYYT = EYY/(SCAL**.66667)
      EXXT = EXX/((SCAL*COS(YCEN/57.296)))**0.666667
 10   CONTINUE
C
C     CALCULATE SCALE DEPENDENT DIFFUSION COEFFICIENTS
```

Figure VII.-3. MAIN

```
C
        SL=3.*SQRT(2.*SIGX*SIGY)
        DXX=EXXX*(SL**POWX)
        DYY=EYYY*(SL**POWY)
C
C   RETURN IF NO PRINTOUT IS DESIRED.
C
      IF(NPRSUB.EQ.0) RETURN
        WRITE(NW, 50) DXX, DYY
 50     FORMAT(10X, 'HORIZONTAL X-Y SCALE DEPENDENT DIFFUSION COEFF.=',
     1  2(2X, G13.4))
C
        WRITE(NW,16) XAVG, YAVG, ZAVG, SIGX, SIGY
 16     FORMAT(5X,'XAVG=',G10.3,5X,'YAVG=',G10.3,5X,'ZAVG=',G10.3,
     .  5X, 'SIGX=', G10.3, 'SIGY=', G10.3)
        IF( (AX.LE.1.0) .OR. (AY.LE.1.0) ) RETURN
        RETURN
        END
        SUBROUTINE DISPY( N, X, Y, Z, DPLT, NPLT, NORDR)
C
C                 SUBROUTINE DESCRIPTION
C
C     IN THIS SUBROUTINE THE DISPLACEMENT OF EACH OF THE MARKER
C   PARICLES DURING THIS TIME STEP IS CALCULATED.
C
C.. ...........................................................
C
C                 COMMON STATEMENTS
C
      COMMON /DIFU/ NCRIT, NDIFF, DXX, DYY, DZZ, EXX, EYY,
     1      POWX, POWY
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1      NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
      COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1      DMASS(200), DVELZ(200), DCOMP(200,8), NICLAS, NUMIL
      COMMON /SUBS/ NTRANS, NSUB, NEXTR, NMAX, MMAX, DX, DY, DZ,
     1    XORIG, YORIG, ZORIG
C
C                 DIMENSION STATEMENTS
C
        DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
        DIMENSION DPLT(15,15), NPLT(15,15)
        INTEGER N(15,15,10)
        INTEGER*2 NORDR(NMAX)
C
C                 S T A R T   H E R E
C
C    LOCATE PARTICLE GRID COORDINATES
C
       IX=1
       XDN=0.0
       YDN=0.0
       ZDN=C.0
C
C   CALCULATE AVERAGE PARTICLE POSITION FOR ANALYTICAL DIFFUSION
C
       IF(NSUB.EQ.1)
     1    CALL AVGSIG( X, Y, Z, XAV, YAV, ZAV,
     2          SIGX, SIGY, SIGZ, 0)
       SIGX = 1.0


       SIGY = 1.0
       SIGZ = 1.0
       DO 1 N=1, NMAX
       IF(X(N).LE.0..OR.Y(N).LE 0..OR.Z(N).LE.0.) GO TO 1
       XN=X(N)
       YN=Y(N)
       ZN=Z(N)
       CALL PARTV(UP, VP, WP, XN, YN, ZN, N, X, Y, Z, I, J, K)
C
C   OBTAIN THE SUBSCRIPT FOR THIS PARTICLE CLASS
C
       II = NORDR(N)
       WSS = DVELZ(II)
C
C   CALCULATE THE SETTLING VELOCITY FOR THIS PARTICLE
C
       WP = WP + WSS
       IF(NSUB.EQ.0) GO TO 22
C
C   CALCULATE SUB GRID DIFFUSION DISTANCE IN X, Y, Z DIRECTIONS
C
       XDN=(X(N)-XAV)*(1.+((1.+(DT/((SIGX**2)/(2.*DXX)))
     . **0.5)-1.)))
       YDN=(Y(N)-YAV)*(1.+((1.+(DT/((SIGY**2)/(2 *DYY)))
     . **0.5)-1.)))
       ZDN=(Z(N)-ZAV)*(1.+((1.+(DT/((SIGZ**2)/(2.*DZZ)))
     . **0.5)-1.)))
C
C   CALCULATE THE NEW PARTICLE POSITIONS.
C
 22    XN=X(N)+UP*DT+XDN
       YN=Y(N)+VP*DT+YDN
       ZN=Z(N)+WP*DT+ZDN
       X(N)=XN
       Y(N)=YN
       Z(N)=ZN
 1     CONTINUE
C
C                 R E T U R N   H E R E
C
       RETURN
       END
       SUBROUTINE GRIDEX( X, Y, Z, NST)
C
C                 SUBROUTINE DESCRIPTION
C
C     IN THIS SUBROUTINE THE FLOATING GRID IS EXPANDED AND
C   TRANSLATED TO INCORPORATE ALL OF THE MARKER PARTICLES. THE GRID
C   IS MADE SUFFICIENTLY LARGE THERE IS A ONE EMPTY GRID ELEMENT
C   BAND ON ALL EDGES.
C
C.............................................................
C
C                 COMMON STATEMENTS
C
      COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30,30), XDL, YDL,
     1      XDS, YDS
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1      NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(200)
      COMMON /PART/ NPRTY, NPRTC, NPRTP, NPXD, NPRY, NPRC, NPRP,
```

```
     1   NPTSUB, NPRSUB
      COMMON /SUBS/ NTRANS, NSUB, NEXTR, NMAX, MMAX, DX, DY, DZ,
     1   XORIG, YORIG, ZORIG
      COMMON /UNIT/ UNITS3(2)
C
C                 DIMENSION STATEMENTS
C
       DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
C
C
C                 DATA STATEMENTS
C
       DATA NW / 6/
C                 S T A R T   H E R E
C
C    INITIALIZE MIN AND MAX STORAGE LOCATIONS
C
       XMIN = X(NMAX)
       XMAX = X(NMAX)
       YMIN = Y(NMAX)
       YMAX = Y(NMAX)
C
C    FIND MIN AND MAX VALUES OF X(N) AND Y(N) WITH RESPECT TO THE DEPTH G
C
       DO 1 N=1, NMAX
       XN = X(N)
       YN = Y(N)
       IF((XN.EQ.0.0) .OR. (YN.EQ.0.0)) GO TO 1
       IF(XN.GT XMAX) XMAX = XN
       IF(XN.LT.XMIN) XMIN = XN
       IF(YN.GT.YMAX) YMAX = YN
       IF(YN.LT.YMIN) YMIN = YN
       CONTINUE
       XMAX= XMAX+XORIG*XDS
       XMIN= XMIN+XORIG*XDS
       YMAX= YMAX+YORIG*YDS
       YMIN= YMIN+YORIG*YDS
C
C     KEEP THE FLOATING GRID INSIDE OF THE FIXED GRID
C
        XFMIN = XDS*2.0
        XFMAX = ((MAXDX-1)*XDS)-XDS*2.0
        YFMIN = YDS*2.0
        YFMAX = ((MAXDY-1)*YDS)-YDS*2.0
        IF(XMIN LT.XFMIN) XMIN=XFMIN
        IF(XMAX.GT.XFMAX) XMAX=XFMAX
        IF(YMAX.GT.YFMAX) YMAX=YFMAX
        IF(YMIN.LT.YFMIN) YMIN=YFMIN
C
C    EXPAND AND MOVE GRID IN X DIRECTION
C
       DX = (XMAX-XMIN)/FLOAT(IMSUB-3)
C
C    EXPAND AND MOVE GRID IN Y DIRECTION
C
       DY = (YMAX-YMIN)/FLOAT(JMSUB-3)
C
C    MOVE THE ORIGIN OF THE FLOATING GRID AND PRINTOUT
C
       XORIGN=(XMIN-(1.5*DX))/XDS



        YORIGN=(YMIN-(1.5*DY))/YDS
        XORIGT=XORIGN*XDS
        YORIGT=YORIGN*YDS
        IF(NPRSUB.EQ.0) GO TO 80
       WRITE(NW,120)
 120   FORMAT(//T34, 'FLOATING GRID DEFINITION AND PARTICLE LOCATION',
     1  ' STATISTICS'/'+', T34, 57('_')/)
       WRITE(NW,100) XORIGT, YORIGT, UNITS3, DX, UNITS3, DY, UNITS3, XDS,
     1   UNITS3, YDS, UNITS3
 100   FORMAT(' ORIGIN OF FLOATING GRID IS AT (', F11.4, ', ',
     1 F11.4, ') IN  ', 2A4, ' WITH RESPECT TO THE ORIGIN',
     2 ' OF THE FIXED DEPTH GRID'/' THE NEW GRID SEPERATION IN',
     3 ' THE FLOATING SYSTEM IS ', F15.7, 1X,2A4, ' IN X AND ', F15.7,
     4 1X,2A4, ' IN Y'/
     5 ' THE GRID SEPERATION IN THE FIXED SYSTEM IS ', F10.3,
     6 1X, 2A4, ' IN X AND', F10 3, 1X, 2A4, ' IN Y'/)
 80    CONTINUE
C
C  DETERMINE THE CHANGE IN POSITION OF THE NEW ORIGIN
C
       XSEP = (XORIG - XORIGN) * XDS
       YSEP = (YORIG - YORIGN) * YDS
C
C  REDEFINE THE ORIGIN
C
       XORIG = XORIGN
       YORIG = YORIGN
C   MOVE THE PARTICLES WITH RESPECT TO NEW ORIGIN
C    AND  CALCULATE AVERAGES AND STANDARD DEVIATIONS.
C
       XSUM = 0.
       YSUM = 0.
       ZSUM = 0.
       SIGX=C.0
       SIGY=0.0
       SIGZ=0.0
       DO 2 N=1, NMAX
       IF((X(N).EQ.0.) .OR. (Y(N).EQ.0.)) GO TO 2
      X(N) = X(N) + XSEP
      Y(N) = Y(N) + YSEP
       XSUM = XSUM + X(N)
       YSUM = YSUM + Y(N)
       ZSUM = ZSUM + Z(N)
       SIGX = SIGX + X(N)*X(N)
       SIGY = SIGY + Y(N)*Y(N)
       SIGZ = SIGZ + Z(N)*Z(N)
 2     CONTINUE
      IF(NPRSUB.EQ.0) GO TO 81
      XNUM = FLOAT(NMAX)
      SIGX=(SIGX-XSUM*XSUM/XNUM)/(XNUM-1)
      SIGY=(SIGY-YSUM*YSUM/XNUM)/(XNUM-1)
      SIGZ=(SIGZ-ZSUM*ZSUM/XNUM)/(XNUM-1)
      SIGX=SQRT(ABS(SIGX))
      SIGY=SQRT(ABS(SIGY))
      SIGZ=SQRT(ABS(SIGZ))
C
C   OBTAIN AND PRINT THE MEAN VALUE AND STANDARD DEVIATION OF X, OF Y AN. OF
C
       XMEAN = XSUM / FLOAT(NMAX)
       YMEAN = YSUM / FLOAT(NMAX)
```

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```
      ZMEAN = ZSUM / FLOAT(NMAX)
      WRITE(NW,200) XMEAN, YMEAN, ZMEAN
      WRITE(NW,201) SIGX, SIGY, SIGZ
 200  FORMAT(' THE AVERAGE VALUES OF X, Y AND Z ARE',3F18.6)
 201  FORMAT(' THE STANDARD DEVIATIONS ARE    ',3X,3F16.6)
 81   CONTINUE
C
C               R E T U R N   H E R E
C
      IF( (DX.GT.0.0) .AND. (DY.GT.0.0) ) RETURN
C
C   HERE FOR AN ERROR IN THE CALCULATION OF DX OR OF DY.
C
      WRITE(NW,110) DX, DY
 110  FORMAT('0 ERROR ', 50('*')/'  DX=', E16.5, '  DY=', E16.5)
C
C               S T O P   H E R E
C
      STOP
      END
      SUBROUTINE PARTV(UPP, VPP, WPP, XNP, YNP, ZNP, N,
     1 X, Y, Z, IP, JP, KP)
C
C               SUBROUTINE DESCRIPTION
C
C     THIS SUBROUTINE IS USED TO CALCULATE THE FLUID VELOCITY
C   AT THE POSITION OF EACH OF THE MARKER PARTICLES. A LINEAR
C   INTERPOLATION SCHEME IS USED FROM THE SURROUNDING VELOCITY NODES.
C
C.................................................................
C
C               COMMON STATEMENTS
C
      COMMON /PLOT/ NAXPX, NAXPY, NAXPZ, AP, UPLT(15,15,10),
     1     VPLT(15,15,10), WPLT(15,15,10), XPL, YPL, ZPL, XPS, YPS, ZPS
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPRTA,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(200)
      COMMON /SUBS/ NTRANS, NSUB, NEXTN, NMAX, MMAX, DX, DY, DZ,
     1     XORIG, YORIG, ZORIG
C
C               DIMENSION STATEMENTS
C
      DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
      INTEGER N(15,15,10)
C
C               S T A R T   H E R E
C
C   OBTAIN THE SUBSCRIPTS FOR THE GRID ELEMENT FOR THIS PARTICLE
C
      PI = XNP / DX
      IP = PI + 1
      PJ = YNP / DY
      JP = PJ + 1
      PK = ZNP / DZ
      KP = PK + 1
C
C   OBTAIN THE XYZ POSITION OF THE MARKER RELATIVE TO CELL CENTER
C
      XP = PI - FLOAT(IP) + 0.5
      YP = PJ - FLOAT(JP) + 0.5

      ZP = PK - FLOAT(KP) + 0.5
C
C   OBTAIN THE XYZ POSITION OF THE PARTICLE RELATIVE TO CELL CORNER
C
      XQ = 0.5 + XP
      YQ = 0.5 + YP
      ZQ = 0.5 + ZP
C
C   MAKE SURE THAT NONE OF THE P SUBSCRIPTS ARE OUT OF RANGE
C
      IF(IP.GT.INSUB) IP=INSUB
      IF(IP.LT.1) IP=1
      IF(JP.GT.JNSUB) JP=JNSUB
      IF(JP.LT.1) JP=1
      IF(KP.GT.KNSUB) KP=KNSUB
      IF(KP.LT.1) KP=1
      IF(N(IP, JP, KP).NE.0) GO TO 16
      UPP=UPLT(IP, JP, KP)
      VPP= VPLT(IP, JP, KP)
      WPP=WPLT(IP, JP, KP)
      RETURN
 16   CONTINUE
C
C   OBTAIN SUBSCRIPTS OF CONTRIBUTING ELEMENTS TO THE VELOCITY AVG
C
      IF(XP) 1, 2, 2
 1    IQ = IP - 1
      AXP = -XP
      GO TO 3
 2    IQ = IP + 1
      AXP = XP
 3    IF(YP) 4, 5, 5
 4    JQ = JP - 1
      AYP = -YP
      GO TO 6
 5    JQ = JP + 1
      AYP = YP
 6    IF(ZP) 7, 8, 8
 7    KQ = KP - 1
      AZP = -ZP
      GO TO 9
 8    KQ = KP + 1
      AZP = ZP
 9    CONTINUE
C
C   MAKE SURE THAT NONE OF THE Q SUBSCRIPTS ARE OUT OF RANGE
C
      IF(IQ.GT.INSUB) IQ=INSUB
      IF(IQ.LT.1) IQ=1
      IF(JQ.GT.JNSUB) JQ=JNSUB
      IF(JQ.LT.1) JQ=1
      IF(KQ.GT.KNSUB) KQ=KNSUB
      IF(KQ.LT.1) KQ=1
C
C   CALCULATE THE U VELOCITY COMPONENT
C
      IN = IP - 1
      IF(IN.LE.0) IN = 1
      U1 = UPLT(IN, JP, KP)
      U1 = XQ * ( UPLT(IP, JP, KP) - U1 ) + U1
      U2 = UPLT(IN, JP, KQ)
      U2 = XQ * ( UPLT(IP, JP, KQ) - U2 ) + U2
      U3 = UPLT(IN, JQ, KP)
      U3 = XQ * ( UPLT(IP, JQ, KP) - U3 ) + U3
      U4 = UPLT(IN, JQ, KQ)
      U4 = XQ * ( UPLT(IP, JQ, KQ) - U4 ) + U4
      U31 = AYP * ( U3 - U1 ) + U1
      U42 = AYP * ( U4 - U2 ) + U2
      UPP = AZP * ( U42 - U31 ) + U31
C
C   CALCULATE THE V VELOCITY COMPONENT
C
      JN = JP - 1
      IF(JN.LE.0) JN = 1
      V1 = VPLT(IP, JN, KP)
      V1 = YQ * ( VPLT(IP, JP, KP) - V1 ) + V1
      V2 = VPLT(IP, JN, KQ)
      V2 = YQ * ( VPLT(IP, JP, KQ) - V2 ) + V2
      V3 = VPLT(IQ, JN, KP)
      V3 = YQ * ( VPLT(IQ, JP, KP) - V3 ) + V3
      V4 = VPLT(IQ, JN, KQ)
      V4 = YQ * ( VPLT(IQ, JP, KQ) - V4 ) + V4
      V31 = AXP * ( V3 - V1 ) + V1
      V42 = AXP * ( V4 - V2 ) + V2
      VPP = AZP * (  V42 - V31 ) + V31
C
C   CALCULATE THE Z VELOCITY COMPONENT
C
      KN = KP - 1
      IF(KN.LE.0) KN = 1
C
C   BE CAREFUL HERE! THE ADVECTIVE VELOCITY IN THE Z DIRECTION
C   IN THE BOTTOM ELEMENT OF THE WATER COLUMN IS CALCULATED USING
C   ONLY THE PLANE ABOVE THE ELEMENT AND NOT BY AVERAGING THE
C   PLANE ABOVE AND THE PLANE BELOW AS IN ALL OTHER CASES
C
      W1 = WPLT(IP, JP, KN)
      W1 = ZQ * ( WPLT(IP, JP, KP) - W1 ) + W1
      W2 = WPLT(IP, JQ, KN)
      W2 = ZQ * ( WPLT(IP, JQ, KP) - W2 ) + W2
      W3 = WPLT(IQ, JP, KN)
      W3 = ZQ * ( WPLT(IQ, JP, KP) - W3 ) + W3
      W4 = WPLT(IQ, JQ, KN)
      W4 = ZQ * ( WPLT(IQ, JQ, KP) - W4 ) + W4
      W31 = AXP * ( W3 - W1 ) + W1
      W42 = AXP * ( W4 - W2 ) + W2
      WPP = AYP * ( W42 - W31 ) + W31
C
C               R E T U R N   H E R E
C
      RETURN
      END
      SUBROUTINE PRINT(C, N, X, Y, Z, NODES, NST, DPLT, WPLT, CC)
C
C               SUBROUTINE DESCRIPTION
C
C     THIS SUBROUTINE HANDLES ALMOST ALL OUTPUT OPERATIONS.
C
C.................................................................
C


C               COMMON STATEMENTS
C
      COMMON /DEPOS/ NLOST, NDEP
      COMMON /DIFD/ NCRIT, NDIFF, DXX, DYY, DZZ, EXX, EYY,
     1     POWX, POWY
      COMMON /DPTH/ NAXDX, NAXDY, AD, DEPTH(30,30), XDL, YDL,
     1     XDS, YDS
      COMMON /ELVN/ NAXEX, NAXEY, AE, HGHT(30,30), XEL, YEL,
     1     XES, YES
      COMMON /PLOT/ NAXPX, NAXPY, NAXPZ, AP, UPLT(15,15,10),
     1     VPLT(15,15,10), WPLT(15,15,10), XPL, YPL, ZPL, XPS, YPS, ZPS
      COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPRTA,
     1     NPRTC, DT,  TIME, TIMMAX, ISCAL, NSAV(200)
      COMMON /OUTP/ NOSP, NOBS, NOCN, NOPX, NOMS, NOLT,
     1     NODP, NOVL
      COMMON /PRNT/ KPRTV, KPRTC, KPRTP, NPRD, NPRV, NPRC, NPRF,
     1     NPTSUB, KPRSUB
      COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1     DMASS(200), DVELS(200), DCOMP(200, 8), NTCLAS, NDECL
      COMMON /SUBS/ NTRANS, NSUB, NEXTN, NMAX, MMAX, DX, DY, DZ,
     1     XORIG, YORIG, ZORIG
      COMMON /TIDE/ NAXTX, NAXTY, AT, UT(30,30), VT(30,30), XTLU, YTLU,
     1     XTS, YTS, XTLV, YTLV
      COMMON /UNIT/ UNITS3(2)
C
C               DIMENSION STATEMENTS
C
      DIMENSION C(15,15,10)
      DIMENSION DPLT(15,15), WPLT(15,15), CC(15,15)
      DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
      DIMENSION NJO(30), NIO(30)
      DIMENSION VPTT(15,15,10),UPTT(15,15,10)
      INTEGER N(15,15,10)
      INTEGER*2 NODES(NMAX)
C
C
C               DATA STATEMENTS
C
      DATA NW / 6/
C               S T A R T   H E R E
C
C   INITIALIZE CALL FLAG SO AS NOT TO CALL CONC TWICE HERE.
C
      NCALL1 = 0
C
C  FIX FORMAT STATEMENTS
C
C
C
C   FIND DISTANCE FROM ORIGIN OF FIXED SYSTEM TO GRID LOCATIONS
C
      XL1 = XORIG + XDS -0.5*DX
      YL1 = YORIG + YDS -0.5*DY
      DO 150 I=1, INSUB
      XL1 = XL1 + DX
 150  NIO(I) = XL1
      DO 160 J=1, JNSUB
      YL1 = YL1 + DY
 160  NJO(J) = YL1
C
C
```

Figure VII.-3. MAIN

```
C        PRINT U, V, W VELOCITY FIELDS AT EACH Z LEVEL
C
         IF(KPRTV.EQ.0)  GO TO 24
        TST = AMOD(FLOAT(NST), FLOAT(KPRTV))
        IF(TST.NE.0.0) GO TO 24
        WRITE(NW,100)
 100    FORMAT('1')
          DO 800 I=1,IMSUB
          DO 800 J=1,JMSUB
          DO 800 K=1,KMSUB
          UPTT(I,J,K)=UPLT(I,J,K)
 800      VPTT(I,J,K)=VPLT(I,J,K)
          IF(ISCAL.EQ.1) GO TO 801
          WRITE(NW,902)
 902      FORMAT(1X,' ALL HORIZONTAL VELOCITIES ARE MULTIPLIED BY 10**6')
C
        DO 802 I=1,IMSUB
        DO 802 J=1,JMSUB
        DO 802 K=1,KMSUB
        UPTT(I,J,K)=UPTT(I,J,K)*(10**6)
 802    VPTT(I,J,K)=VPTT(I,J,K)*(10**6)
 801     CONTINUE
         DO 7 K=1, KMSUB
         WRITE(NW, 2)NST, TIME, K
2        FORMAT(1H0,10X, 'U VELOCITY FIELD', 5X, 'STEP NUMBER', I4, 5X,
     1   'TIME ', F12.2, 2X, 'LEVEL', I4)
         WRITE(NW, 4)(YJO(J), J=1, JMSUB)
 4      FORMAT(8X,15F8.2)
         DO 5 I=1, IMSUB
5        WRITE(NW, 6) XIO(I), (UPTT(I, J, K), J=1, JMSUB)
 6      FORMAT(1X, F6.1, 2X,15(1X,F7.3))
7        CONTINUE
         DO 8 K=1, KMSUB
         WRITE(NW, 9)NST, TIME, K
9        FORMAT(1H0,10X, 'V VELOCITY FIELD', 5X, 'STEP NUMBER', I4, 5X,
     1   'TIME ', F12.2, 2X, 'LEVEL', I4)
         WRITE(NW, 4)(YJO(J), J=1, JMSUB)
         DO 11 I=1, IMSUB
11       WRITE(NW, 6) XIO(I), (VPTT(I, J, K), J=1, JMSUB)
8        CONTINUE
         DO 12 K=1, KMSUB
         WRITE(NW,13)NST, TIME, K
13       FORMAT(1H0,10X, 'W VELOCITY FIELD', 5X, 'STEP NUMBER', I4, 5X,
     1   'TIME', F12.2, 2X, 'LEVEL', I4)
         WRITE(NW, 4)(YJO(J), J=1, JMSUB)
         DO 15 I=1, IMSUB
15       WRITE(NW, 6) XIO(I), (WPLT(I, J, K), J=1, JMSUB)
12       CONTINUE
 24      CONTINUE
C
C        PRINT 3-D CONCENTRATION FIELD AT EACH Z-LEVEL
C   NOTE: C IS IN METRIC TONS OF OIL PER CUBIC METER OF WATER,
C          BELOW CC IS PRINTED OUT AS MG OIL PER ML WATER[illegible]
C          THE FACTOR OF 1000 WHEN GOING FROM C TO CC.
C
        IF(KPRTC.EQ.0)  GO TO 16
        TST = AMOD( FLOAT(NST), FLOAT(KPRTC))
        IF(TST.NE.0.0) GO TO 16
        IF(NMAX.GE.NCRIT) GO TO 722
        CALL GRIDER( X, Y, Z, NST)


        CALL BOUNY( N, X, Y, Z, NORDR)
        CALL CONC( C, X, Y, Z, NORDR)
        NCALL1 = 1
 722    CONTINUE
        WRITE(NW,100)
         DO 19 K=1, KMSUB
         WRITE(NW,17)NST, TIME, K
17       FORMAT(1H0,10X, 'CONCENTRATION IN MG OF OIL PER ML OF WATER',
     1    5X, 'STEP NUMBER', I4, 5X, 'TIME', F12.2, 2X, 'LEVEL', I4/)
         WRITE(NW, 4)(YJO(J), J=1, JMSUB)
         DO 19 I=1, IMSUB
         IF(NTRANS.NE.0) GO TO 30
         DO 191 J=1, JMSUB
            CC(I, J) = C(I, J, K) * 1000.0
 191     CONTINUE
         WRITE (NW, 66) XIO(I), (CC(I, J), J=1, JMSUB)
 66      FORMAT(1X, F8.2, 2X,15F8.5)
         GO TO 19
C
C        TRANSFORM CONCENTRATION FIELD FROM DIMENSIONLESS Z-SPACE
C        BACK TO REAL CARTESIAN X-Y-Z SPACE
C
  30     DO 18 J=1, JMSUB
        CC(I, J) = 0.0
        DH = DPLT(I, J) + HPLT(I, J)
        IF(DH.EQ.0.0) GO TO 18
        CC(I, J) = C(I, J, K) * 1000.0 / DH
  18     CONTINUE
         WRITE (NW, 66) XIO(I), (CC(I, J), J=1, JMSUB)
  19     CONTINUE
  16     CONTINUE
C
C        PRINT PARTICLE X, Y, Z COORDINATES AND PARTICLE PARAMETERS
C
        IF(KPRTP EQ.0)  GO TO 23
        TST = AMOD( FLOAT(NST), FLOAT(KPRTP))
        IF(TST.NE.0.0) GO TO 23
         WRITE(NW, 20) UNITS3, TIME
 20     FORMAT(1H1, 5X, 'PARTICLE POSITIONS X AND Y IN THE FLOATING'
     1 ,' SYSTEM IN ',2A4,' Z IN METERS',/,20X,' PARTICLE PARAMETERS',
     1' AT TIME', F12.2)
         WRITE(NW,51)
 51      FORMAT(///19X, 'PARTICLE POSITION',16X, 'PARTICLE POSITION',
     1 24X, 'PARTICLE PARAMETERS'/20X, 'FLOATING SYSTEM',19X,
     2 'FIXED SYSTEM')
         WRITE(NW,52)
 52      FORMAT(4X, 'N',10X, 'X',10X, 'Y',10X, 'Z',10X, 'X',10X, 'Y',
     1 10X, 'Z',9X, 'DIAMETER', 5X,
     1 'DENSITY',3X, 'SET. VEL.', 9X, 'MASS'//)
         II = 1
          DO 21 N=1, NMAX
         XTEMP = X(N) + XORIG * XDS
         YTEMP = Y(N) + YORIG * YDS
         ZTEMP = Z(N)
C
C   UNTRANSFORM Z IF NECESSARY. DEPTH BELOW IS IN METERS
C
         IF(NTRANS.EQ.0) GO TO 640
         X1 = XTEMP / XDS
         Y1 = YTEMP / YDS
         ML = X1
         MU = ML + 1
         NL = Y1
         NU = NL + 1
         IF(ML.LT.1) ML = 1
         IF(NL.LT.1) NL = 1
         IF(MU.GT.MAXDX) MU = MAXDX
         IF(NU.GT.MAXDY) NU = MAXDY
         IF(MU.LT.1) MU = 1
         IF(ML GT.MAXDX) ML = MAXDX
         IF(NU.LT.1) NU = 1
         IF(NL.GT MAXDY) NL = MAXDY
         H0 = DEPTH(ML, NL)
         H1 = H0 + (X1 - FLOAT(ML)) * (DEPTH(MU, NL) - H0)
         H2 = DEPTH(ML, NU)
         H3 = H2 + (X1 - FLOAT(ML)) * (DEPTH(MU, NU) - H2)
         DEP = H1 + (Y1 - FLOAT(NL)) * (H3 - H1)
         ZTEMP = (1.0 - ZTEMP) * DEP
 640     CONTINUE
         ZTEMP = ZTEMP + ZORIG
           II = NORDR(N)
           WRITE(NW,22) N, X(N), Y(N), Z(N), XTEMP, YTEMP, ZTEMP,
     1     DDIAM(II), DDENS(II), DVELZ(II), DMASS(II)
 22      FORMAT(1X, I4, 4X,3F11 4, 2F11.3, F11.4,3F12.4, F15 3)
 21      CONTINUE
  23      CONTINUE
C
C     WRITE OUT TO DISK
C
         IF(KPRD.EQ.0) RETURN
          TST = AMOD(FLOAT(NST), FLOAT(KPRD))
         IF(TST.NE.0.0) RETURN
C
C   OUTPUT CONCENTRATION, DEPTH AND SEA LEVEL
C
C   DCB FOR UNIT NOCN
C
C      NTRANS = 0
C      RECFM = VS
C      LRECL = IMSUB * JMSUB * KMSUB + 4  (3379)
C   BLKSIZE = LRECL + 4
C
C   NTRANS = 1
C      RECFM = VBS
C      LRECL = IMSUB * JMSUB * 2 + 4     (456)
C      BLKSIZE = 912
C
         IF(KPRC.EQ.0) GO TO 750
         TST = AMOD( FLOAT(NST), FLOAT(KPRC))
         IF(TST.NE.0.0) GO TO 750
         WRITE (NOCN) IMSUB,JMSUB,KMSUB,NMAX,NCLASS,NOCN,NST,NLOST,NDEP,
     1 TIME, XORIG, YORIG, ZORIG, DX, DY, DZ, XDL, YDL, AD, XDS, YDS
         WRITE (NOCN) (XIO(I), I=1, IMSUB)
         WRITE (NOCN) (YJO(J), J=1, JMSUB)
         IF( (NMAX.GE.NCRIT) .OR.  (NCALL1 NE.0) ) GO TO 721
         CALL GRIDER( X, Y, Z, NST)
         CALL BOUNY( N, X, Y, Z, NORDR)
         CALL CONC( C, X, Y, Z, NORDR)
 721     CONTINUE
         IF(NTRANS.EQ.0) GO TO 700


         DO 708 K=1, KMSUB
         DO 710 I=1, IMSUB
         DO 710 J=1, JMSUB
         IF(DPLT(I, J).EQ.0.0.AND HPLT(I, J).EQ.0.0) GO TO 720
         GO TO 730
 720     CC(I, J)=0.0
         GO TO 710
 730     CC(I, J) = C(I, J, K) * 1000.0 / (DPLT(I, J) + HPLT(I, J))
 710     CONTINUE
        WRITE (NOCN) ((CC(I, J), I=1, IMSUB), J=1, JMSUB)
 708    CONTINUE
        GO TO 750
 700    CONTINUE
        DO 701 K=1, KMSUB
            DO 702 J=1, JMSUB
            DO 702 I=1, IMSUB
                CC(I, J) = C(I, J, K) * 1000.0
 702        CONTINUE
            WRITE (NOCN) ((CC(I, J), I=1, IMSUB), J=1, JMSUB)
 701    CONTINUE
 750   CONTINUE
C
C   OUTPUT PARTICLE POSITIONS TO UNIT NOPT
C
C   DCB FOR UNIT NOPT
C     RECFM = VBS
C     LRECL = 68
C     BLKSIZE = 1296   - 19 LOGICAL RECORDS
C                      - 10 BLOCKS PER TRACK
C
C   THE FIRST BLOCK CONTAINS STEP INFORMATION (FIRST TWO WRITES)
C   AND THE POSITIONS OF 32 PARTICLES.
C   THE NEXT BLOCK CONTAINS THE POSITIONS OF 35 PARTICLES
C
C
        IF(KPRP.EQ.0) GO TO 631
        TST = AMOD( FLOAT(NST), FLOAT(KPRP))
        IF(TST.NE.0) GO TO 631
        WRITE (NOPT) IMSUB,JMSUB,KMSUB,NMAX,NCLASS,NOP1,NST,NLOST,NDEP,
     1  TIME, XORIG, YORIG, ZORIG, DX, DY, DZ, XDL, YDL, AD, XDS, YDS
        WRITE (NOPT) (XIO(I), I=1, IMSUB)
        WRITE (NOPT) (YJO(J), J=1, JMSUB)
        DO 650 II=1, NCLASS
        WRITE (NOPT) II, NUMBD(II), DDIAM(II), DDENS(II), DMASS(II),
     1       DVELZ(II), (DCOMP(II, JJ), JJ=1, 8)
 650  CONTINUE
        DO 630 N=1, NMAX
        XTEMP = X(N) + XORIG * XDS
        YTEMP = Y(N) + YORIG * YDS
        ZTEMP = Z(N)
C
C   UNTRANSFORM Z IF NECESSARY. DEPTH BELOW IS IN METERS.
C
        IF(NTRANS.EQ.0) GO TO 641
        X1 = XTEMP / XDS
        Y1 = YTEMP / YDS
        ML = X1
        MU = ML + 1
        NL = Y1
        NU = NL + 1
```

Figure VII.-3. MAIN

```
      IF(ML.LT.1) ML = 1
      IF(NL.LT.1) NL = 1
      IF(MU.GT.MAXDX) MU = MAXDX
      IF(NU.GT.MAXDY) NU = MAXDY
      IF(MU.LT.1) MU = 1
      IF(ML.GT.MAXDX) ML = MAXDX
      IF(NU.LT.1) NU = 1
      IF(NL.GT.MAXDY) NL = MAXDY
      H0 = DEPTH(ML, NL)
      H1 = H0 + (X1 - FLOAT(ML)) * (DEPTH(MU, NL) - H0)
      H2 = DEPTH(ML, NU)
      H3 = H2 + (X1 - FLOAT(ML)) * (DEPTH(MU, NU) - H2)
      DEP = H1 + (Y1 - FLOAT(NL)) * (H3 - H1)
      ZTEMP = (1.0 - ZTEMP) * DEP
 641  CONTINUE
      ZTEMP = ZTEMP + ZORIG
      WRITE (NOPT) NODNO(N), X(N), Y(N), Z(N), ZTEMP
 630  CONTINUE
 631  CONTINUE
C
C       WRITE VELOCITY MATRIX TO DISK
C
      IF(NPRV.EQ.0) RETURN
      TST = AMOD(FLOAT(NST),FLOAT(NPRV))
      IF(TST.NE.0.0) RETURN
      WRITE (NOVL) IMSUB,JMSUB,KMSUB,NMAX,NCLASS,NOVL,NST,NLOST,NDIF,
     1 TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDL,YDL
     WRITE (NOVL)(XIO(I),I=1,IMSUB)
     WRITE (NOVL)(XJO(J),J=1,JMSUB)
     DO 991 K=1,KMSUB
     DO 991 I=1,IMSUB
     WRITE (NOVL) (UPLT(I,J,K),J=1,JMSUB)
     WRITE (NOVL) (VPLT(I,J,K),J=1,JMSUB)
 991 WRITE (NOVL) (WPLT(I,J,K),J=1,JMSUB)
C
C            R E T U R N   H E R E
C
       RETURN
       END
      SUBROUTINE RESEPS
      RETURN
      END
      SUBROUTINE SUSDPT
      RETURN
      END
       SUBROUTINE VELC( DPLT, HPLT)
C
C              SUBROUTINE DESCRIPTION
C
C      THIS SUBROUTINE CALCULATES THE WATER DEPTH BELOW
C    MLW, THE TIDE HEIGHT AND THE U AND V VELOCITIES AT EACH OF
C    THE FLOATING GRID LOCATIONS
C
C . .............................................................
C
C              COMMON STATEMENTS
C
      COMMON /COMP/ MAXCX, MAXCY, AC, NCOMP(30,30), XCL, YCL,
     1     XCS, YCS
      COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30,30), XDL, YDL,

     1     XDS, YDS
      COMMON /ELVN/ MAXEX, MAXEY, AE, HGHT(30,30), XEL, YEL,
     1     XES, YES
      COMMON /PLOT/ MAXPX, MAXPY, MAXPZ, AP, UPLT(15,15,10),
     1     VPLT(15,15,10), WPLT(15,15,10), XPL, YPL, ZPL, XPS, YPS, ZPS
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1     NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
      COMMON /SUBS/ NTRANS, NSUB, NRITE, NMAX, MMAX, DX, DY, DZ,
     1     XORIG, YORIG, ZORIG
      COMMON /TIDE/ MAXTX, MAXTY, AT, UT(30,30), VT(30,30), XTLU, YTLU,
     1     XTS, YTS, XTLV, YTLV
C
C              DIMENSION STATEMENTS
C
      DIMENSION DPLT(15,15), HPLT(15,15)
C
C              DATA STATEMENTS
C
       DATA NW / 6/
C
C              S T A R T   H E R E
C
C
C
C    IS THE FLOATING GRID TOO NEAR FIXED GRID EDGES TO INTERPOLATE?
C
       XO = DX*(IMSUB+1)
       YO = DY*(JMSUB+1)
       XMIN = (XORIG-1.0)*XDS
       YMIN = (YORIG-1.0)*YDS
       XO = XO + XMIN
       YO = YO + YMIN
       CALL ROTAT(XTLU, YTLU, XTS, YTS, AT, XO, YO, XGM, YGM,
       JMAX=XGM +1.0
       KMAX=YGM +1.0
       CALL ROTAT(XTLU, YTLU, XTS, YTS, AT, XMIN, YMIN, XGN, YGN)
       MMIN = XGN-1.0
       NMIN = YGN-1.0
       IF(KMAX.GT.JMAX) JMAX=KMAX
       IF(MMIN.LT.1.OR.NMIN.LT.1)GO TO 30
       IF(JMAX.GT.MAXTX.OR.JMAX.GT.MAXTY)GO TO 30
       GO TO 40
   30  CONTINUE
       WRITE(NW, 50)
   50  FORMAT(//1X, 'SURFACE FITTING ROUTINE IS OUTSIDE BOUNDS OF FIXED G
     1 RID ARRAYS--FLOATING GRID TOO NEAR BOUNDARY OF FIXED GRID')
  40   CONTINUE
       CALL ROTAT( XEL, YEL, XES, YES, AE, XO, YO, XGM, YGM)
       JMAX = XGM +1.0
       KMAX = YGM + 1.0
       CALL ROTAT( XEL, YEL, XES, YES, AE, XMIN, YMIN, XGN, YGN)
       MMIN = XGN-1.0
       NMIN = YGN-1.0
       IF(KMAX.GT.JMAX) JMAX=KMAX
       IF(MMIN.LT.1.OR.NMIN.LT.1) GO TO 31
       IF(JMAX.GT.MAXEX.OR.JMAX.GT.MAXEY) GO TO 31
       GO TO 41
  31   CONTINUE
       WRITE(NW, 50)
  41   CONTINUE
C
```

```
C    DO LOOP OVER FLOATING GRID LOCATIONS.
C
       XO = XORIG*XDS-0.5*DX-XDS
       DO 100 IPLT=1, IMSUB
       XO = XO + DX
       YO = YORIG*YDS-0.5*DY-YDS
       DO 100 JPLT=1, JMSUB
C
C    DETERMINE THE LOCATION OF THE FLOATING GRID NODE IN THE FIXED GRID
C
       YO = YO + DY
       XOU = XO + DX/2.0
       YOU = YO
       XOV = XO
       YOV = YO + DY/2.0
       CALL ROTAT(XTLU, YTLU, XTS, YTS, AT, XOU, YOU, XGTU, YGTU)
       CALL ROTAT(XTLV, YTLV, XTS, YTS, AT, XOV, YOV, XGTV, YGTV)
C
C    DETERMINE THE CLOSEST FIXED GRID NODE AND GENERATE THE LOCAL
C    COORDINATES WITH RESPECT TO AN ORIGIN AT THAT NODE.
C
       MFIU=XGTU
       NFIU=YGTU
       MFIV=XGTV
       NFIV=YGTV
       XLCLU=AMOD(XGTU,1.0)
       YLCLU=AMOD(YGTU,1.0)
       XLCLV=AMOD(XGTV,1.0)
       YLCLV=AMOD(YGTV,1.0)
C
C    USE A LINEAR EXTRAPOLATION TECHNIQUE WHICH EMPLOYS THE FOUR
C    SURROUNDING GRID POINTS IF ANY OF THE 12 NEAREST FIXED GRID
C    CELLS ARE NOT COMPUTATIONAL CELLS.
C
       UTEMP=UT(MFIU, NFIU)+(UT(MFIU+1, NFIU)-UT(MFIU, NFIU))*XLCLU
     1 +(UT(MFIU+1, NFIU+1)-UT(MFIU+1, NFIU))*YLCLU
       VTEMP=VT(MFIV, NFIV)+(VT(MFIV+1, NFIV)-VT(MFIV, NFIV))*XLCLV
     1 +(VT(MFIV+1, NFIV+1)-VT(MFIV+1, NFIV))*YLCLV
C
C    EXTEND U AND V TO OTHER 2 LEVELS
C
       DO 100 KPLT=1, KMSUB
       UPLT(IPLT, JPLT, KPLT)=UTEMP
       VPLT(IPLT, JPLT, KPLT)=VTEMP
  100  CONTINUE
C
C   COMMENTS ABOVE ARE THE SAME FOR TIDAL HEIGHT
        XO = XORIG*XDS-0.5*DX-XDS
        DO 101 IPLT=1, IMSUB
        XO = XO + DX
        YO = YORIG*YDS-0.5*DY-YDS
        DO 101 JPLT=1, JMSUB
        YO = YO + DY
C  LOCATION
        CALL ROTAT(XEL, YEL, XES, YES, AE, XO, YO, XGT, YGT)
C  LOCATE CLOSEST GRID NODE
        MFIX=XGT
        NFIX=YGT
        XLCL=AMOD(XGT,1.0)
        YLCL=AMOD(YGT,1.0)

        HPLT(IPLT, JPLT)=HGHT(MFIX, NFIX)+(HGHT(MFIX+1, NFIX)-HGHT(MFIX,
      1 NFIX))*XLCL+(HGHT(MFIX+1, NFIX+1)-HGHT(MFIX+1, NFIX))*YLCL
 101    CONTINUE
C  DEPTH GRID REQUIRES NO ROTATION
C
         XO = XORIG *XDS
         DC 102 IPLT=1, IMSUB
         XO = XO + DX
         YO = YORIG*YDS
        DO 102 JPLT=1, JMSUB
        YO= YO + DY
        XT = XO/XDS
        YT = YO/YDS
        MFIX=XT
        NFIX=YT
        XLCL=AMOD(XT,1.0)
        YLCL=AMOD(YT,1.0)
C
        DPLT(IPLT,JPLT)=DEPTH(MFIX,NFIX)+(DEPTH(MFIX+1,NFIX)-DEPTH(MFIX,
      1 NFIX))*XLCL+(DEPTH(MFIX+1,NFIX+1)-DEPTH(MFIX+1,NFIX))*YLCL
 102    CONTINUE
C
C              R E T U R N   H E R E
C
        RETURN
        END
        SUBROUTINE VELCT(C, N, X, Y, Z, DPLT, HPLT, NST)
C
C              SUBROUTINE DESCRIPTION
C
C      THIS SUBROUTINE CALCULATES THE PSEUDO VELOCITIES: U, V, W.
C    THESE ARE THE VELOCITIES RESULTING FROM THE SUM OF THE
C    ADVECTIVE TERM AND THE DIFFUSIVE TERM.
C
C.................................................................
C
C              COMMON STATEMENTS
C
       COMMON /DIFU/ NCRIT, NDIFF, DXX, DYY, DZZ, EXX, EYY,
     1     PORX, PORY
       COMMON /DPTH/ MAXDX, MAXDY, AD, DEPTH(30,30), XDL, YDL,
     1     XDS, YDS
       COMMON /ELVN/ MAXEX, MAXEY, AE, HGHT(30,30), XEL, YEL,
     1     XES, YES
       COMMON /PLOT/ MAXPX, MAXPY, MAXPZ, AP, UPLT(15,15,10),
     1     VPLT(15,15,10), WPLT(15,15,10), XPL, YPL, ZPL, XPS, YPS, ZPS
       COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPRTA,
     1     NPRTC, DT, TIME, TIMMAX, ISCAL, NSAV(200)
       COMMON /MAXVEL/ UAMAX, VAMAX, WAMAX, UDMAX, VDMAX, WDMAX
       COMMON /SUBS/ NTRANS, NSUB, NRITE, NMAX, MMAX, DX, DY, DZ,
     1     XORIG, YORIG, ZORIG
       COMMON /TIDE/ MAXTX, MAXTY, AT, UT(30,30), VT(30,30), XTLU, YTLU,
     1     XTS, YTS, XTLV, YTLV
C
C              DIMENSION STATEMENTS
C
       DIMENSION C(15,15,10)
        DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
        DIMENSION DPLT(15,15), HPLT(15,15)
        INTEGER N(15,15,10)
```

Figure VII.-3. MAIN

```
C
C              S T A R T   M A I N
C
C   ZERO PSEUDO TOTAL VELOCITIES.
C
      DO 5 I=1, INSUB
      DO 5 J=1, JNSUB
      DO 5 K=1, KNSUB
      UPLT(I, J, K)=0.0
      VPLT(I, J, K)=0.0
    5 WPLT(I, J, K)=0.0
C
C   ZERO MAX VELOCITY VARIABLES USED IN THE COURANT CALCULATION
C
      UDMAX = 0.0
      VDMAX = 0.0
      WDMAX = 0.0
      UAMAX = 0.0
      VAMAX = 0.0
      WAMAX = 0.0
C
C      INTERPOLATE ADVECTIVE VELOCITY FIELD FROM FIXED HYDRODYNAMIC FIELD
C
      IF(NTRANS EQ 0) CALL VELT( UPLT, VPLT)
C
C   CALCULATE SCALE DEPENDENT DIFFUSION COEFFICIENTS
C
      DXSC=0.0
      DYSC=0 0
      IF(NDIFF.EQ.1) CALL DIFF( U, V, W)
C
C   INITIALIZE VARIABLES TO BE USED IN DIFFUSIVE VELOCITY CALC
C
      DZF = DZZ * (-2.0)
      AKNSUB = FLOAT(KNSUB)
      INSUB1 = INSUB - 1
      JNSUB1 = JNSUB - 1
      KNSUB1 = KNSUB - 1
C
C   DO LOOP OVER GRID ELEMENTS
C
      DO 1 I=1, INSUB1
C
C  FIND LATITUDE IF NEEDED TO CONVERT DEGREES TO METERS
C
       YO = (YORIG*YDS)+YDL-DY
C
C  DXT AND DYT ARE TO BE IN METERS ALWAYS, DX AND DY DO NOT
C
      DO 1 J=1, JNSUB1
      DXT = DX
      DYT = DY
      IF(ISCAL EQ.1) GO TO 45
      YO = YO + DY
      SCAL = 6371.0*1000.0*3.14159/180.0
      DYT = DY*SCAL
      DXT = DX*SCAL*COS(YO/57 296)
C  NOW THESE ARE IN METERS.
   45   CONTINUE
C

C   STORE ARRAY ELEMENTS TO BE USED EXTENSIVELY BELOW
C
      HIJ = DPLT(I, J)
      HI1J = DPLT(I+1, J)
      HIJ1 = DPLT(I, J+1)
      ZIJ = EPLT(I, J)
      ZI1J = EPLT(I+1, J)
      ZIJ1 = EPLT(I, J+1)
      HZ = HIJ + ZIJ
      DO 1 K=1, KNSUB1
C
C   SKIP THIS GRID ELEMENT IF IT IS NOT A COMPUTATIONAL CELL
C
      IF(N(I, J, K).EQ.0) GO TO 1
C
C   CALCULATE THE DIFFUSION COEFFICIENT TIMES (-2) / DX
C
      DXQ = -2.0/DXT
      DYQ = -2.0/DYT
      DXP = DXX * DXQ
      DYP = DYY * DYQ
C
C   ZERO THE DIFFUSION VELOCITY
C
      UD = 0.0
      VD = 0.0
      WD = 0.0
C
C FIND THE MAXIMUM VELOCITY/GRID VALUE FOR THE COURANT CALCULATION
C
      IF(ABS(UPLT(I, J, K)/XTS) GT.UAMAX)
     1   UAMAX = ABS(UPLT(I, J, K)/XTS)
      IF(ABS(VPLT(I, J, K)/YTS) GT.VAMAX)
     1   VAMAX = ABS(VPLT(I, J, K)/YTS)
      IF(ABS(WPLT(I, J, K)/DZ) GT WAMAX)
     1   WAMAX = ABS(WPLT(I, J, K)/DZ)
C
C   SKIP CALCULATION OF DIFFUSION VELOCITY IF LESS THAN A CRITICAL
C   NUMBER OF PARTICLES HAVE BEEN ENTRAINED.
C
      IF(NMAX.LT.NCRIT) GO TO 12
C
C   IF ANALYTICAL DIFFUSION IS TO BE USED SKIP NEXT PORTION
C
      IF(NSUB.EQ.1) GO TO 12
C
C   STORE CONCENTRATION VALUES AND CHECK FOR CONCENTRATION = 0
C
      CIJK = C(I, J, K)
      CI1JK = C(I+1, J, K)
      CIJ1K = C(I, J+1, K)
      CIJK1 = C(I, J, K+1)
      CDIFX = CI1JK - CIJK
      CDIFY = CIJ1K - CIJK
      CDIFZ = CIJK1 - CIJK
      CSUMX = CI1JK + CIJK
      CSUMY = CIJ1K + CIJK
      CSUMZ = CIJK1 + CIJK
      AK = FLOAT(K)
C
```

```
C   IF Z IS NOT TRANSPORTED SKIP TO 11
C
      IF(NTRANS.EQ.0) GO TO 11
C
C   BELOW, ETAP = ETA * KNSUB / HZ
C
      ETAP = (0.5 - AK) / HZ
      ETAQ = AKNSUB / HZ + ETAP
C
C   CALCULATE THE X COMPONENT OF THE DIFFUSION VELOCITY
C
      IF(CSUMX EQ.0.) GO TO 2
      CTX = 1.0 + ( (ZI1J-ZIJ) * ETAQ + (HI1J-HIJ) * ETAP)
      UD = DXP * CDIFX * CTX / CSUMX
C
C   CALCULATE THE Y COMPONENT OF THE DIFFUSION VELOCITY
C
    2 IF(CSUMY EQ.0.) GO TO 3
      CTY = 1.0 + ( (ZIJ1-ZIJ) * ETAQ + (HIJ1-HIJ) * ETAP)
      VD = DYP * CDIFY * CTY / CSUMY
C
C   CALCULATE THE Z COMPONENT OF THE DIFFUSION VELOCITY
C
    3 IF(CSUMZ.EQ.0.) GO TO 4
      CTZ = 1.0 / (HZ * HZ * AKNSUB)
      CTZ2 = (ETAP / AKNSUB) *
     1 ( UPLT(I, J, K) * (HI1J-HIJ) / DXT +
     2   VPLT(I, J, K) * (HIJ1-HIJ) / DYT )
      WD = DZF * CDIFZ / CSUMZ * CTZ - CTZ2
    4 CONTINUE
      GO TO 12
C
C   HERE IF THE Z COORDINATE IS NOT TRANSPORTED
C
   11 CONTINUE
      IF(CSUMX GT.0.0) UD = DXP * CDIFX / CSUMX
      IF(CSUMY.GT.0.0) VD = DYP * CDIFY / CSUMY
      IF(CSUMZ.GT.0.0) WD = DZP * CDIFZ / CSUMZ / DZ
C
C   CALCULATE THE TOTAL VELOCITY COMPONENTS
C
   12 CONTINUE
      IF(ISCAL.EQ.1) GO TO 13
C
C  IF HERE, CONVERT UD AND VD BACK TO DEGREES/SEC.
C
       UD = UD/(SCAL*COS(YO/57.296))
       VD = VD/SCAL
   13  CONTINUE
       UPLT(I, J, K)=UPLT(I, J, K)+UD
       VPLT(I, J, K)= VPLT(I, J, K)+VD
       WPLT(I, J, K)=WPLT(I, J, K)+WD
C
C   OBTAIN THE MAX U, V AND W ADVECTIVE AND DIFFUSIVE VELOCITIES
C
      IF(ABS(UPLT(I, J, K)/XTS) GT.UAMAX)
     1   UAMAX = ABS(UPLT(I, J, K)/XTS)
      IF(ABS(VPLT(I, J, K)/YTS) GT.VAMAX)
     1   VAMAX = ABS(VPLT(I, J, K)/YTS)
      IF(ABS(WPLT(I, J, K)/DZ).GT.WAMAX)



     1   WAMAX = ABS(WPLT(I, J, K)/DZ)
      IF(ABS(UD/DX).GT.UDMAX) UDMAX = ABS(UD/DX)
      IF(ABS(VD/DY).GT VDMAX) VDMAX = ABS(VD/DY)
      IF(ABS(WD/DZ).GT.WDMAX) WDMAX = ABS(WD/DZ)
    1 CONTINUE
   10 CONTINUE
C
C              R E T U R N   H E R E
C
       RETURN
       END
```

Figure VII.-3. MAIN

```
//K2105610 JOB (EXA100),'DATAOUT',MSGLEVEL=1
//*        EXEC SCPDSN,DSN='UNI.EXA1.DEBUG.PREVIEW'
//*        EXEC DSALLOC
//*DSNAME1 DD DSN=UNI.EXA1.DEBUG.PREVIEW,DISP=(NEW,CATLG),
//* UNIT=SYSDA,SPACE=(TRK,(5,1),RLSE),
//* DCB=(RECFM=VBS,BLKSIZE=1954)
//  EXEC FORTGCG,REGION.GO=192K,P1='SYSOUT=(C,,2019)',
//   P3='SYSOUT=(C,,2019)'
//FORT.SYSIN DD *
C
C                 PROGRAM DESCRIPTION
C
C   THIS PROGRAM READS THOSE DATA OUTPUT BY OILSP AND
C   AND PRINTS THIS DATA OUT ON PAPER OR IN A REDUCED FORM TO DISK.
C
C                   VARIABLE DESCRIPTION
C
C   NPRT CONTROLS THE PRINTOUT.
C
C           - -1 PRINT OUT TO DISK FOR PLOTTING ROUTINES
C           -  0 NO PRINTOUT
C           -  1 PRINT ONLY AS READ IN
C           -  2 PRINT ONLY FORMATTED OUTPUT
C           -  3 PRINT BOUTH AS READ IN AND FORMATTED OUTPUT.
C
C   NRDPT CONTROLS READING OF PARTICLE DATA SET
C
C           - 0 PARTICLES NOT READ
C           > 0 PARTICLES READ IN THAT UNIT
C
C   CCUT    - THIS IS THE MINIMUM CONCENTRATION IN
C             PARTS PER THOUSAND WHICH IS TO BE USED
C             FOR OUTPUT.
C
C   NRDCN CONTROLS READING OF THE CONCENTRATION DATA SET
C
C   NRDSP CONTROLS READING OF THE SPILLET DATA SET
C
C..............................................................
C
C                 DIMENSION STATEMENTS
C
      DIMENSION BSPIL(61), DSPIL(61), PSPIL(61), SSPIL(61),
     1   USPIL(61), WSPIL(61), XSPIL(61), YSPIL(61), GSPIL(61,8)
      DIMENSION XID(30), YJD(30), CONC(30,30,3), CC(30,30)
      DIMENSION NUMBD(100), DCOMP(100,8), DDENS(100), DDIAM(100),
     1   DMASS(100), DVELZ(100)
      DIMENSION X(2000), Y(2000), Z(2000), ZT(2000)
      DIMENSION CT(899),XG(899),YG(899)
      INTEGER*2 NORDR(2000)
C
C                 DATA STATEMENTS
C
      DATA NW, PI/ 6, 3.14159/
C
C                 S T A R T   H E R E
C
      WRITE(NW,445)
 445  FORMAT('1        INPUT PARAMETERS')
```

```
      IF(NPRT.EQ.-1) PRINT 7,IDAY,TIME,NSPIL
 7    FORMAT(2X,I10,3X,F15.5,3X,I10)
      DO 100  I=1,NSPIL
      IF(I.GT.1) READ(NRDSP) TIME,NSPIL
        READ(NRDSP,END=901) II,BSPIL(I),XSPIL(I),YSPIL(I),RSPIL(I),
     1   WSPIL(I),DSPIL(I),SSPIL(I),USPIL(I),(GSPIL(II,J),J=1,8)
        IF( (NPRT.EQ.1) .OR.  (NPRT.EQ.3) )
     1   WRITE(NW,20) II,BSPIL(I),XSPIL(I),YSPIL(I),RSPIL(I),
     1   WSPIL(I),DSPIL(I),SSPIL(I),USPIL(I),(GSPIL(II,J),J=1,8)
 20     FORMAT(2X,I3,8F10.3/5X,8F8.2/)
C
C   CONVERT GM/CC TO TONS/M**3
C
        DEN =DSPIL(I) * 0.5
C
C  DETERMINE THE VOLUME OF THE SLICK AND THEN
C   THE SPILLET THICKNESS.
C
        VOL = WSPIL(I)/DSPIL(I)
        THIC = VOL/(PI*RSPIL(I)*RSPIL(I))
        IF(NPRT.EQ.-1) WRITE (2) XSPIL(I), YSPIL(I), RSPIL(I), THIC
 100  CONTINUE
      GO TO 951
C
C   HERE IF AN EOF WAS ENCOUNTERED ON UNIT 1
C
 901  CONTINUE
      PRINT 801
 801  FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 1'/)
       STOP
 951  CONTINUE
       IF(NRDCN.EQ.0) GO TO 1
C
C   READ IN CONCENTRATION PARAMETERS
C
       READ (NRDCN,END=910) IMSUB,JMSUB,KMSUB,NMAX,NCLASS,NFLG,NCT,NLT ,
     1 NDEP,TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDS,YDS
       IF( (NPRT.EQ.1) .OR.  (NPRT.EQ.3) )
     1 WRITE(NW,10) IMSUB,JMSUB,KMSUB,NMAX,NCLASS,NFLG,NCT,NLT,
     1 NDEP,TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDS,YDS
 10    FORMAT(3X,9I6/3X,F15.3,6F10.3,5F10.6)
       READ (NRDCN,END=910)  (XID(I),I=1,IMSUB)
       READ (NRDCN,END=910)  (YJD(J),J=1,JMSUB)
       IF( (NPRT.EQ.1) .OR.  (NPRT.EQ.3) )
     1 WRITE(NW,24) (XID(I),I=1,IMSUB)
       IF( (NPRT.EQ.1) .OR.  (NPRT.EQ.3) )
     1 WRITE(NW,24) (YJD(J),J=1,JMSUB)
 24    FORMAT(/2X,15F8.3/)
       DO 99 K=1,KMSUB
          READ (NRDCN,END=910)  ((CONC(I,J,K),I=1,IMSUB),J=1,JMSUB)
          IF( (NPRT.EQ.1) .OR.  (NPRT.EQ.3) )
     1     WRITE(NW,95) ((CONC(I,J,K),I=1,IMSUB),J=1,JMSUB)
 95        FORMAT(5X,15F8.2)
 99    CONTINUE
       GO TO 960
C
C   HERE IF AN EOF WAS ENCOUNTERED ON UNIT 10.
C
 910   CONTINUE
       PRINT 810
```

```
C   INITAILIZE CONSTANTS
C
       SCALE = PI * 6371.0 * 1000.0 / 180.0
C
C   READ IN CONTROL PARAMETERS.
C
       CALL READI( NPRT, 'NPRT    ', -1, 3)
       CALL READI (ISCAL,'ISCAL   ',1,2)
       CALL READI( NRDSP, 'NRDSP   ', 0, 15)
       CALL READI( NRDCN, 'NRDCN   ', 0, 15)
       CALL READI( NRDPT, 'NRDPT   ', 0, 15)
       CALL READF( CCUT, 'CCUT    ')
C
C   READ DAY I.D. FORM ALL THREE INPUT DATA SETS.
C
       IF(NRDSP.GT.0) READ (NRDSP) IDAY1
       IF(NRDCN.GT.0) READ (NRDCN) IDATCN
       IF(NRDPT.GT.0) READ (NRDPT) IDAYPT
C
C   DO THE STARTING DAYS OF THE CONC AND THE SPILLET DATA SETS
C   CORRESPOND. IF NOT PRINT OUT AN ERROR MESSAGE AND STOP.
C
       IF(NRDSP.EQ.0) GO TO 770
       IF(NRDCN.EQ.0) GO TO 550
       IF(IDAY1.EQ.IDATCN) GO TO 550
       WRITE(NW,560)
 560  FORMAT(' STARTING TIMES OF DATA SETS DO NOT CORRESPOND:',
     1  2I5/)
      STOP
 550  CONTINUE
      IF(NRDPT.EQ.0) GO TO 770
      IF(IDAY1.EQ.IDAYPT) GO TO 770
      WRITE (NW,560)
      STOP
 770  CONTINUE
C
C   PRINT OUT HEADERS FOR DATA WRITTEN TO DISK.
C
         PRINT 3
 3       FORMAT('1  JULIAN DATE  HOURS SINCE SPILL  NOF SPILLETS',
     1     1X,'MIN LONG',3X,'MAX LONG',3X,'MIN LAT',4X,'MAX LAT',
     2     1X,'ELEMENTS',2X,'ANGLE')
C
C      H E R E   T O   I T E R A T E   O V E R   T I M E   S T E P S
C
 1    CONTINUE
C
C   READ IN SPILL PARAMETERS
C
      IF(NRDSP.EQ.0) GO TO 951
      READ(NRDSP,END=901) TIME,NSPIL
      TIME = TIME / 3600.0
      IF( (NPRT.EQ.1) .OR. (NPRT.EQ.3) ) WRITE (6,6) TIME, NSPIL
 6    FORMAT(2X,F9.1,2X,2I3)
C
C   CALCULATE JULIAN DATE FOR THIS TIME STEP AND TIME SINCE START OF
C   THE SPILL. PRINT OUT TIME AND NUMBER OF SPILLETS IF REQUESTED.
C
      IDAY =(TIME/24.) + FLOAT(IDAY1)
      IF(NPRT.EQ.-1) WRITE (2) IDAY, TIME, NSPIL
```

```
 810  FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 10'/)
      STOP
 960  CONTINUE
C
C   AVERAGE CONCENTRATION OVER WATER COLUMN FIND MAX AND MIN X AND Y
C   AND OUTPUT TO DISK IF REQUESTED.
C
      XMAX = 0.0
      YMAX = 0.0
      XMIN = FLOAT(IMSUB) * DX
      YMIN = FLOAT(JMSUB) * DY
      XGRD = -DX
      SUM = 0.0
       NSUM =0
      DO 400 I=1,IMSUB
         XGRD = XGRD + DX
         YGRD = -DY
         DO 400 J=1,JMSUB
            YGRD = YGRD + DY
            CC(I,J) = 0.0
            DO 410 K=1,KMSUB
               CC(I,J) = CC(I,J) + CONC(I,J,K)
 410        CONTINUE
            CC(I,J) = CC(I,J) * 1000.0 / FLOAT(KMSUB)
            IF(CC(I,J).LT.CCUT) GO TO 400
            SUM = SUM + DX * DY
             NSUM = NSUM+1
             CT(NSUM) = CC(I,J)*1000.0
             XG(NSUM)=XGRD
             YG(NSUM) = YGRD
             IF(XGRD.GT.XMAX) XMAX = XGRD
             IF(YGRD.GT.YMAX) YMAX = YGRD
             IF(XGRD.LT.XMIN) XMIN = XGRD
             IF(YGRD.LT.YMIN) YMIN = YGRD
 400  CONTINUE
      SUM = SUM / (50. * 50.)
C
C   CONVERT TO LONGITUDE AND LATITUDE.
C
      XMAX = XMAX + XDS * (XORIG - 1.0) + DX / 2.0
      XMIN = XMIN + XDS * (XORIG - 1.0) + DX / 2.0
      YMAX = YMAX + YDS * (YORIG - 1.0) + DY / 2.0
      YMIN = YMIN + YDS * (YORIG - 1.0) + DY / 2.0
      IF(AD.NE.0.0) GO TO 67
      IF(ISCAL.EQ.2) GO TO 65
      YLAT = YDL + (YMAX-YMIN)/(2.0*SCALE)
      YMAX = YMAX/SCALE
      YMIN = YMIN /SCALE
      XMAX = XMAX/(SCALE*COS(YLAT/57.296))
      XMIN = XMIN/(SCALE*COS(YLAT/57.296))
 65   XMAX = XDL - XMAX
      XMIN = XDL - XMIN
      YMAX = YDL + YMAX
      YMIN = YDL + YMIN
 67   CONTINUE
       DO 609 KP=1,NSUM
        XG(KP) = XG(KP)+XDS*(XORIG-1.0) + DX/2.0
        YG(KP) = YG(KP)+YDS*(YORIG-1.0) + DY/2.0
        IF(AD.NE.0.0) GO TO 609
        IF(ISCAL.EQ.2) GO TO 77
```

Figure VII.-4. DATAOUT

```
      YG(KR) = YG(KP)/SCALE
      YLAT = YDL+YG(KR)
      XG(KR) = XG(KP)/(SCALE*COS(YLAT/57.296))
77    CONTINUE
      XG(KR) = XDL-XG(KR)
     YG(KR) = YDL + YG(KP)
609  CONTINUE
     DXT = DX
     DYT = DY
     IF(ISCAL.EQ.1) GO TO 96
     YLAT = (YMAX+YMIN)/2.0
     DYT  = DY*SCALE
     DXT = DX*SCALE*COS(YLAT/57.296)
 96  CONTINUE
     IF(NPRT.EQ.-1) PRINT 2,XMIN,XMAX,YMIN,YMAX,NSOR,AD
 2   FORMAT(1H+,43X,4(2X,F9.4),2X,I4,5X,F7.4)
     IF(NPRT.NE.-1) GO TO 665
     WRITE(2) XMIN,XMAX,YMIN,YMAX,DXT,DYT,NSOR,AD,XDL,YDL
      DO 554 IJ=1,NSOR
       WRITE(2) XG(IJ), YG(IJ),CT(IJ)
554   CONTINUE
665   CONTINUE
C
C   READ IN PARTICLE PARAMETERS
C
      IF(NRDPT.EQ.0) GO TO 1
      READ (NRDPT,END=911) IRSUB,JRSUB,KRSUB,NMAX,NCLASS,NFLG,NST,NLOST,
     1 NDEP,TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDS,YDS
      IF( (NPRT.EQ.1) .OR. (NPRT.EQ.3) )
     1 WRITE(NW,10) IRSUB,JRSUB,KRSUB,NMAX,NCLASS,NFLG,NST,
     1 NLOST,NDEP,TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDS,YDS
      READ (NRDPT,END=911) (RIO(I),I=1,IRSUB)
      READ (NRDPT,END=911) (RJO(J),J=1,JRSUB)
      IF( (NPRT.EQ.1) .OR. (NPRT.EQ.3) )
     1 WRITE(NW,24) (RIO(I),I=1,IRSUB)
      IF( (NPRT.EQ.1) .OR. (NPRT.EQ.3) )
     1 WRITE(NW,24) (RJO(J),J=1,JRSUB)
      DO 650 II=1,NCLASS
         READ (NRDPT,END=911) N,NUMSD(II),DDIAM(II),DDENZ(II),DMASS(II),
     1     DVELZ(II),(DCONF(II,JJ),JJ=1,8)
         IF( (NPRT.EQ.1) .OR. (NPRT.EQ.3) )
     1     WRITE(NW,660) N,NUMSD(II),DDIAM(II),DDENZ(II),DMASS(II),
     1     DVELZ(II),(DCONF(II,JJ),JJ=1,8)
660      FORMAT(2X,2I3,4F15.3/3X,8F10.3)
650   CONTINUE
C
C  READ IN PARTICLE POSITIONS
C
      DO 66 K=1,NMAX
         READ (NRDPT,END=911)NORDR(K),X(K),Y(K),Z(K),ZT(K)
         XTEMP = X(K) + XORIG + XDS
         YTEMP = Y(K) + YORIG + YDS
         IF( (NPRT.EQ.1) .OR. (NPRT.EQ.3) )
     1     WRITE(NW,56) NORDR(K),X(K),Y(K),Z(K),XTEMP,YTEMP,ZT(K)
 66   CONTINUE
 56   FORMAT(2X,I4,6F9.2)
      GO TO 961
C
C   HERE IF AN EOF WAS ENCOUNTERED ON UNIT 11.
C
```

```
       WRITE(NW,17)NST,TIME,K
 17    FORMAT(1H0,10X,'CONCENTRATION IN MG OF OIL PER ML OF WATER',
     1 5X,'STEP NUMBER',I4,5X,'TIME',F12.2,2X,'LEVEL',I4/)
       WRITE(NW,4) (RJO(J),J=1,JRSUB)
  4    FORMAT(7X,15I8)
       DO 19 I=1,IRSUB
       WRITE (6,60) RIO(I), (CONC(I,J,K),J=1,JRSUB)
 60    FORMAT(1X,F6.3,4X,15F8.5)
 19   CONTINUE
C
C      PRINT PARTICLE X,Y,Z COORDINATES AND PARTICLE PARAMETERS
C
       WRITE(NW,31) TIME
 31    FORMAT(1H1,10X,'PARTICLE POSITIONS X,Y,Z IN THE FLOATING'
     1 ,' SYSTEM IN METERS AND PARTICLE PARAMETERS AT TIME',F12.2)
      PRINT 51
 51   FORMAT(///19X,'PARTICLE POSITION',16X,'PARTICLE POSITION',
     1 24X,'PARTICLE PARAMETERS'/20X,'FLOATING SYSTEM',19X,
     2 'FIXED SYSTEM')
      PRINT 52
 52   FORMAT(4X,'N',10X,'X',10X,'Y',10X,'Z',10X,'X',10X,'Y',10X,'Z',
     1 11X,'DIAMETER',5X,
     1 'DENSITY',3X,'SET. VEL.',9X,'MASS'//)
       DO 27 N=1,NMAX
      II = NORDR(N)
      XTEMP = X(N) + XORIG + XDS
      YTEMP = Y(N) + YORIG + YDS
      PRINT 22, N, X(N), Y(N), Z(N), XTEMP, YTEMP, ZT(N),
     1   DDIAM(II), DDENZ(II), DVELZ(II), DMASS(II)
 22   FORMAT(1X,I4,4X,3F11.4,2F11.0,F11.4,3F12.4,F15.3)
 27   CONTINUE
      GO TO 1
 69   CONTINUE
      STOP
     END
     SUBROUTINE READC(I,INAME,NL,NU)
     REAL*8 INAME, IPNAME
     DATA NR,NW/5,6/
     READ (NR,10) I,IPNAME
 10  FORMAT(I15,5X,A8)
     IF(IPNAME.EQ.INAME) GO TO 100
     WRITE (NW,20) IPNAME, INAME
 20  FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
     STOP
100  CONTINUE
     IF(NL.EQ.NU) GO TO 200
     IF( (I.GE.NL) .AND. (I.LE.NU) ) GO TO 200
     WRITE (NW,40) INAME, NL, NU, INAME, I
 40  FORMAT(16H0 THE LIMITS ON ,A8,5H ARE ,I5,4H TO ,I5,
    1  6H, BUT ,A8,16H WAS READ IN AS  ,I5)
     STOP
200  CONTINUE
     WRITE (NW,30) I, INAME
 30  FORMAT(2X,I15,5X,A8)
     RETURN
     END
     SUBROUTINE READF( X, INAME)
     REAL*8 INAME, IPNAME
     DATA NR,NW/5,6/
     READ (NR,10) X, IPNAME
```

```
911  CONTINUE
     PRINT 811
811  FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 11'/)
961  CONTINUE
     IF(NPRT.LT.2) GO TO 1
C
C   H E R E   F O R   F O R M A T T E D   P R I N T O U T
C
C   PRINT OUT HEADER FOR SPILLET INFORMATION.
C
     WRITE (NW,200) TIME
200  FORMAT('1',T29,'EXISTING SPILLETS ',F6.3,' HOURS AFTER',
    1         ' THE BEGINNING OF THE SPILL'/'+',T29,65('_')/)
     IF(NSPIL.LE.0) GO TO 300
     WRITE (NW,210)
210  FORMAT(30X,'SPILLETS CREATED PRIOR TO THIS STEP'/)
C
C   DO LOOP OVER ALL EXISTING SPILLETS.
C
     DO 11 I=1,NSPIL
        IF(I-NSPIL-1) 26, 21, 26
C
C   HERE TO PRINT OUT HEADER FOR NEW SPILLETS.
C
 21     CONTINUE
        WRITE (NW,220)
 220    FORMAT('0',30X,'NEW SPILLETS ADDED THIS STEP'/)
 26     CONTINUE
C
C   PRINT OUT ALL SPILLET PARAMETERS.
C
        WRITE (NW,230) I, NSPIL(I), XSPIL(I), YSPIL(I), RSPIL(I),
    1                     WSPIL(I)
 230    FORMAT(4X,'THE',I4,' SPILLET APPEARED ',F6.2,
    1      '  HOURS  AFTER THE BEGINNING OF THE SPILL'/4X,'IT IS',
    2      ' CENTERED AT LONGITUDE ',F10.6,' AND LATITUDE ',F10.6,
    3      ','/4X,'IS OF RADIUS ',F10.2,
    4      ' METERS AND IS OF WEIGHT ',F10.4,' METRIC TONS.')
        WRITE (NW,240) DSPIL(I), SSPIL(I), USPIL(I)
 240    FORMAT(4X,'SOME PROPERTIES OF THE SPILLED OIL ARE:'/
    1      20X,' DENSITY ',12X,F10.6,' GRAMS/CC'/20X,
    2      ' INTERFACIAL TENSION ',F10.6,' DYNES/CM'/20X,
    3      ' KINEMATIC VISCOSITY ',F10.6,' CENTISTOKES')
        WRITE (NW,250) (GSPIL(I,J),J=1,9)
 250    FORMAT(4X,'BY WEIGHT THE OIL FRACTIONS ARE:',20X,
    1     'PARAFFIN (C6-C12)',10X,F10.6/56X,
    2     'PARAFFIN (C13-C22)',9X,F10.6/56X,
    3     'CYCLOPARAFFIN (C6-C12)',5X,F10.6/56X,
    4     'CYCLOPARAFFIN (C13-C22)',4X,F10.6/56X,
    5     'AROMATIC (C6-C11)',10X,F10.6/56X,'AROMATIC (C12-C18)',
    6     9X,F10.6/56X,'NAPTHENO-AROMATIC (C9-C25)',
    7     1X,F10.6/56X,'RESIDUAL',19X,F10.6)
 11  CONTINUE
300  CONTINUE
C
C       PRINT 3-D CONCENTRATION FIELD AT EACH Z-LEVEL
C
     PRINT 102
102  FORMAT('1')
       DO 19 K=1,KRSUB
```

```
 10  FORMAT(F15.5,5X,A8)
     IF(INAME.EQ.IPNAME) GO TO 100
     WRITE (NW,20) IPNAME, INAME
 20  FORMAT(21H CARDS OUT OF ORDER, ,A8,6H READ ,A8,10H REQUESTED)
     STOP
100  WRITE (NW,30) X, INAME
 30  FORMAT(2X,F15.5,5X,A8)
     RETURN
     END
//GO.SYSIN DD *
            -1       NPRT
             1       ISCAL
             1       NRDSP
             0       NRDCN
             0       NRDPT
  0.05               CCUT
//GO.FT01F001 DD DSN=OBI.EXA1.DEBUG.SND350,DISP=SHR
//GO.FT02F001 DD DSN=OBI.EXA1.DEBUG.PARVIEW,DISP=SHR
//GO.FT10F001 DD DSN=OBI.EXA1.DEBUG.CND350,DISP=SHR
//
```

Figure VII.-4. DATAOUT

```
//E2345678 JOB (EXX100,180,2,5,,2019),'CHECDATA',MSGLEVEL=1
//  EXEC FORTGCG,REGION.GO=180K,P1='SYSOUT=(C,,2019)',
//  P3='SYSOUT=(C,,2019)'
//FORT.SYSIN DD *
C
C                 PROGRAM DESCRIPTION
C
C   THIS PROGRAM READS IN THE OUTPUT GENERATED BY THE PROGRAM DATAOUT
C AND PRINTS THIS DATA OUT.
C     NUNIT     - UNIT FROM WHICH THIS DATA IS READ FROM
C
C     NPRCN     - CONTROLS WHETHER CONCENTRATION PARAMETERS
C                 ARE READ IN
C               -  0  PARAMETERS NOT READ IN.
C               -  1  PARAMETERS ARE READ IN.
C
C                  VARIABLE DESCRIPTION
C
C
C..............................................................
C
C                 DIMENSION STATEMENTS
C
      DIMENSION XSPIL(30), YSPIL(30), RSPIL(30)
       DIMENSION XG(895), YG(899), CT(899)
C
C                 DATA STATEMENTS
C
      DATA NW, PI/ 6, 3.14159/
C
      WRITE(NW,447)
 447  FORMAT('1         INPUT PARAMETERS')
C
C                 S T A R T   H E R E
C
C   READ IN CONTROL PARAMETERS.
C
      CALL READI (NUNIT, 'NUNIT   ', 0, 15)
      CALL READI (NPRCN, 'NPRCN   ', 0, 1)
C
C      H E R E   T O   I T E R A T E   O V E R   T I M E   S T E P S
C
      PRINT 5
 5    FORMAT('1')
 1    CONTINUE
C
C   READ IN JULIAN DAY AND NUMBER OF SPILLETS.
C
      READ (NUNIT,END=901) IDAYS, TIME, NSPIL
       PRINT 10, IDAYS, TIME
 10    FORMAT(///10X,'SPILLET PARAMETERS FOR JULIAN DAY',I5,
    1         ' WHICH IS',F15.5,' HOURS FROM THE START OF THE SPILL'
    1         //5X,/30X,'SPILLET LOCATIONS AND RADII'//5X,
    1         'SPILLET #',12X,'LONGITUDE',12X,'LATITUDE',12X,'RADIUS',
    2       12X,' THICKNESS')
      DO 100  I=1,NSPIL
         READ (NUNIT,END=901) XSPIL(I), YSPIL(I), RSPIL(I), THIC
          PRINT 20, I, XSPIL(I), YSPIL(I), RSPIL(I), THIC
 20       FORMAT(5X,I5,10X,4(F15.5,5X))
```

```
 100  CONTINUE
         IF(NPRCN.EQ.0)  GO TO 1
C
C   READ IN SUBSURFACE PARTICLE LIMITS
C
      READ (NUNIT,END=901) XMIN,XMAX,YMIN,YMAX,DX,DY,NSUM,AD,XOL,YOL
      WRITE(NW,32) DX , DY, NSUM
 32   FORMAT(2X,'THE GRID SEPARATION IN THE X DIRECTION IS',F10.2,
    1    ' METERS','AND IN THE Y DIRECTION IS',F10.2,' METERS',/,
    2  10X'THERE ARE ', I4,' GRIDS OVER THE MINIMUM CONCENTRATION')
C
C    CONVERT TO DEGREES FOR PRINTOUT
C
      AD = AD * 57.296
      WRITE(NW,69) AD, XOL, YOL
 69   FORMAT(2X,/,5X,'THE DEPTH GRID HAS BEEN ROTATED ',F6.4,
    1  ' IN THE COUNTER CLOCKWISE DIRECTION ',/,4X,
    2  ' AND HAS AN ORIGIN AT ',F7.3,' N',F7.3,' W')
      WRITE(NW,33)
 33   FORMAT(/,5X,'LONGITUDE',1X,'LATITUDE',1X,'PARTS/BILLION')
       DO 788 KK=1,NSUM
        READ(NUNIT) XG(KK), YG(KK), CT(KK)
        WRITE(NW,210) XG(KK), YG(KK), CT(KK)
 210    FORMAT(3X,2F10.4,1X,F11.2)
 788   CONTINUE
       PRINT 30, XMAX, XMIN, YMAX, YMIN
 30   FORMAT('0MAXIMUM LONGITUDE',F15.5/' MINIMUM LONGITUDE',F15.5/
    1        ' MAXIMUM LATITUDE',F16.5/' MINIMUM LATITUDE',F16.5)
      GO TO 1
C
C   HERE IF AN EOF HAS ENCOUNTERED ON UNIT 1
C
 901  CONTINUE
      PRINT 801
 801  FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 1'/)
 951  CONTINUE
      STOP
      END
      SUBROUTINE READI(I,XNAME,NL,NU)
      REAL*8 XNAME, XPNAME
      DATA NR,NW/5,6/
      READ (NR,10) I,XPNAME
  10  FORMAT(I15,5X,A8)
      IF(XPNAME.EQ.XNAME) GO TO 100
      WRITE (NW,20) XPNAME, XNAME
  20  FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A6,10H REQUESTED)
      STOP
 100  CONTINUE
      IF(NL.EQ.NU) GO TO 200
      IF( (I.GE.NL) .AND. (I.LE.NU) ) GO TO 200
      WRITE (NW,40) XNAME, NL, NU, XNAME, I
  40  FORMAT(16H0 THE LIMITS ON ,A8,5H ARE ,I5,4H TO ,I5,
    1  6H. BUT ,A8,16H WAS READ IN AS  ,I5)
      STOP
 200  CONTINUE
      WRITE (NW,30) I, XNAME
  30  FORMAT(2X,I15,5X,A8)
      RETURN
      END
//GO.SYSIN DD *
```

```
               1        NUNIT
               0        NPRCN
//GO.FT01F001 DD DSN=UA1.ZZA1.TEST6.PERVIER,DISP=OLD
//
```

Figure VII.-5. CHECDATA

```
//K2345678 JOB (KXA100),'PLOT MASS '
//*  EXEC RCRDSN,DSN='MAL.EXA1.MASS.PLOT'
//*  EXEC DSALLOC
//*DSNAM DD DSN=UNI EXA1.MASS.PLOT,SPACE=(TRK,(2,2)),
//*  UNIT=SYSDA,DISP=(,CATLG),
//*  DCB=(RECFM=VBS,BLKSIZE=1954)
// EXEC FORTGCG,REGION GO=128K,LIB1=CPLOT,
// P1='SYSOUT=(C,,2019)',P3='SYSOUT=(C,,2019)'
//FORT.SYSIN DD *
C
C  THIS PROGRAM PLOTS THE DISTRIBUTION OF THE MASS
C  AS A FUNCTION OF TIME AND LOCATION(IE. ON SURFACE,
C  SUBSURFACE,ETC.)
C      THE VARIABLES ARE :
C      NST     - NUMBER OF STEPS TO BE PLOTTED
C      NPLOT   - NUMBER OF DATA SETS TO BE PLOTTED
C      NDN     - CONTROLS WHICH DATA SET IS TO BE PLOTTED
C              - 0 USE THE SAME DATA SET
C              - 1 USE A NEW DATA SET.
C      NATM    - PLOT THE MASS IN THE ATMOSPHERE
C      NBIO    - PLOT THE MASS BIOLOGICALLY CONSUMED
C      NBOT    - PLOT THE MASS DEPOSITED ON THE BOTTOM
C      NCLN    - PLOT THE MASS PHYSICALLY CLEANED UP'
C      NLOS    - PLOT THE MASS LOST THRU AN OPEN BOUNDRY
C      NSHR    - PLOT THE MASS WHICH WAS DEPOSITED ON THE SHORE.
C      NSUR    - PLOT THE MASS ON THE SURFACE.
C      NSUS    - PLOT THE MASS IN THE WATER COLUMN.
C      NDMP    - PLOT THE TOTAL AMOUNT OF MASS SPILLED
C
      DIMENSION XMATM(103),XMBIO(103),XMBOT(103),XMCLN(103),
     1   XMDMP(103),XMLOS(103),XMSHR(103),XMSUR(103),
     2   XMSUS(103),TIME(103),TMASS(103)
      DATA NPT, NW / 0, 6/
C
      WRITE(NW,447)
 447  FORMAT('1     INPUT PARAMETERS')
C
C  READ IN NUMBER OF STEPS, LENGTH OF STEP IN SECONDS
C AND THE NUMBER OF PLOTS DESIRED. THIS LAST PARAMETER
C  MUST MATCH THE NUMBER OF INPUT PARAMETERS .
C
       CALL READI( NST, 'NST      ', 1,100)
       CALL READI(  NPLOT, 'NPLOT    ', 1,2)
C
C  READ IN THE MASS AMOUNTS AND INITIALIZE VARIABLES
C
      CALL PLOTS(0,0,8)
      X1 = 0.3
      Y1 = 8.75
      DO 20 K=1,NPLOT
       NT = NST+2
       WRITE(NW,998)
 998   FORMAT(35X,'MASS IN METRIC TONS',//,
     1  8X,'TIME',2X,'ATMOSPHERE',2X,'BIO CONSUM',2X,'DEPOSITED',
     2  2X,'CLEANED UP',2X,'DUMPED',5X,' LOST  ',3X,'ON SHORE',
     3  1X,'ON SURFACE',2X,'IN WATER ')
       DO 10 I=1,NST
       READ(K,END=10) TIME(I),XMATM(I),XMBIO(I),XMBOT(I),XMCLN(I),
     1   XMDMP(I),XMLOS(I),XMSHR(I),XMSUR(I),XMSUS(I)
       TIME(I) = TIME(I)/3600.0
       WRITE(NW,800) TIME(I), XMATM(I),XMBIO(I),XMBOT(I),XMCLN(I),
     1   XMDMP(I),XMLOS(I),XMSHR(I),XMSUR(I),XMSUS(I)
 800   FORMAT(2X,10F11.3)
 10    CONTINUE
C
C  NOW LET'S PLOT
C
      IF(NPLOT.EQ.1) GO TO 77
      IF(K.NE.1) GO TO 665
      CALL PLOT(X1,Y1,3)
      CALL PLOT(X1+0.75,Y1,2)
      CALL SYMBOL(X1+0.76,Y1,0.16,' CASE1',0.0,7)
      GO TO 664
 665  CONTINUE
      Y1 = Y1 - 0.18
      CALL PLOT(X1,Y1,3)
      CALL DASHP(X1+0.75,Y1,0.05)
      CALL SYMBOL(X1+0.76,Y1,0.16,' CASE 2',0.0,7)
      GO TO 78
 664  CONTINUE
 77   CONTINUE
      CALL RECT(-.75,-.75,10.0,7.75,0.0,3)
      CALL SYMBOL(0.6,9.5,0.25,' MASS DISTRIBUTION',0.0,19)
C
C  READ IN PLOTTING PARAMETERS, THESE TELL WHICH DATA TO PLOT
C
 78   CONTINUE
      READ(5,200) NDN,NATM,NBIO,NBOT,NCLN,NLOS,NSHR,NSUR,NSUS,NDMP
      NPT = NPT + 1
 200  FORMAT(2X,10I4)
      WRITE(NW,776) NPT
 776   FORMAT(//,2X,' FOR PLOT NUMBER ',I4/)
C
C   SCALE THE DATA AND PLOT THE AXIS
C
       XMDMP(NST+1) = 0.0
       CALL SCALE(XMDMP,8.0,NST+1,1)
       XMDMP(NT-1) = XMDMP(NST+2)
       XMDMP(NT)    = XMDMP(NST+3)
       CALL SCALE(TIME,6.0,NST,1)
       RLAST = TIME(NST)/TIME(NT)+0.2
       IF(K.EQ.1)CALL AXIS(0.0,0.0,'HOURS SINCE START OF SPILL',
     1  -26,6.0,0.0,TIME(NT-1),TIME(NT))
       IF(K.EQ.1)CALL AXIS(0.0,0.0,'MASS SPILLED (METRIC TONS)',
     1  26,8.0,90.0,XMDMP(NT-1),XMDMP(NT))
       DO 11 JJ=1,NST
 11    TMASS(JJ)=0.0
C
C   SAVE SCALE FACTORS
C
       TMASS(NT-1) = XMDMP(NT-1)
       TMASS(NT) = XMDMP(NT)
C
C  PLOT MASS IN WATER COLUMN
C
      IF(NSUS.EQ.0) GO TO 40
      DO 41 I=1,NST
 41   TMASS(I)=XMSUS(I)+TMASS(I)
      IF(K.EQ.1) CALL LINE (TIME,TMASS,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = TMASS(NST)/TMASS(NT)
      YO = YY
      CALL SYMBOL(RLAST,YY,.14,'1',0.0,1)
      Y1 = Y1 - 0.18
      WRITE(NW,540)
 540  FORMAT(2X,' MASS IN WATER COLUMN PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 1 - MASS IN WATER COLUMN',
     1            0.0,25)
C
C  PLOT MASS LOST THROUGH BOUNDRY
C
 40   IF(NLOS.EQ.0) GO TO 50
      DO 51 I=1,NST
 51   TMASS(I)=TMASS(I)+XMLOS(I)
      IF(K.EQ.1) CALL LINE(TIME,TMASS,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = TMASS(NST)/TMASS(NT)
      DIF = YO - YY
      IF(ABS(DIF).LE.0.14) YY = YY - 0.165
      CALL SYMBOL(RLAST,YY,.14,'2',0.0,1)
      YO = YY
      Y1 = Y1-0.18
      WRITE(NW,541)
 541  FORMAT(2X,' MASS LOST THROUGH BOUNDRY PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 2 - MASS LOST THROUGH BOUNDRY',
     1            0.0,30)
C
C  PLOT MASS DEPOSITED ON THE BOTTOM
C
 50   IF(NBOT.EQ.0) GO TO 60
      DO 61 I=1,NST
 61   TMASS(I)=TMASS(I)+XMBOT(I)
      IF(K.EQ.1) CALL LINE(TIME,TMASS,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = TMASS(NST)/TMASS(NT)
      DIF = YO - YY
      IF(ABS(DIF).LE.0.14) YY = YY - 0.165
      CALL SYMBOL(RLAST,YY,.14,'3',0.0,1)
      YO = YY
      Y1 = Y1-0.18
      WRITE(NW,542)
 542  FORMAT(2X,' MASS DEPOSITED ON BOTTOM PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 3 - MASS DEPOSITED ON BOTTOM',
     1            0.0,29)
C
C  PLOT MASS CLEANED UP.
C
 60   IF(NCLN.EQ.0) GO TO 70
      DO 71 I=1,NST
 71   TMASS(I)=TMASS(I)+XMCLN(I)
      IF(K.EQ.1) CALL LINE(TIME,TMASS,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = TMASS(NST)/TMASS(NT)
      DIF = YO - YY
      IF(ABS(DIF).LE.0.14) YY = YY - 0.165
      CALL SYMBOL(RLAST,YY,.14,'4',0.0,1)
      YO = YY
      Y1 = Y1-0.18
      WRITE(NW,543)
 543  FORMAT(2X,' MASS PHYSICALLY CLEANED UP PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 4 - MASS CLEANED UP',
     1            0.0,20)
C
C  PLOT MASS BIOLOGICALLY CONSUMED
C
 70   IF(NBIO.EQ.0) GO TO 80
      DO 81 I=1,NST
 81   TMASS(I)=TMASS(I)+XMBIO(I)
      IF(K.EQ.1) CALL LINE(TIME,TMASS,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = TMASS(NST)/TMASS(NT)
      DIF = YO - YY
      IF(ABS(DIF).LE.0.14) YY = YY - 0.165
      CALL SYMBOL(RLAST,YY,.14,'5',0.0,1)
      YO = YY
      Y1 = Y1-0.18
      WRITE(NW,544)
 544  FORMAT(2X,' MASS BIOLOGICALLY CONSUMED PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 5 - MASS BIOLOGICALLY CONSUMED',
     1            0.0,31)
C  PLOT MASS DEPOSITED ON SHORE
C
 80   IF(NSHR.EQ.0) GO TO 95
      DO 96 I=1,NST
 96   TMASS(I)=TMASS(I)+XMSHR(I)
      IF(K.EQ.1) CALL LINE(TIME,TMASS,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = TMASS(NST)/TMASS(NT)
      DIF = YO -YY
      IF(ABS(DIF).LE.0.14) YY = YY - 0.165
      CALL SYMBOL(RLAST,YY,.14,'6',0.0,1)
      YO = YY
      Y1 = Y1-0.18
      WRITE(NW,545)
 545  FORMAT(2X,' MASS DEPOSITED ON SHORE PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 6 - MASS DEPOSITED ON SHORE',
     1            0.0,28)
C
C   PLOT MASS ON SURFACE.
C
  95  IF(NSUR.EQ.0) GO TO 110
      DO 105 I=1,NST
 105  TMASS(I)=TMASS(I)+XMSUR(I)
      IF(K.EQ.1) CALL LINE(TIME,TMASS,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = TMASS(NST)/TMASS(NT)
      DIF = YO - YY
      IF(ABS(DIF).LE.0.14) YY = YY - 0.165
      CALL SYMBOL(RLAST,YY,.14,'7',0.0,1)
      YO = YY
      Y1 = Y1-0.18
      WRITE(NW,546)
 546  FORMAT(2X,' MASS ON THE SURFACE PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 7 - MASS ON THE SURFACE',
     1            0.0,24)
C
C  PLOT MASS IN ATMOSPHERE
C
 110  IF(NATM.EQ.0) GO TO 109
```

Figure VII.-5. PLOTMASS

```
      DO 121 I=1,NST
 121  TMASS(I)=TMASS(I)+XMATM(I)
      IF(K.EQ.1) CALL LINE(TIME,TMASS,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = TMASS(NST)/TMASS(NT)
      DIF = YO - YY
      IF(ABS(DIF).LE.0.14) YY = YY - 0.165
      CALL SYMBOL(XLAST,YY,.14,'8',0.0,1)
      YO = YY
      Y1 = Y1-0.18
      WRITE(NW,547)
 547  FORMAT(2X,' MASS IN ATMOSPHERE PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 8 - MASS IN ATMOSPHERE',
     1                0.0,23)
C
C  PLOT TOTAL AMOUNT OF MASS DUMPED
C
 109  IF(NDMP.EQ.0) GO TO 129
      IF(K.EQ.1) CALL LINE(TIME,XMDMP,NST,1,0,0)
      IF(K.EQ.2) CALL DASHL(TIME,TMASS,NST,1)
      YY = XMDMP(NST)/XMDMP(NT)
      DIF = YO - YY
      IF(ABS(DIF).LE.0.14) YY = YY - 0.165
      CALL SYMBOL(XLAST,YY,.14,'9',0.0,1)
      Y1 = Y1-0.18
      WRITE(NW,548)
 548  FORMAT(2X,' TOTAL MASS SPILLED PLOTTED')
      CALL SYMBOL(X1,Y1,.14,' 9 - TOTAL MASS SPILLED',
     1                 0.0,23)
 129  CONTINUE
        IF(NPLOT.EQ.1) CALL PLOT(9.0,0.0,-3)
C
C  IF NUN = ZERO, THEN USE THE SAME DATA
C  TO DO ANOTHER PLOT.
C
        IF(NUN.EQ.0) Y1 = 8 75
        IF(NUN.EQ.0) GO TO 77
 20     CONTINUE
        CALL PLOT(0.0,0.0,999)
        RETURN
        END
      SUBROUTINE READI(I,XNAME,NL,NU)
      REAL*8 XNAME, XPNAME
      DATA NR,NW/5,6/
      READ (NR,10) I,XPNAME
  10  FORMAT(I15,5X,A8)
      IF(XPNAME.EQ.XNAME) GO TO 100
      WRITE (NW,20) XPNAME, XNAME
  20  FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H EXPECTED)
      STOP
 100  CONTINUE
      IF(NL.EQ NU) GO TO 200
      IF( (I.GE.NL) .AND. (I.LE NU) ) GO TO 200
      WRITE (NW,40) XNAME, NL, NU, XNAME, I
  40  FORMAT(16H0 THE LIMITS ON ,A8,5H ARE ,I5,4H TO ,I5,
     1  6H, BUT ,A8,16H WAS READ IN AS  ,I5)
      STOP
 200  CONTINUE
      WRITE (NW,30) I, XNAME
  30  FORMAT(2X,I15,5X,A8)
```

```
        RETURN
        END
//GO.SYSIN DD *
              10      NST
               1      NPLOT
     1   1   0   0   1   0   0   1   1   0
//GO.FT01F001 DD DSN=DAI.EAA1.DEBUG.NND350,DISP=SHR
//GO FT08F001 DD DSN=DAI.EAA1.MASS.PLOT,DISP=OLD
//
```

Figure VII.-6. PLOTMASS

```
//E2345678 JOB (EIA100),'PLOT AREAL EXTENT'
//*  EXEC SCRDSN,DSN='URI.EIA1.AREA'
//*  EXEC DSALLOC
//*DSNAM DD DSN=URI.EIA1.AREA,SPACE=(TRK,(2,2)),
//*  UNIT=SYSDA,DISP=(,CATLG),
//*  DCB=(RECFM=VBS,BLKSIZE=1954)
//  EXEC FORTGCG,REGION.GO=128K,LIB1=CPLOT,
// P1='SYSOUT=(C,,2019)',P3='SYSOUT=(C,,2019)'
//FORT.SYSIN DD *
C
C  THIS PLOTTING PROGRAM CALCULATES AND PLOTS THE
C  AREAL EXTENT OF THE SURFACE SPILLETS AND SUBSURFACE
C  GRID OVER A THRESHOLD LEVEL AS DETERMINED BY THE PROGRAM CHACUIL.
C  IT ONLY INCLUDES THE SPILLETS WHICH ARE THICKER
C  THAN THE INDICATED MINIMUM
C  THIS PROGRAM READS THE UNIT NUMBER IN THE LOOP AS
C  DEFINED THE VARIBLE JK. IF ONLY ONE PLOT IS BEING
C  DONE, THE UNIT NUMBER IS THEREFORE 1  THE CASE WHICH
C  HAS THE MAXIMUM EXTENT ALWAYS HAS TO  HAVE ITS DATA SET AS
C  UNIT ONE AS THE SCALE FACTOR IS DETERMINED BY USING THE
C  DATA FROM THAT UNIT  OTHERWISE SOME DATA MAY BE PLOTTED
C  OFF OF THE PAPER.
C  THE VARIBLE NAR CONTROLS WHETHER THE SUBSURFACE,
C  SURFACE, OR BOTH ARE TO BE PLOTTED.
C  NAR = -1 - PLOT SURFACE ONLY
C         0 - PLOT SUBSURFACE ONLY
C         1 - PLOT BOTH
C
C.............................. ....................   ..
C
      DIMENSION XSPIL(20), YSPIL(20), RSPIL(20),
     1  TIME(103), CONC(200)
       DIMENSION ASUR(50), ASUB(50), ATOT(50), ATOTP(50)
       DATA PI, NW/ 3.14159, 6 /
       WRITE(NW,447)
 447   FORMAT('1          INPUT  PARAMETERS')
C
C  READ NUMBER OF STEPS AND LENGTH OF TIME STEPS IN SECONDS
C
       CALL READI( NAR, 'NAR      ', -1, 1)
       CALL READI( NPLOT, 'NPLOT    ', 1, 5)
       CALL READF(  THICK,'THICK    ')
       CALL READI( NSTEP,'NSTEP    ', 0, 100)
      CALL PLOTS(0,0,6)
C
C   DO LOOP OVER THE DATA SETS
C
       DO 200 JK=1,NPLOT
       NL = 0
       WRITE(NW,445) JK
 445  FORMAT('1',' NOW PLOTTING CASE   ',I4)
       IF(JK.EQ.5) JK = 10
      DO 20 I=1,NSTEP
      ATOT(I)=0.0
      ASUR(I) = 0.0
      ATOTP(I) = 0.0
 20   ASUB(I) = 0.0
C
C  ITERATE OVER STEPS
```

```
C
      DO 100 KK=1,NSTEP
C
 14   READ(JK) IDAY, TIME(KK), NSPIL
C
      ASP = 0.0
C
C  LOOP OVER THE SPILLETS AND CALCULATE THE AREA OF EACH
C
      DO 3 I=1,NSPIL
      READ(JK,END=100)XSPIL(I),YSPIL(I),RSPIL(I), THIC
C
C  IF SPILLET IS NOT THICK ENOUGH, DO NOT INCLUDE IT
C
      IF(THIC.LT.THICK) GO TO 3
      RSP = RSPIL(I)/1000.0
      ASPT = PI*RSP*RSP
      ASP=ASP+ASPT
    3 CONTINUE
      ASUR(KK) =  ASP
      NUMELM = 0
      IF(NAR.EQ.-1) GO TO 29
      READ(JK,END=100)XOILMN,XOILMX,YOILMN,YOILMX,DX,DY,NUMELM,AL,ALL,[illegible]
C
C  READ IN ELEMENTS POSITION AND CONCENTRATION
C
      DO 5 I=1,NUMELM
      READ(JK,END=100) XC, YC, CC
    5 CONTINUE
      DX = DX/1000.0
      DY = DY/1000.0
      ASUB(KK) = NUMELM*DX*DY
 29   CONTINUE
      WRITE(NW,827)NUMELM, NSPIL, TIME(KK)
 827  FORMAT(//,2X,'   THERE ARE',I6,'  CONCENTRATION VALUES AND',
     1  I4,' SPILLETS OUT THERE AT TIME  ',F12.2,' HOURS')
      ATOT(KK) = ASUB(KK) + ASUR(KK)
      WRITE(NW,28) ASUR(KK), ASUB(KK), ATOT(KK)
 28   FORMAT(10X,F12.4,' SQUARE KILOMETERS ON SURFACE',/,
     1  10X,F12.4,' SQUARE KILOMETERS IN SUBSURFACE',/,
     2  10X,F12.4,'  TOTAL AREA EXTENT',/)
 100   CONTINUE
       NT = NSTEP+2
       IF(JK.GT.1) GO TO 67
C
C  NOW LETS DO SOME PLOTTING
C
       CALL RECT(-0.75,-0.75,10 0,7.75,0.0,3)
       CALL SYMBOL(0.4,9.75,0.25,' AREA COVERED BY SPILL',0.0,22)
       X1 = 0.5
       Y1 = 9.10
       CALL SCALE(TIME,6.0,NSTEP,1)
       IF(NAR.EQ.1)  CALL SCALE(ATOT,8.0,NSTEP,1)
       IF(NAR.EQ.0)  CALL SCALE(ASUB,8.0,NSTEP,1)
       IF(NAR.EQ.-1) CALL SCALE(ASUR,6.0,NSTEP,1)
       CALL AXIS(0.0,0.0,'HOURS SINCE START OF SPILL',-26,6.0,0 0,
     1  TIME(NT-1),TIME(NT))
       IF(NAR.EQ.1) TOT1 = ATOT(NT-1)
       IF(NAR.EQ.1) TOT2 = ATOT(NT)
       IF(NAR.EQ.0) TOT1 = ASUB(NT-1)
```

```
      IF(NAR.EQ.0) TOT2 = ASUB(NT)
      IF(NAR.EQ.-1) TOT1 = ASUR(NT-1)
      IF(NAR.EQ.-1) TOT2 = ASUR(NT)
      CALL AXIS(0.0,0.0,'AREAL EXTENT (KM**2)',20,8 0,
     1  90.0,TOT1,TOT2)
 67   CONTINUE
      ATOTP(NT-1) = TOT1
      ATOTP(NT) = TOT2
      X = TIME(NSTEP)/TIME(NT) + 0.1
C
C  IF ONLY THE SUBSURFACE AREA  IS TO BE PLOTTED THEN
C  SKIP THIS SECTION, OTHERWISE PLOT THE SURFACE AREA
C  COVERED HERE.
C
      IF(NAR.EQ.0) GO TO 34
      DO 40 K=1,NSTEP
   40 ATOTP(K) = ATOTP(K) + ASUR(K)
      NL = NL + 1
       CALL LINE(TIME,ATOTP,NSTEP,1,0,0)
       Y = ATOTP(NSTEP)/ATOTP(NT)
       CALL NUMBER(X,Y,0.14,FLOAT(NL),0.0,-1)
       Y1 = Y1 - 0.2
       CALL NUMBER(X1,Y1,0.14,FLOAT(NL),0 0,-1)
       CALL SYMBOL(X1,Y1,0.14,'  - AREA ON SURFACE - CASE',
     1              0.0,26)
       XT = X1 + 4.0
       IF(JK.EQ.10) JK = 5
       CALL NUMBER(XT,Y1,0.14,FLOAT(JK),0.0,-1)
  34    CONTINUE
        IF(NAR.EQ.-1) GO TO 200
C
C  PLOT AREA COVERED BY THE SUBSURFACE.
C
        DO 50 K=1,NSTEP
  50    ATOTP(K) = ATOTP(K) + ASUB(K)
        NL = NL + 1
        CALL LINE(TIME,ATOTP,NSTEP,1,0,0)
        Y = ATOTP(NSTEP)/ATOTP(NT)
        CALL NUMBER(X,Y,0.14,FLOAT(NL),0.0,-1)
        Y1 = Y1-0.2
        CALL NUMBER(X1,Y1,0.14,FLOAT(NL),0 0,-1)
        CALL SYMBOL(X1,Y1,.14,'  - AREA COVERED BY SUBSURFACE - CASE',
     1                 0.0,37)
        XT = X1 + 5.6
        IF(JK.EQ.10) JK = 5
        CALL NUMBER(XT,Y1,0.14,FLOAT(JK),0.0,-1)
 200    CONTINUE
        CALL PLOT(0.0,0.0,999)
        STOP
        END
      SUBROUTINE READI(I,NNAME,NL,NU)
      REAL*8 NNAME, IPNAME
      DATA NR,NW/5,6/
      READ (NR,10) I,IPNAME
   10 FORMAT(I15,5X,A8)
      IF(IPNAME.EQ.NNAME) GO TO 100
      WRITE (NW,20) IPNAME, NNAME
   20 FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
      STOP
  100 CONTINUE
```

```
      IF(NL.EQ.NU) GO TO 200
      IF( (I.GE.NL) .AND. (I.LE NU) ) GO TO 200
      WRITE (NW,40) NNAME, NL, NU, NNAME, I
   40 FORMAT(16H0 THE LIMITS ON ,A8,5H ARE ,I5,4H TO ,I5,
     1  6H. BUT ,A8,16H WAS READ IN AS  ,I5)
      STOP
  200 CONTINUE
      WRITE (NW,30) I, NNAME
   30 FORMAT(2X,I15,5X,A8)
      RETURN
      END
      SUBROUTINE READF( X, NNAME)
      REAL*8 NNAME, IPNAME
      DATA NR,NW/5,6/
      DATA ISCAL / 2/
      READ (NR,10) X, IPNAME
   10 FORMAT(F15.5,5X,A8)
      IF(NNAME.EQ.IPNAME) GO TO 100
      WRITE (NW,20) IPNAME, NNAME
   20 FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
      STOP
  100 WRITE (NW,30) X, NNAME
   30 FORMAT(2X,F15.5,5X,A8)
      RETURN
      END
//GO SYSIN DD *
              1       NAR
              1       NPLOT
          8.00        THICK
             10       NSTEP
//GO FT01F001 DD DSN=URI.EIA1.DEBUG.CUT50,DISP=SHR
//GO FT02F001 DD DSN=URI.EIA1.PER75.PUD350.CUT1000,DISP=SHR
//GO.FT03F001 DD DSN=URI.EIA1.PER50.PUD350.CUT1000,DISP=SHR
//GO FT04F001 DD DSN=URI.EIA1.PER25.PUD350.CUT1000,DISP=SHR
//GO.FT10F001 DD DSN=URI.EIA1.NODE.PUD350.CUT1000,DISP=SHR
//GO.FT08F001 DD DSN=URI.EIA1.AREA,DISP=OLD
//
```

Figure VII.-7. PLOTAREA

```
//CODCAT9Q    JOB (EXA100),'HANSEN-PLTNUM2',TIME=(1)
/*JOBPARM LINES=10
//*  EXEC SCRDSN,DSN='USI.EXA1.PLTNUM'
//*  EXEC DSALLOC
//*NEW DD DSN=USI.EXA1.PLTNUM,SPACE=(TRK,(2,2)),
//*  DISP=(NEW,CATLG),UNIT=SYSDA,
//*  DCB=(RECFM=VBS,BLKSIZE=1954)
//  EXEC FORTGCG,LIB1=CPLOT,REGION.GO=128K,
//  P1='SYSOUT=(C,,2019)',P3='SYSOUT=(C,,2019)'
//FORT.SYSIN DD *
C
C   THIS PROGRAM PLOTS AN AERIAL VIEW OF THE LOCATION OF
C   THE SPILLETS AND THE SUBSURFACE PORTION. IT FIRST
C   DETERMINES THE MAXIMUM AND MINIMUM EXTENT (IN LONGITUDE
C   AND LATITUDE IF ISCAL=2 AND IN METERS FROM THE (1,1)
C   POSITION IF ISCAL=1). THESE ARE THEN USED TO DETERMINE
C   THE ORIGIN AND SCALE OF THE PLOT.
C****************************************************
C
      COMMON /POST/ XDL, YDL, AD, SCAL, XOF, YOF
      INTEGER VECTOR(31,31)
      DIMENSION XC(799),YC(799),CC(799)
C
      NCH = 0
 1    CONTINUE
C
C
      CALL READI(NPLOT, 'NPLOT   ', 1, 2)
      CALL READI(NSTEP, 'NSTEP   ', 1, 50)
      CALL READF (HR , 'HR      ')
      CALL READF (THICK, 'THICK   ')
      CALL READF ( XLNG, 'XLNG    ')
      CALL READF ( YLTD, 'YLTD    ')
      CALL READI( NPDIO, 'NPDIO   ', 0, 1)
      CALL READI( ISCAL, 'ISCAL   ', 1, 2)
      CALL READI( NSHOT, 'NSHOT   ', 0, 1500)
C
C  READ IN DATA AND DETERMINE THE MAXIMUM EXTENTS
C
      DO 32 NF = 1,NPLOT
      DO 32 JN=1,NSTEP
      READ(KF) IDAT,TIME,NSPIL
C
C  OBTAIN INITIAL SPILLET POSITION TO KEEP TO
C
       DO 47 I=1,NSPIL
       READ(KF) XSP, YSP, RSP, THIC
       IF(NCH.EQ.1) GO TO 84
       XMIN = XSP
       XMAX = XSP
       XSIT = XSP
       YMIN = YSP
       YMAX = YSP
       YSIT = YSP
       WRITE(6,55) XSIT, YSIT
 55    FORMAT(2X,'SITE ',2F10.3)
       NCH = 1
 84    CONTINUE
       RSP = RSP/(1.112E 05)
       XSPL = XSP + RSP
       XSPU = XSP - RSP
       YSPL = YSP - RSP
       YSPU = YSP + RSP
       IF(XSPL.GT.XMIN) XMIN = XSPL
       IF(XSPU.LT.XMAX) XMAX = XSPU
       IF(YSPL.LT.YMIN) YMIN = YSPL
       IF(YSPU.GT.YMAX) YMAX = YSPU
 47    CONTINUE
       IF(NPDIO.EQ.0) GO TO 32
C
C  READ IN SUBSURFACE INFORMATION,
C  BUT NOT THE FIRST STEP
C
       READ(KF) XMN,XMX,YMN,YMX,DX,DY,NUMELM,AD,XDL,YDL
       IF(TIME.NE.0.0) WRITE(6,333) AD
 333   FORMAT(2X,' ANGLE IS ',F10.3)
       IF(AD.EQ.0.0) GO TO 667
       CALL POSIT(XMN,YMX,X1,Y1,1)
       IF(X1.LT.XMAX) XMAX=X1
       IF(X1.GT.XMIN) XMIN=X1
       IF(Y1.GT.YMAX) YMAX=Y1
       IF(Y1.LT.YMIN) YMIN=Y1
       CALL POSIT(XMX,YMX,X1,Y1,1)
       IF(X1.LT.XMAX) XMAX=X1
       IF(X1.GT.XMIN) XMIN=X1
       IF(Y1.GT.YMAX) YMAX=Y1
       IF(Y1.LT.YMIN) YMIN=Y1
       CALL POSIT(XMN,YMN,X1,Y1,1)
       IF(X1.LT.XMAX) XMAX=X1
       IF(X1.GT.XMIN) XMIN=X1
       IF(Y1.GT.YMAX) YMAX=Y1
       IF(Y1.LT.YMIN) YMIN=Y1
       CALL POSIT(XMX,YMN,X1,Y1,1)
       IF(X1.LT.XMAX) XMAX=X1
       IF(X1.GT.XMIN) XMIN=X1
       IF(Y1.GT.YMAX) YMAX=Y1
       IF(Y1.LT.YMIN) YMIN=Y1
       GO TO 776
 667   CONTINUE
       IF(XMN.GT.XMIN) XMIN = XMN
       IF(XMX.LT.XMAX) XMAX = XMX
       IF(YMN.LT.YMIN) YMIN = YMN
       IF(YMX.GT.YMAX) YMAX = YMX
 778    CONTINUE
C
       DO 31 I = 1,NUMELM
       READ(KF) XC,YC,CC
 31    CONTINUE
 32    CONTINUE
       TIMMAX = TIME
C
C  REWIND DATA SETS
C
         DO 64 JJ =1,NPLOT
         REWIND JJ
 64      CONTINUE
       WRITE(6,910) XMIN,XMAX,YMIN,YMAX
 910   FORMAT(/,2X,'MINIMUM LONGITUDE IS',F6.2,' MAXIMUM LONGITUDE',
     1  ' IS',F6.2,/,2X,'MINIMUM LATITUDE IS',1X,F6.2,
     2 ' MAXIMUM LATITUDE IS ',F6.2)
C
C  DETERMINE THE MAXIMUM SPREAD OF THE OIL AND
C  THEN DIVIDE THE SPACING BY 10 AND LEAVE 1.5
C  OF THESE DIVISIONS ON THE OUTSIDE OF THE PLOT.
C  THIS WILL GIVE THE ORIGIN OF ALL OF THE ENSUING
C  PLOTS AS WELL AS DETERMINING A SCALE FACTOR TO
C  CONVERT FROM DEGREES TO INCHES.
C
      XDIF = XMIN - XMAX
      YDIF = YMAX - YMIN
      DX = XDIF/10.0
      DY = YDIF/10.0
      XLON = XMIN + 1.5*DX
      YOF = YMIN - 1.5*DY
      XOF = (XMAX+XMIN)/2.0
      YLAT = (YMAX+YMIN)/2.0
      XDEG = DX * 13.0
      YDEG = DY * 13.0
      XDEG = XDEG / 5.5
      YDEG = YDEG / 5.5
      XDGT = XDEG/COS(YLAT/57.296)
      SCAL = YDEG
      IF(XDGT.GT.SCAL) SCAL = XDEG
       WRITE(6,443) XDEG,YDEG,SCAL
 443   FORMAT(2X,' SCAL FACTORS ARE ',3F12.5)
C
C   WRITE OUT THE ORIGIN OF THIS PLOT
C
       WRITE(6,911) XOF,YOF
 911   FORMAT(2X,'THE ORIGIN OF THIS PLOT IS',F6.2,' W',F6.2,' N')
C
C  DO LOOP OVER THE STEPS AND DATA SETS
C
      CALL PLOTS(0,0,8)
 74    CONTINUE
       DO 35 JJ = 1,NPLOT
 21   CONTINUE
C
C   USE BLACK FOR PLOTTING OUTLINE
C
C
C SET UP THE FIRST MAP
C
      READ(JJ) IDAT, TIME, NSPIL
C
C     END IF TIMMAX HAS BEEN PASSED
C
      IF((TIME.GT.TIMMAX).AND.(JJ.EQ.NPLOT)) GO TO 2121
C
C IS THIS A HOUR WE'RE INTERESTED IN??
C
C
      CHEC = AMOD(TIME,HR)
      IF(CHEC.EQ.0) GO TO 35
C
C  READ IN DATA ALTHOUGH THIS STEP WILL NOT BE PLOTTED
C
 445  CONTINUE
      DO 3 I=1,NSPIL
      READ(JJ,END=2121)XDUM,YDUM,ZDUM,THICC
 3    CONTINUE
      IF(NPDIO.EQ.0) GO TO 89
      READ(JJ,END=2121)XOILMN,XOILMX,YOILMN,YOILMX,DXT,DYT,NUMELM,
     1  AD,XDL,YDL
C
      DO 5 I=1,NUMELM
      READ(JJ,END=2121) XGUM, YGUM, CGUM
 5     CONTINUE
 89   CONTINUE
       GO TO 21
 35    CONTINUE
C
C   WRITE OUT TIME AND DAY
C
      WRITE(6,99) IDAT,TIME
 99   FORMAT('1',2X,'THIS RUN STARTED ON DAY',I4,'AND IT IS',F8.2,
     1  'HOURS AFTER THE START OF THE SPILL'/)
C
C   THIS SECTION PLOTS THE LEGEND.
C
       X = 4.5
       Y = 4.52
      CALL SYMBOL(X-1.0,Y+0.75,0.1,' + SPILL SITE',0.0,13)
      DT = 4.0 * DY * 6371.0*3.14159/180.0
      IDT = DT + 0.5
      DT = FLOAT(IDT)
      DIST = DT/SCAL * (180./(6371.*3.14159))
      XB = X - .6
      Y = 4.92
      CALL PLOT(XB,Y,3)
      CALL PLOT(XB,Y+.1,2)
      CALL PLOT(XB,Y,3)
      CALL PLOT(XB+DIST,Y,2)
      CALL PLOT(XB+DIST,Y+0.1,2)
      X = X - 0.7
      Y = Y+0.2
      CALL NUMBER(X,Y,0.1,DT,0.0,-1)
       CALL SYMBOL(X,Y,0.1,'      KILOMETERS',0.0,15)
       CALL CIRCL(3.6,Y-0.375,0.0,360.0,0.05,0.05,1)
       CALL SYMBOL(3.75,Y-0.4,0.1,' SURFACE SPILLETS',0.0,17)
       CALL RECT(3.5,Y-0.6,0.1,0.1,0.0,3)
       CALL SYMBOL(3.75,Y-0.6,0.1,' SUBSURFACE',0.0,11)
       Y = Y-0.38
       CALL PLOT(X,Y-0.4,3)
       CALL PLOT(X+0.75,Y-0.4,2)
       CALL SYMBOL(X+0.76,Y-0.4,0.1,' CASE 1',0.0,7)
       IF(NPLOT.EQ.1) GO TO 664
       CALL PLOT(X,Y-0.6,3)
       CALL DASHP(X+0.75,Y-0.6,0.05)
       CALL SYMBOL(X+0.76,Y-0.6,0.1,' CASE 4',0.0,7)
 664    CONTINUE
        CALL PLOT(3.4,5.5,3)
        CALL PLOT(3.4,3.90,2)
        CALL PLOT(5.5,3.90,2)
C
C  PLOT RECTANGLES AROUND PLOT
C
       CALL RECT(-0.75,-0.75,7.0,7.0,0.0,3)
       CALL RECT(0.0,0.0,5.5,5.5,0.0,3)
```

Figure VII.-8. PLOTMAP

```
      CALL NUMBER(-0.9,7.0,0.21,TIME,0.0,1)
      CALL SYMBOL(0.1,7.0,0.21,' HOURS AFTER START OF THE SPILL',
     1  0.0,31)
      CALL SYMBOL(-0.60,6.5,0.21,' MAP OF SPILLETS AND SUBSURFACE',
     1        0.0,31)
C
C  DETERMINE MINIMUM LONGITUDE AND LATITUDE TO THE
C  NEXT TENTH FOR PLOTTING
C
     CALL PLOT(2.75,0.0,-3)
C
C  PLOT SPILL SITE AND LONGITUDES AND LATITUDES
C
      Y=(YSIT-YOR)/SCAL
      X=(XOR-XSIT)/SCAL
      RAD=YSIT*3.14159/180.0
      X=X*COS(RAD)
      CALL SYMBOL(X-0.12,Y-0.15,0.3,'+',0.0,1)
     IXOR = 10.0*(XLOR+0.05)
     XN = FLOAT(IXOR)/10.0 + 1.0
      XLN1 = XN
      XLN2 = XN
     XN1 = (XOR - XN)/SCAL
     XN2 = XN1
     IYOR=10.0*(YOR+0.05)
     YN = FLOAT(IYOR)/10.0 - 1.0
     YLT1 = YN
     YLT2 = YN
     IXT = 10.0 * (XDIF+(3.0*DX))/0.1
     IYT = 10.0 * (YDIF+(3.0*DY))/0.1
     YN1 = (YN - YOR)/SCAL
     YN2 = (YN - YOR)/SCAL
     DO 34 I=1,IXT
      II = I - 1
      NCH = AMOD(FLOAT(II),XLNG)
      YD = -0.08
      IF(NCH.EQ.0)  YD = -0.11
     XNP = XN1 * COS(YLT1/57.296)
      IF((XNP.GT.2.74).OR.(XNP.LT.-2.71)) GO TO 92
      CALL PLOT(XNP,0.00,3)
      CALL PLOT(XNP,YD,2)
      IF(NCH.EQ.0) CALL NUMBER(XNP-0.25,-0.25,0.12,XLN1,0.0,1)
92    CONTINUE
      XN1 = XN1 +0.1/SCAL
      XLN1 = XLN1-0.1
34   CONTINUE
      DO 36 I=1,IXT
       II = I-1
       NCH=AMOD(FLOAT(II),XLNG)
       YD = 5.58
       IF(NCH.EQ.0) YD = 5.61
       YYY = YLT1+5.5*SCAL
       XNP = XN2 * COS(YYY/57.296)
       IF((XNP.GT..75).OR.(XNP.LT.-2.74)) GO TO 96
       CALL PLOT(XNP,5.5,3)
       CALL PLOT(XNP,YD,2)
       IF(NCH.EQ.0) CALL NUMBER(XNP-0.25,5.64,0.12,XLN2,0.0,1)
96     CONTINUE
       XN2 = XN2 + 0.1/SCAL
       XLN2 = XLN2 - 0.1
```

```
36     CONTINUE
     DO 33 J=1,IYT
      JJ = J - 1
      IF((YN1.GT.5.49).OR.(YN1.LT.0.01)) GO TO 93
      NCH = AMOD(FLOAT(JJ),YLTD)
      XL = -2.83
      IF(NCH.EQ.0) XL = -2.86
      CALL PLOT(-2.75,YN1,3)
      CALL PLOT(XL,YN1,2)
      IF(NCH.EQ.0) CALL NUMBER(-3.33,YN1-0.06,0.12,YLT1,0.0,1)
93    CONTINUE
      YN1 = YN1 + 0.1/SCAL
      YLT1 = YLT1 + 0.1
33   CONTINUE
      DO 38 J=1,IYT
       JJ = J - 1
       NCH=AMOD(FLOAT(JJ),YLTD)
       IF((YN2.GT.3.90).OR.(YN2.LT.0.01)) GO TO 98
       XR = 2.83
       IF(NCH.EQ.0) XR = 2.86
       CALL PLOT(2.75,YN2,3)
       CALL PLOT(XR,YN2,2)
       IF(NCH.EQ.0) CALL NUMBER(2.86,YN2-0.06,0.12,YLT2,0.0,1)
98     CONTINUE
       YN2 = YN2 + 0.1/SCAL
       YLT2 = YLT2 + 0.1
38    CONTINUE
C
C     PLOT SHORELINE
C
      IF(NSHOR.GT.0) CALL PLTSHR( SCAL, XOR, YOR)
C
C     READ IN SPILLET LOCATIONS AND RADII
C
     DO 811 JJ=1,NPLOT
     WRITE(6,875) JJ
875  FORMAT(//,3X,'******* CASE ' ,I4,' *******')
     WRITE(6,876)
876  FORMAT(/,5X,'LONGITUDE',1X,'LATITUDE ',3X, 'RADIUS ',
    1   2X,'THICKNESS')
     DO 19 I=1,NSPIL
     READ(JJ)XSPIL,YSPIL,RSPIL,THIC
     WRITE(6,824)XSPIL,YSPIL,RSPIL,THIC
824  FORMAT(2X,2F10.3,2X,F10.3,F10.6)
     IF(THIC.LT.THICK) GO TO 19
     YSP = YSPIL
     YSPIL=YSPIL-YOR
     XSPIL=XOR-XSPIL
     RAD = YSP*3.14159/180.0
     XSPIL=XSPIL*COS(RAD)
     RSPIL = RSPIL/(1.11E 05)
C
C  PLOT SPILLETS AS CIRCLES
C
     XPT=XSPIL + RSPIL
     YPT=YSPIL + RSPIL
     YPT = YPT/SCAL
     XPT = XPT/SCAL
     RSPIL = RSPIL/SCAL
     CALL CIRCL(XPT,YPT,0.0,360.0,RSPIL,RSPIL,1)
```

```
  19  CONTINUE
C
C
      IF(NRD10.EQ.0) GO TO 97
      DO 11 I=1,200
  11  CG(I)=0.0
C
C
      DO 12 I=1,31
      DO 12 J=1,31
  12  VECTOR(I,J)=0.0
      READ(JJ,END=2121)XOILMN,XOILMX,YOILMN,YOILMX,DXT,DYT,NUMELM,
     1   AD,XOL,YOL
      WRITE(6,827)NUMELM
 827  FORMAT(//,'    THERE ARE',I6,'  CONCENTRATION VALUES OUT THERE.')
C
       IF(AD.NE.0.0) GO TO 91
       DXT = DXT/((1.11E 05)*SCAL)
       DYT = DYT/((1.11E 05)*SCAL)
      YLAT=(YOILMN+YOILMX)/2.0
      YOILMN = (YOILMN-YOR)/SCAL
      YOILMX = (YOILMX-YOR)/SCAL
      XOILMN = XOR-XOILMN
      XOILMX = XOR-XOILMX
      RAD = YLAT*3.14159/180.0
      XOILMX = XOILMX*COS(RAD)/SCAL
      XOILMN = XOILMN *COS(RAD)/SCAL
  91  CONTINUE
C
C  READ IN GRID LOCATIONS AND CONCENTRATIONS
C
       WRITE(6,822)
 822  FORMAT(6X,'LONGITUDE',8X,'LATITUDE',9X,'PARTS/MILLION')
      DO 50 I=1,NUMELM
 49   READ(JJ,END=2121) XG(I), YG(I), CG(I)
      WRITE(6,831) XG(I), YG(I), CG(I)
 831  FORMAT(2X,3F12.3)
      IF(AD.NE.0.0) GO TO 50
       YGT = YG(I)
      YG(I)=(YG(I)-YOR)/SCAL
      XG(I)=XOR-XG(I)
      RAD = YGT*3.14159/180.0
      XG(I)=XG(I)*COS(RAD)/SCAL
 50    CONTINUE
C
C NOW SORT INTO ROWS OF VECTOR STARTING IN THE NORTH
C
      YLATMX=YOILMX
      DO 70 I=1,31
      DO 68 J=1,NUMELM
      IF(ABS(YG(J)-YLATMX).LT.(DYT/3.0))GO TO 65
      GO TO 68
  65  CONTINUE
C
C IT'S IN THE ITH ROW, SO NOW LOCATE THE COLUMN
C
      DO 67 K=1,31
      PERIN=FLOAT(K-1)
      DELTAX=PERIN*DXT + XOILMN
      IF(ABS(DELTAX-XG(J)).LT.DXT/3.0)VECTOR(I,K)=1
```

```
  67  CONTINUE
  68  CONTINUE
      YLATMX=YLATMX - DYT
  70  CONTINUE
C
C NOW ALL THE 1'S AND 0'S SHOULD BE IN PLACE
C
      DO 72 I=1,31
  72  WRITE(6,881)(VECTOR(I,J),J=1,31)
 881  FORMAT(31I2)
C
C SO PLOT THE SUBSURFACE OIL OUTLINES, WEST SIDE FIRST, GOING CCW
C
      DO 85 I=1,31
      DO 85 J=1,30
      JPLUS=J+1
      IPLUS=I+1
      XDIST=XOILMN - DXT/2.0 + DXT*FLOAT(J)
      YDIST=YOILMX + DYT/2.0 -DYT*FLOAT(I-1)
      XPL = XDIST
      YPL = YDIST
      IF(VECTOR(I,J).EQ.VECTOR(I,JPLUS))GO TO 75
C
C HERE TO PUT A VERTICAL BETWEEN THEM
C
      IF(AD.NE.0.0) CALL POSIT(XDIST,YDIST,XPL,YPL,0)
      CALL PLOT(XPL,YPL,3)
      XPL = XDIST
      YPL = YDIST-DYT
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      IF(JJ.EQ.1) CALL PLOT(XPL,YPL,2)
      IF(JJ.EQ.2) CALL DASHP(XPL,YPL,0.05)
C
  75  IF(VECTOR(I,J).EQ.VECTOR(IPLUS,J))GO TO 76
      IF(I.EQ.31.AND.VECTOR(I,J).EQ.0)GO TO 76
C
C HERE FOR A HORIZONTAL
C
      XPL = XDIST-DXT
      YPL = YDIST-DYT
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      CALL PLOT(XPL,YPL,3)
      XPL = XDIST
      YPL = YDIST-DYT
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      IF(JJ.EQ.1) CALL PLOT(XPL,YPL,2)
      IF(JJ.EQ.2) CALL DASHP(XPL,YPL,0.05)
C
  76  IF(I.EQ.1.AND.VECTOR(I,J).EQ.1.OR.I.EQ.31.AND.VECTOR(I,J).EQ.1)
     $        GO TO 77
      GO TO 78
  77  CONTINUE
      XPL = XDIST-DXT
      YPL = YDIST
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      CALL PLOT(XPL,YPL,3)
      XPL = XDIST
      YPL = YDIST
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      IF(JJ.EQ.1) CALL PLOT(XPL,YPL,2)
```

Figure VII.-8. PLOTMAP

```
      IF(JJ.EQ.2) CALL DASHP(XPL,YPL,0.05)
 78   IF(J.EQ.1.AND.VECTOR(1,J).EQ.1)GO TO 79
      GO TO 81
 79   CONTINUE
      XPL = XDIST-DXT
      YPL = YDIST
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      CALL PLOT(XPL,YPL,3)
      XPL = XDIST-DXT
      YPL = YDIST-DYT
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      IF(JJ.EQ.1) CALL PLOT(XPL,YPL,2)
      IF(JJ.EQ.2) CALL DASHP(XPL,YPL,0.05)
 81   IF(J.EQ.31.AND. VECTOR(1,J).EQ.1)GO TO 82
      GO TO 85
 82   CONTINUE
      XPL = XDIST
      YPL = YDIST
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      CALL PLOT(XPL,YPL,3)
      XPL = XDIST
      YPL = YDIST-DYT
      IF(AD.NE.0.0) CALL POSIT(XPL,YPL,XPL,YPL,0)
      IF(JJ.EQ.1) CALL PLOT(XPL,YPL,2)
      IF(JJ.EQ.2) CALL DASHP(XPL,YPL,0.05)
 85   CONTINUE
 97   CONTINUE
 811  CONTINUE
C
       CALL PLOT(9.0,0.0,-3)
       IF(TIME.LT.TIMMAX) GO TO 74
 2121 CONTINUE
      CALL PLOT(0.0,0.0,999)
      STOP
      END
      SUBROUTINE POSIT(XO,YO,XF,YP,NCH)
C
C  THIS SUBROUTINE CONVERTS THE POSITIONS XO, YO, WHICH
C         ARE WITH RESPECT TO THE DEPTH GRID TO A
C        POSITION IN LONGITUDE AND LATITUDE AND THEN
C        TO PLOTTING UNITS(INCHES) IF NCH=0.
C
C.........................................................
       COMMON /POST/ XOL, YOL, AD, SCAL, XOF, YOF
C
      XN = XO*COS(-AD)+YO*SIN(-AD)
      YN =-XO*SIN(-AD)+YO*COS(-AD)
C
C   CONVERT FROM METERS TO DEGREES
C
       YP = YOL +YN/(1.112E 05)
       RAD = YP/57.296
       XP = XOL -XN/(1.112E 05*COS(RAD))
       IF(NCH.NE.0) RETURN
       XP = (XOF-XP)/SCAL
       XF = XP*COS(RAD)
       YF = (YP-YOF)/SCAL
       RETURN
       END
      SUBROUTINE READI(I,INAME,NL,NU)
      REAL*8 INAME, IPNAME
      DATA NR,NW /5,6/
      READ (NR,10) I,IPNAME
 10   FORMAT(I15,5X,A8)
      IF(IPNAME.EQ.INAME) GO TO 100
      WRITE (NW,20) IPNAME, INAME
 20   FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
      STOP
 100  CONTINUE
      IF(NL.EQ.NU) GO TO 200
      IF( (I.GE.NL) .AND. (I.LE.NU) ) GO TO 200
      WRITE (NW,40) INAME, NL, NU, INAME, I
 40   FORMAT(16H0 THE LIMITS ON ,A8,5H ARE ,I5,4H TO ,I5,
     1 6H. BUT ,A8,16H WAS READ IN AS  ,I5)
      STOP
 200  CONTINUE
      WRITE (NW,30) I, INAME
 30   FORMAT(2X,I15,5X,A8)
      RETURN
      END
      SUBROUTINE READF( X, INAME)
      REAL*8 INAME, IPNAME
      DATA NR,NW/5,6/
      DATA ISCAL / 2/
      READ (NR,10) X, IPNAME
 10   FORMAT(F15.5,5X,A8)
      IF(INAME.EQ.IPNAME) GO TO 100
      WRITE (NW,20) IPNAME, INAME
 20   FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
      STOP
 100  WRITE (NW,30) X, INAME
 30   FORMAT(2X,F15.5,5X,A8)
      RETURN
      END
      SUBROUTINE PLTSHR( SCAL, XOR, YOR)
C
C  SUBROUTINE DESCRIPTION
C
C   THIS SUBROUTINE PLOTS THE COASTLINE.
C
C..............................................................
C
C
C           DIMENSION STATEMENTS
C
      DIMENSION XSHOR(1495), YSHOR(1495)
C
C
C  S T A R T   H E R E
C
C   INITIALIZE VARIABLES.
C
      IF(NPASS.EQ.1) GO TO 500
C
      NPTS = 1495
      READ (2) XSHOR
      READ (2) YSHOR
      REWIND 2
  500 CONTINUE
C
C
C   DO OVER SHORELINE POINTS.
C
        DO 99 IPT=1,NPTS
          IF(XSHOR(IPT).GT.0.0) GO TO 110
          NFLG1 = 1
          GO TO 99
  110     CONTINUE
C
C   CALCULATE THE SHORE POINT IN CALCOMP INCHES.
C
          XPT = (XOR - XSHOR(IPT)) * COS(YSHOR(IPT) * 3.14159 / 180.0)
     1     / SCAL
          YPT = (YSHOR(IPT) - YOR) / SCAL
C
C   IS THIS POINT OUT OF RANGE IN X?
C
          IF( (XPT.GT.-2.75) .AND. (XPT.LT.2.75) ) GO TO 120
          NFLG1 = 1
          GO TO 100
  120     CONTINUE
C
C   IS THIS POINT OUT OF RANGE IN Y?
C
          IF( (YPT.GT.0.) .AND. (YPT.LT.5.5) ) GO TO 130
          NFLG1 = 1
          GO TO 100
  130     CONTINUE
C
C   IS THIS POINT IN THE LABEL BOX?
C
          GO TO 140
 567      IF((XPT.LT..65) .OR. (YPT.LT.4.125)) GO TO 140
          NFLG1 = 1
          GO TO 100
  140     CONTINUE
C
C   CHECK FLAGS AND DRAW TO (XPT,YPT) IF REQUIRED.
C
          IF(NFLG1.EQ.1) GO TO 150
          IF(IPT.EQ.1) GO TO 150
          CALL PLOT( XPT, YPT, 2)
C
C
C   SKIP TO LOCATION (XP,YP).
C
  150     CONTINUE
          NFLG1 = 0
          CALL PLOT( XPT, YPT, 3)
  100     CONTINUE
          XLST = XPT
          YLST = YPT
   99 CONTINUE
C
C         R E T U R N    H E R E
C
      RETURN
      END
//GO.SYSIN DD *
                1      NPLOT
               10      NSTEP
            3.000      NP
             0.00      TRICK
            10.00      XLNG
             5.00      YLTD
                1      NRD10
                2      ISCAL
                0      NSHOR
//GO.FT08F001 DD DSN=URI.XXA1.PLTRON,DISP=OLD
//GO.FT01F001 DD DSN=URI.XXA1.DEBUG.COT50,DISP=SHR
//*GO.FT02F001 DD DSN=URI.XXA1.PRP75.FWD350.COT50,DISP=SHR
```

Figure VII.-8. PLOTMAP

```
//K2345678 JOB (EXA100),'CONCENTRATION'
/*JOBPARM LINES=9
/*STOP          DD
//  EXEC FORTGCG,REGION.GO=320K,P1='SYSOUT=(C,,2019)',
//  P3='SYSOUT=(C,,2019)'
//FORT.SYSIN DD *
C
C  THIS PROGRAM READS IN THE POSITIONS OF THE DROPLETS
C  WHICH HAS BEEN PUT OUT TO DISK BY THE MAIN OILSPILL
C  SIMULATION AND CREATES A NEW FLOATING GRID AND NEW
C  CONCENTRATION VALUES. IT USES SEVERAL SUBROUTINES WHICH
C  ARE CONTAINED IN THE SUBSURFACE SECTION OF THE MAIN
C PROGRAM.
C  THE VARIABLES MATCH THOSE OF THE MAIN PROGRAM.
C  THE EXCEPTIONS ARE:
C        NUNCH - THIS IS THE UNIT NUMBER TO WHICH THE NEW
C       CONCENTRATION VALUES ARE WRITTEN TO.
C        NUNPT - THIS IS THE UNIT NUMBERS FROM WHICH THE
C       PARTICLE PARAMETERS ARE READ FROM.
C ..............................................................
C
C
C  THIS PROGRAM READS IN THE PARTICLE POSITIONS AND
C CALCULATES THE CONCENTRATION
C
      DIMENSION X(5000),Y(5000),Z(5000),RIO(30),RJO(30),
     1   C(30,30,10), CC(30,30)
      INTEGER N(30,30,10)
      INTEGER*2 NORDR(5000)
C
C  COMMON STATEMENTS
C
     COMMON /DPTH/XDL,YDL,XDS,YDS
     COMMON /CNTL/ IMSUB, JMSUB, KMSUB, NPPTA,
    1        DT, TIME, ISCAL, NUNCH, NUNPT
     COMMON /SUBS/ NEXTR, NMAX, NMAX, DX, DY, DZ,
    1    XORIG,YORIG,ZORIG
     COMMON /PRNT/ KPRTC, KPRTP, NPRD, NPRC, NPRP
     COMMON /UNIT/ UNITS3(2)
     COMMON /PTYP/ NCLASS,NUMBD(200),DDIAM(200),DDENZ(200),
    1        DMASS(200), DVELZ(200),DCOMP(200,8),NTCLAS
      DATA NW / 6/
C
C       START  HERE
C
     CALL READI( NMAX,'NMAX    ',0,5000)
     CALL READI( NSTEP,'NSTEP   ',1,800)
     CALL READI( ISCAL,'ISCAL   ',1,2)
     CALL READI( NPTPLT,'NPTPLT  ',1, 10)
     CALL READI( NTRANS, 'NTRANS  ', 0, 1)
     CALL READI (IMSUB, 'IMSUB   ', 1, 30)
     CALL READI (JMSUB, 'JMSUB   ', 1, 30)
     CALL READI (KMSUB, 'KMSUB   ', 1, 30)
     CALL READI( KPRTC, 'KPRTC   ',0,100)
     CALL READI( KPRTP, 'KPRTP   ',0, 100)
     CALL READI (NPRD, 'NPRD    ', 0, 100)
     CALL READI( NPRC, 'NPRC    ', 0, 100)
     CALL READI( NPRP, 'NPRP    ', 0, 100)
     CALL READN2( UNITS3, 'UNITS3  ')
```

```
     CALL READI (NUNCH, 'NUNCH   ', 1, 95)
     CALL READI (NUNPT, 'NUNPT   ', 1, 15)
     READ(NUNPT) IDAY
     WRITE(6,78) IDAY
   78 FORMAT(2X,'IDAY = ',I8)
C
C  DO LOOP OVER THE STEPS
C
      DO 70 ITT=1,NSTEP
C
C   READ IN PARTICLE PARAMETERS
C
      READ(NUNPT,END=911) IMSB,JMSB,KMSB,NMAX,NCLASS,NPLT,NST,NLOST,
     1 NDEP,TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDS,YDS
      TIME = TIME / 3600.0
      WRITE(6,79) TIME,  IMSUB, JMSUB, KMSUB
  79  FORMAT('1',20X,' CONCENTRATIONS AT TIME ',F10.2,' HOURS',
    1       /,10X,'WITH NEW MAX NUMBER OF GRIDS OF',I4,1X,I4,
    2       ' AND ',I4,' FOR X, Y, AND Z.')
      READ (NUNPT,END=911) (RIO(KK),KK=1,IMSB)
      READ (NUNPT,END=911) (RJO(JJ),JJ=1,JMSB)
      DO 650 II=1,NCLASS
      READ(NUNPT,END=911) N,NUMBD(II),DDIAM(II),DDENZ(II),DMASS(II),
    1      DVELZ(II),(DCOMP(II,JJ),JJ=1,8)
 650  CONTINUE
C
C  READ IN PARTICLE POSITIONS
C
      DO 66 K=1,NMAX
      READ (NUNPT,END=911)NORDR(K),X(K),Y(K),Z(K),ZT
      XTEMP = X(K) + XORIG * XDS
      YTEMP = Y(K) + YORIG * YDS
  66  CONTINUE
     GO TO 961
C
C   HERE IF AN EOF WAS ENCOUNTERED ON UNIT 11.
C
 911 CONTINUE
     WRITE(NW,811)
 811 FORMAT('0',50('*'),' EOF ENCOUNTERED ON UNIT 11'/)
 961 CONTINUE
C
C      CALL SUBROUTINE PRINT, THIS CALLS ALL OF THE
C       REMAINING SUBROUTINES.
C
       CALL PRINT(C,N,X,Y,Z,NORDR,NST,CC,NPTPLT,NTRANS)
C
  70   CONTINUE
       STOP
       END
      SUBROUTINE GRIDEX( X, Y, Z, NST, NPTPLT)
C
C   SUBROUTINE DESCRIPTION
C
C     IN THIS SUBROUTINE THE FLOATING GRID IS EXPANDED AND
C   TRANSLATED TO INCORPORATE ALL OF THE NUMBER PARTICLES. THE GRID
C   IS MADE SUFFICIENTLY LARGE THERE IS A ONE EMPTY GRID ELEMENT
C   BAND ON ALL EDGES.
C
C..................................................................1050
```

```
C
C    COMMON STATEMENTS
C
      COMMON /DPTH/   XDL, YDL, XDS, YDS
      COMMON /CNTL/ IMSUB, JMSUB, KMSUB,  NPPTA,
     1        DT,  TIME, ISCAL, NUNCH, NUNPT
      COMMON /SUBS/   NEXTR, NMAX, NMAX, DX, DY, DZ,
     1    XORIG,YORIG,ZORIG
      COMMON /UNIT/ UNITS3(2)
C
C    DIMENSION STATEMENTS
C
       DIMENSION X(NMAX),Y(NMAX),Z(NMAX)
       DATA NW / 6/
C
C    S T A R T   H E R E
C
C   INITIALIZE MIN AND MAX STORAGE LOCATIONS
C
       XMIN = X(NMAX)
       XMAX = X(NMAX)
       YMIN = Y(NMAX)
       YMAX = Y(NMAX)
C
C   FIND MIN AND MAX VALUES OF X(N) AND Y(N) WITH RESPECT TO THE ORIGI
C
       DO 1 N=1,NMAX
       XN = X(N)
       YN = Y(N)
       IF((XN.EQ.0.0) .OR. (YN.EQ.0.0)) GO TO 1
       IF(XN.GT.XMAX) XMAX = XN
       IF(XN.LT.XMIN) XMIN = XN
       IF(YN.GT.YMAX) YMAX = YN
       IF(YN.LT.YMIN) YMIN = YN
    1  CONTINUE
       XMAX= XMAX+XORIG*XDS
       XMIN= XMIN+XORIG*XDS
       YMAX= YMAX+YORIG*YDS
       YMIN= YMIN+YORIG*YDS
C
C  KEEP THE FLOATING GRID WITHIN THE FIXED DEPTH GRID.
C
C   EXPAND AND MOVE GRID IN X DIRECTION
C
       DX =  (XMAX-XMIN)/FLOAT(IMSUB-3)
C
C   EXPAND AND MOVE GRID IN Y DIRECTION
C
       DY =  (YMAX-YMIN)/FLOAT(JMSUB-3)
C
C   MOVE THE ORIGIN OF THE FLOATING GRID AND PRINTOUT
C
       XORIGN=(XMIN-(1.5*DX))/XDS
       YORIGN=(YMIN-(1.5*DY))/YDS
       XORIGT=XORIGN*XDS
       YORIGT=YORIGN*YDS
       NPRIT = 0
       NTEMP=AMOD(FLOAT(NST),FLOAT(NPTPLT))
       IF(NTEMP.EQ.0) NPRIT=1
      -IF(NPRIT.EQ.0) GO TO 80
```

```
       WRITE(NW,120)
  120  FORMAT(//T34,'FLOATING GRID DEFINITION AND PARTICLE LOCATION',
     1     ' STATISTICS'/'+',T34,57('_')/)
       WRITE(NW,100) XORIGT,YORIGT,UNITS3,DX,UNITS3,DY,UNITS3,XDS,
     1     UNITS3,YDS,UNITS3
  100   FORMAT(' ORIGIN OF FLOATING GRID IS AT (',F11.4,',',
     1  F11.4,') IN  ',2A4,' WITH RESPECT TO THE ORIGIN',
     2  ' OF THE FIXED DEPTH GRID'/' THE NEW GRID SEPERATION IN',
     3 ' THE FLOATING SYSTEM IS ',F15.7,2A4,' IN X AND ',F15.7,
     4  2A4,' IN Y'/
     5  ' THE GRID SEPERATION IN THE FIXED SYSTEM IS ',F10.3,
     6  2A4,' IN X AND',F10.3,2A4,' IN Y'/)
   80  CONTINUE
C
C  DETERMINE THE CHANGE IN POSITION OF THE NEW ORIGIN
C
       XSEP = (XORIG - XORIGN) * XDS
       YSEP = (YORIG - YORIGN) * YDS
C
C  REDEFINE THE ORIGIN
C
       XORIG = XORIGN
       YORIG = YORIGN
C
C   MOVE THE PARTICLES WITH RESPECT TO NEW ORIGIN
C
       XSUM = 0.
       YSUM = 0.
       ZSUM = 0.
       SIGX=0.0
       SIGY=0.0
       SIGZ=0.0
       DO 2 N=1,NMAX
       IF((X(N).EQ.0.) .OR. (Y(N).EQ.0.)) GO TO 2
       X(N) = X(N) + XSEP
       Y(N) = Y(N) + YSEP
       XSUM = XSUM + X(N)
       YSUM = YSUM + Y(N)
       ZSUM = ZSUM + Z(N)
       SIGX = SIGX + X(N)*X(N)
       SIGY = SIGY + Y(N)*Y(N)
       SIGZ = SIGZ + Z(N)*Z(N)
    2  CONTINUE
      XNUM = FLOAT(NMAX)
      SIGX=(SIGX-XSUM*XSUM/XNUM)/(XNUM-1)
      SIGY=(SIGY-YSUM*YSUM/XNUM)/(XNUM-1)
      SIGZ=(SIGZ-ZSUM*ZSUM/XNUM)/(XNUM-1)
      SIGX=SQRT(ABS(SIGX))
      SIGY=SQRT(ABS(SIGY))
      SIGZ=SQRT(ABS(SIGZ))
C
C   OBTAIN AND PRINT THE MEAN VALUE AND STANDARD DEVIATION OF X, OF Y A
C
       XMEAN = XSUM / FLOAT(NMAX)
       YMEAN = YSUM / FLOAT(NMAX)
       ZMEAN = ZSUM / FLOAT(NMAX)
       IF(NPRIT.EQ.0) GO TO 81
       WRITE(NW,200) XMEAN, YMEAN, ZMEAN
       WRITE(NW,201) SIGX,SIGY,SIGZ
  200  FORMAT(' THE AVERAGE VALUES OF X, Y AND Z ARE',3F18.6)
```

Figure VII.-9. Particle Program

```
 201  FORMAT(' THE STANDARD DEVIATIONS ARE    ',3X,3F16.6)
  81  CONTINUE
C
C     R E T U R N   H E R E
C
      IF( (DX.GT.0.0) .AND. (DY.GT.0.0) ) RETURN
C
C   HERE FOR AN ERROR IN THE CALCULATION OF DX OR OF DY.
C
      WRITE(NW,110) DX, DY
 110  FORMAT('0 ERROR ',50('*')/'  DX=',E16.5,'  DY=',E16.5)
C
C     S T O P   H E R E
C
      STOP
      END
      SUBROUTINE CONC( C, X, Y, Z, NORDR)
C
C     SUBROUTINE DESCRIPTION
C
C      IN THIS SUBROUTINE THE CONCENTRATION OF MARKER PARTICLES
C    IS CALCULATED IN EACH OF THE FLOATING GRID CELLS.
C
C.......................................................................
C
C     COMMON STATEMENTS
C
       COMMON /CNTL/ INSUB, JNSUB, KNSUB,  NPRTA,
     1        DT,  TIME, ISCAL, NONCH, NONPT
       COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1       DMASS(200), DVEL2(200), DCOMP(200,8), NCLAS
       COMMON /SUBS/   NSTEP, NMAX, NMAT, DX, DY, DZ,
     1     XORIG,YORIG,ZORIG
       COMMON /DPTH/  XDL, YDL, XDS, YDS
       COMMON /PRNT/ KPRTC, KPRTF, NPRD, NPRC, NPRP
C
C        DIMENSION STATEMENTS
C
       DIMENSION C(30,30,10)
       DIMENSION X(NMAX),Y(NMAX),Z(NMAX)
       INTEGER*2 NORDR(NMAX)
       DATA NW / 6/
C
C     S T A R T   H E R E
C
C   INITIALIZE THE CONCENTRATION ARRAY
C
        DO 111 I=1,INSUB
        DO 111 J=1,JNSUB
        DO 111 K=1,KNSUB
 111    C(I,J,K)=0.0
C
C   DO LOOP OVER ALL MARKER PARTICLES
C
        DO 100 N=1,NMAX
        IF(X(N).LT.0..OR.Y(N).LT.0..OR.Z(N).LE.0.) GO TO 100
        DXT = DX
        DYT = DY
        IF(ISCAL.EQ.1) GO TO 75
        SCAL = (6371.0*1000.0*3.14159)/180.0
```

```
        TPAR = YDS*YORIG+Y(N) + (YDL-YDS)
        DYT = DYT * SCAL
        DXT = DXT*(SCAL*COS(TPAR/57.296))
  75    CONTINUE
C
C    OBTAIN THE VOLUME OF A GRID ELEMENT
C
       DSQ = DXT*DYT*DZ
C
C    OBTAIN THE MASS DENSITY PER UNIT VOLUME. XND IS IN
C    METRIC TONS PER CUBIC METER OR MILLIGRAMS PER MILLILITER.
C
       II = NORDR(N)
       XND = DMASS(II) / DSQ
C
C    OBTAIN THE SUBSCRIPTS FOR THE GRID ELEMENT FOR THIS PARTICLE
C
       PI = X(N) / DX
       IP = PI + 1
       PJ = Y(N) / DY
       JP = PJ + 1
       PK = Z(N) / DZ
       KP = PK + 1
C
C    OBTAIN THE XYZ POSITION OF THE MARKER RELATIVE TO CELL CENTER
C
       XP = PI - FLOAT(IP) + 0.5
       YP = PJ - FLOAT(JP) + 0.5
       ZP = PK - FLOAT(KP) + 0.5
C
C    OBTAIN THE SUBSCRIPTS OF THOSE ELEMENTS AFFECTED BY THIS MARKER
C    AXP, AYP AND AZP ARE THE ABSOLUTE VALUES OF XP, YP AND ZP
C
       IF(XP) 1,2,2
   1   IQ = IP - 1
       AXP = -XP
       GO TO 3
   2   IQ = IP + 1
       AXP = XP
   3   CONTINUE
       IF(YP) 4,5,5
   4   JQ = JP - 1
       AYP = -YP
       GO TO 6
   5   JQ = JP + 1
       AYP = YP
   6   CONTINUE
       IF(ZP) 7,8,8
   7   KQ = KP - 1
       AZP = -ZP
       GO TO 9
   8   KQ = KP + 1
       AZP = ZP
   9   CONTINUE
C
C    CALCULATE THE ABSOLUTE DISTANCE OFFCENTER FOR  THIS MARKER
C
       XQ = 1.0 - AXP
       YQ = 1.0 - AYP
       ZQ = 1.0 - AZP
```

```
C
C    MULTIPLY AXP AND XQ BY XND TO SAVE MULTIPLICATIONS LATER
C
        AXP = XND * AXP
        XQ = XND * XQ
C
C    MARK ALL SUBSCRIPTS WHICH ARE OUT OF RANGE
C
        L1 = 0
        L2 = 0
        L3 = 0
        L4 = 0
        L5 = 0
        L6 = 0
        IF( (IP.GT.INSUB) .OR. (IP.LT.1) ) L1 = 1
        IF( (IQ.GT.INSUB) .OR. (IQ.LT.1) ) L2 = 1
        IF( (JP.GT.JNSUB) .OR. (JP.LT.1) ) L3 = 1
        IF( (JQ.GT.JNSUB) .OR. (JQ.LT.1) ) L4 = 1
        IF( (KP.GT.KNSUB) .OR. (KP.LT.1) ) L5 = 1
        IF( (KQ.GT.KNSUB) .OR. (KQ.LT.1) ) L6 = 1
C
C    ADD CONCENTRATION DUE TO THIS MARKER
C
        IF((L1.EQ.1) .OR. (L3.EQ.1) .OR. (L5.EQ.1)) GO TO 10
        C(IP,JP,KP) =   C(IP,JP,KP) + XQ * YQ * ZQ
  10    IF((L2.EQ.1) .OR. (L3.EQ.1) .OR. (L5.EQ.1)) GO TO 11
        C(IQ,JP,KP) =   C(IQ,JP,KP) + AXP * YQ * ZQ
  11    IF((L1.EQ.1) .OR. (L4.EQ.1) .OR. (L5.EQ.1)) GO TO 12
        C(IP,JQ,KP) =   C(IP,JQ,KP) + XQ * AYP * ZQ
  12    IF((L1.EQ.1) .OR. (L3.EQ.1) .OR. (L6.EQ.1)) GO TO 13
        C(IP,JP,KQ) =   C(IP,JP,KQ) + XQ * YQ * AZP
  13    IF((L2.EQ.1) .OR. (L4.EQ.1) .OR. (L5.EQ.1)) GO TO 14
        C(IQ,JQ,KP) =   C(IQ,JQ,KP) + AXP * AYP * ZQ
  14    IF((L2.EQ.1) .OR. (L3.EQ.1) .OR. (L6.EQ.1)) GO TO 15
        C(IQ,JP,KQ) =   C(IQ,JP,KQ) + AXP * YQ * AZP
  15    IF((L1.EQ.1) .OR. (L4.EQ.1) .OR. (L6.EQ.1)) GO TO 16
        C(IP,JQ,KQ) =   C(IP,JQ,KQ) + XQ * AYP * AZP
  16    IF((L2.EQ.1) .OR. (L4.EQ.1) .OR. (L6.EQ.1)) GO TO 17
        C(IQ,JQ,KQ) =   C(IQ,JQ,KQ) + AXP * AYP * AZP
  17    CONTINUE
 100     CONTINUE
C
C     R E T U R N   H E R E
C
         RETURN
         END
        SUBROUTINE PRINT(C,N,X,Y,Z,NORDR,NST,CC,NPTPLT,NTRANS)
C
C     SUBROUTINE DESCRIPTION
C
C      THIS SUBROUTINE HANDLES ALMOST ALL OUTPUT OPERATIONS.
C
C.......................................................................
C
C     COMMON STATEMENTS
C
       COMMON /DPTH/  XDL, YDL, XDS, YDS
C
       COMMON /CNTL/ INSUB, JNSUB, KNSUB, NPRTA,
     1        DT,  TIME, ISCAL, NONCH, NONPT
```

```
       COMMON /PRNT/ KPRTC, KPRTP, NPRD, NPRC, NPRP
       COMMON /PTYP/ NCLASS, NUMBD(200), DDIAM(200), DDENS(200),
     1       DMASS(200), DVEL2(200), DCOMP(200,8), NCLAS
       COMMON /SUBS/  NSTEP,  NMAX, NMAT, DX, DY, DZ,
     1       XORIG,YORIG,ZORIG
       COMMON /UNIT/ UNITS3(2)
C
C     DIMENSION STATEMENTS
C
       DIMENSION C(30,30,10)
        DIMENSION DPLT(30,30), NPLT(30,30), CC(30,30)
        DIMENSION X(NMAX), Y(NMAX), Z(NMAX)
        DIMENSION BJO(30), BIO(30)
        INTEGER N(30,30,10)
         INTEGER*2 NORDR(NMAX)
        DATA NW / 6/
C
C     S T A R T   H E R E
C
        DO 54 I=1,30
        DO 54 J=1,30
        NPLT(I,J)=0.0
        DPLT(I,J)=10.0
  54    CONTINUE
C
C    PRINT 3-D CONCENTRATION FIELD AT EACH LEVEL
C   NOTE: C IS IN METRIC TONS OF OIL PER CUBIC FEET OF WATER.
C         CC IS PRINTED OUT AS MG OIL PER ML WATER.
C         THIS IS A FACTOR OF 1000, ALSO CC IS IN
C         PARTS PER THOUSAND.
C
        IF( (KPRTC.EQ.0) .OR. (NPRC.EQ.0) ) GO TO 16
        TST = AMOD( FLOAT(NST),FLOAT(KPRTC))
        IF(TST.NE.0.0) GO TO 16
        CALL GRIDXY( X, Y, Z, NST, NPTPLT)
        CALL CONT( C, X, Y, Z, NORDR)
C
C    FIND THE DISTANCE FROM ORIGIN OF FIXED SYSTEM TO GRID LOCATIONS
C
        XL1 = XORIG + XDS -0.5*DX
        YL1 = YORIG + YDS -0.5*DY
        DO 150 I=1,INSUB
        XL1 = XL1 + DX
 150    BIO(I) = XL1
        DO 160 J=1,JNSUB
        YL1 = YL1 + DY
 160    BJO(J) = YL1
        DO 19 K=1,KNSUB
        WRITE(NW,17) NST, TIME, K
  17    FORMAT(//,10X,'CONCENTRATION IN MG OF OIL PER ML OF WATER',
     1   5X,'STEP NUMBER',I4,5X,'TIME',F12.2,2X,'LEVEL',I4/)
        WRITE(NW,4) (BJO(J),J=1,JNSUB)
   4    FORMAT(9X,15F8.2)
        DO 19 I=1,INSUB
        IF(NTRANS.NE.0) GO TO 30
        DO 191 J=1,JNSUB
        CC(I,J) = C(I,J,K) * 1000.0
 191    CONTINUE
        WRITE(NW,66) BIO(I), (CC(I,J),J=1,JNSUB)
  66    FORMAT(1X,F8.2,2X,15F8.5)
```

Figure VII.-5. Particle Program

```
         GO TO 19
C
C  TRANSFORM CONCENTRATION FIELD FROM DIMENSIONLESS X-SPACE
C  BACK TO REAL CARTESIAN X-Y-Z SPACE
C
  30     DO 18 J=1,JNSUB
          CC(I,J) = 0.0
          DN = DPLT(I,J) + WPLT(I,J)
          IF(DN.EQ.0.0) GO TO 18
          CC(I,J) = C(I,J,K) *1000.0/DN
  18     CONTINUE
         WRITE(NW,66) RIO(I), (CC(I,J),J=1,JNSUB)
  19     CONTINUE
  16     CONTINUE
C
C  PRINT PARTICLE COORDINATES AND PARAMETERS
C
         IF( (KPRTP.EQ.0) .OR. (NPRP.EQ.0) ) GO TO 23
         TST = AMOD( FLOAT(NST), FLOAT(KPRTP))
         IF(TST.NE.0.0) GO TO 23
         WRITE(NW,20) UNITS1, TIME
 20      FORMAT(1H1,5X,'PARTICLE POSITIONS X AND Y IN THE FLOATING'
     1 ,' SYSTEM IN ',2A4,' Z IN METERS ',/,20X,' PARTICLE PARAMETERS'
     2 ' AT TIME ',F12.2)
          WRITE(NW,51)
 51      FORMAT(///19X,'PARTICLE POSITION',16X,'PARTICLE POSITION',
     1  26X,'PARTICLE PARAMETERS'/20X,'FLOATING SYSTEM',19X
     2'FIXED SYSTEM')
         WRITE(NW,52)
 52      FORMAT(4X,'N',10X,'X',10X,'Y',10X,'Z',10X,'X',10X,'Y',10X,'Z',
     1  9X,'DIAMETER',5X,'DENSITY',3X,
     2  'SET. VEL.',4X,'MASS'//)
        DO 21 N=1,NMAX
         XTEMP = X(N) + XORIG + XDS
         YTEMP = Y(N) + YORIG + YDS
         ZTEMP = Z(N) + ZORIG
C
C  UNTRANSFORM Z IF NECESSARY
C
         II = NORDP(N)
         WRITE(NW,22) N, X(N), Y(N), Z(N),XTEMP, YTEMP, ZTEMP,
     1   DDIAM(II), DDENS(II), DVELZ(II), DMASS(II)
  22     FORMAT(1X,I4,4X,3F11.4,2F11.3,F11.4,3F12.4,F15.3)
  21     CONTINUE
   23    CONTINUE
C
C   WRITE OUT TO DISK
C
         IF(NPRD.EQ.0) RETURN
         TST = AMOD(FLOAT(NST), FLOAT(NPRD))
         IF(TST.NE.0.0) RETURN
        IF(NPRC.EQ.0) GO TO 750
         TST = AMOD( FLOAT(NST), FLOAT(NPRC))
         WRITE(NOPCH) INSUB,JNSUB,KNSUB,NMAX,NCLASS,NDNCY,NST,NLOST,
     1 NDIP,TIME,XORIG,YORIG,ZORIG,DX,DY,DZ,XDL,YDL,AD,XDS,YDS
         WRITE(NOPCH) (RIO(I),I=1,INSUB)
         WRITE(NOPCH) (RJO(J),J=1,JNSUB)
         IF(NTPARS.EQ.0) GO TO 700
        DO 708 K=1,KNSUB
        DO 710 I=1,INSUB
```

```
                     5        NSTEP
                     2        ISCAL
                     1        NPTPLT
                     0        NTPARS
                    10        INSUB
                    10        JNSUB
                     3        KNSUB
                     1        KPRTC
                     1        KPRTP
                     1        NPRD
                     1        NPRC
                     1        NPRP
               DEGREES        UNITS3
                    10        NOPCH
                    11        NOPPT
//GO.FT10F001 DD DUMMY
//GO.FT11F001 DD DSN=UBI.ZZA1.DEBUG.PHD350,DISP=SHR
//
```

```
        DO 710 J=1,JNSUB
        IF(DPLT(I,J).EQ.0.0.AND.WPLT(I,J).EQ.0.0) GO TO 720
        GO TO 730
  720   CC(I,J) = 0.0
  730   CC(I,J) = C(I,J,K) * 1000.0 / (DPLT(I,J) + WPLT(I,J))
  710   CONTINUE
        WRITE(NOPCH) ((CC(I,J),I=1,INSUB),J=1,JNSUB)
  708   CONTINUE
         GO TO 750
 700    CONTINUE
        DO 701 K=1,KNSUB
        DO 702 J=1,JNSUB
        DO 702 I=1,INSUB
        CC(I,J) = C(I,J,K) * 1000.0
 702    CONTINUE
        WRITE(NOPCH) ((CC(I,J),I=1,INSUB),J=1,JNSUB)
 701    CONTINUE
 750   CONTINUE
C
C    R E T U R N   H E R E
C
       RETURN
       END
       SUBROUTINE READ1(I,IWANT,NL,NU)
       REAL*8 IWANT,IPWANT
       DATA NR,NW /5,6/
       READ(NR,10) I,IPWANT
 10    FORMAT(I15,5X,A8)
       IF(IPWANT.EQ.IWANT) GO TO 100
        WRITE(NW,20) IPWANT, IWANT
 20     FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
        STOP
 100    CONTINUE
        IF(NL.EQ.NU) GO TO 200
        IF((I.GE.NL) .AND. (I.LE.NU)) GO TO 200
        WRITE(NW,40) IWANT, NL, NU, IWANT, I
 40     FORMAT(16H0 THE LIMITS ON ,A8,5H ARE ,I5,4H TO ,I5,
     1  6H. BUT ,A8,16H WAS READ IN AS  ,I5)
         STOP
 200   CONTINUE
       WRITE(NW,30) I, IWANT
 30    FORMAT(2X,I15,5X,A8)
       RETURN
       END
       SUBROUTINE READ2( X, IWANT)
       DIMENSION X(2)
       REAL*8 IWANT, IPWANT
       DATA NR,NW /5,6/
       READ(NR,10) X, IPWANT
 10    FORMAT(7X,2A4,5X,A8)
       IF(IWANT.EQ.IPWANT) GO TO 100
       WRITE(NW,20) IPWANT,IWANT
 20    FORMAT(21H CARDS OUT OF ORDER  ,A8,6H READ ,A8,10H REQUESTED)
       STOP
 100   WRITE(NW,30) X, IWANT
 30    FORMAT(9X,2A4,5X,A8)
       RETURN
       END
//GO.SYSIN DD *
           5000      NMAX
```

Figure VII.-9. Particle Program

APPENDIX VIII, A SAMPLE RUN

This Appendix presents all data input from cards and the resulting output for a complete simulation. This case simulates a 5.7 million gallon spill of an oil similar to #2 fuel oil released over a six hour period. The location of the spill is off Massachusetts near Georges Bank. The environmental data used here is a sample and is not of the actual data used for previous runs in Cornillon, et al. (1979 and 1980). Figures VIII-1 to VIII-4 present the output for these programs. The reader should refer to Figure VII-1 for the input to the program GRIDS. The output of READATA (Figures VIII-2-4) shows the wind and currents which were used for the main simulation.

The input data stream for the full simulation is illustrated in Figure VIII-5. Note that some of the environmental data sets (wind, currents, etc.) are read from disk data sets and are not shown in the input stream. The output corresponding to the input of Figure VIII-5 is illustrated in Figure VIII-6. The input stream to the Preview Run is not shown here as it is identical to that for the full simulation, figure VIII-5, with the minor exception that the control parameter NRUN is equal to 0 for the Main simulation compared to 1 for the Preview. The output for the first ten time steps of the simulation are shown in Figure VIII-7. Note that the mass balance differs between the Preview and Main simulation due to the depositec particles.

Figure VIII-8 shows the output of a sample restarted run. The subsurface parameters of a restarted run will not be the same as a full run due to the re-initialization of the random number generator in Subroutine INJECT. The remaining figures deal with the input and resulting output for the output programs. Figures VIII-9 and VIII-10 show the printed output and resulting plot from the program PLOTMASS. The user is again referred to Appendix VII where the program listing also displays the input parameters. Figure VIII-11 is an output from DATAOUT, which shows all information which has been written out by the main program for use by DATAOUT. Figure VIII-12 shows the abbreviated output from DATAOUT which is generated for the programs PLOTMAP AND PLOTAREA. Figure VIII-13 is the output from CHECDATA which shows the full amount of data formatted by DATAOUT. Figures VIII-14 and VIII-15 shows the output and an example plot generated by the plotting program PLOTMAP. Figures VIII-16 and VIII-17 give the same for the program PLOTAREA. Figure VIII-18 shows the output from the program PARTICLE which was generated from the data in Figure VIII-11. The output is read left to right.

```
INPUT PARAMETERS:
          1      NPRTA
          2      NO
          1      NU
          1      NUR
          1      ND
          5      NUNIT
10800.00000      DT
          1      TSCAL
          5      IMAX
          5      JMAX
   20.00000      ANGLE
  500.00000      XS
  800.00000      YS
   71.75000      XL
   39.75000      YL
WIND VEL          TITLE
   U             VAR1
      M /SEC      UNITS1
    METERS       UNITS3
   V             VAR2
      M /SEC      UNITS2
```

```
                         WIND VEL     INPUT DATA       0.0  HOURS AFTER THE BEGINNING OF THE SPILL

THE WIND VEL     GRID HAS      5 DIVISIONS IN X SPACED     500.     METERS  APART
                      AND      5 DIVISIONS IN Y SPACED     800.     METERS  APART.

THE (1,1) GRID LOCATION OF THE WIND VEL     COORDINATE SYSTEM IS AT  71.750000 DEGREES LONGITUDE AND  39.750000 DEGREES LATITUDE.

FINALLY THE X AXIS OF THE WIND VEL     GRID MAKES AN ANGLE (COUNTERCLOCKWISE) OF 20.000000 DEGREES WITH LINES OF
CONSTANT LATITUDE.

                                          U        VALUES IN UNITS OF       M /SEC
 Y                                                  X ELEMENTS
ELEMENTS  1        2        3        4        5

   5      5.       5.       5.       5.       5.

   4      4.       4.       4.       4.       4.

   3      3.       3.       3.       3.       3.

   2      2.       2.       2.       2.       2.

   1      1.       1.       1.       1.       1.

                                          V        VALUES IN UNITS OF       M /SEC
 Y                                                  X ELEMENTS
ELEMENTS  1        2        3        4        5

   5      0.0      0.0      0.0      0.0      0.0

   4      0.0      0.0      0.0      0.0      0.0

   3      0.0      0.0      0.0      0.0      0.0

   2      0.0      0.0      0.0      0.0      0.0

   1      0.0      0.0      0.0      0.0      0.0
```

Figure VIII.-1. Sample Output from Program Grids

```
INPUT PARAMETERS
           1      [illegible]
           2      [illegible]
           1      [illegible]
          10      [illegible]
           1      [illegible]
           2      ISCAL

                                        WIND VEL     INPUT DATA       0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

         THE WIND VEL     GRID HAS     1 DIVISIONS IN X SPACED    0.500    DEGREES  APART
                              AND      1 DIVISIONS IN Y SPACED    0.250    DEGREES  APART.

         THE (1,1) GRID LOCATION OF THE WIND VEL     COORDINATE SYSTEM IS AT  69.000003 DEGREES LONGITUDE AND  61.250000 DEGREES LATITUDE


                                                   U       VALUES IN UNITS OF     M/SEC
         Y                                                   X ELEMENTS
       ELEMENTS  1

         1      0.0


                                                   V       VALUES IN UNITS OF     M/SEC
         Y                                                   X ELEMENTS
       ELEMENTS  1

         1      -6.
                                        WIND VEL     INPUT DATA       0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

         THE WIND VEL     GRID HAS     1 DIVISIONS IN X SPACED    0.500    DEGREES  APART
                              AND      1 DIVISIONS IN Y SPACED    0.250    DEGREES  APART.

         THE (1,1) GRID LOCATION OF THE WIND VEL     COORDINATE SYSTEM IS AT  69.000003 DEGREES LONGITUDE AND  61.250000 DEGREES LATITUDE


                                                   U       VALUES IN UNITS OF     M/SEC
         Y                                                   X ELEMENTS
       ELEMENTS  1

         1      0.0


                                                   V       VALUES IN UNITS OF     M/SEC
         Y                                                   X ELEMENTS
       ELEMENTS  1

         1      -9.
                                        WIND VEL     INPUT DATA       0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

         THE WIND VEL     GRID HAS     1 DIVISIONS IN X SPACED    0.500    DEGREES  APART
                              AND      1 DIVISIONS IN Y SPACED    0.250    DEGREES  APART.

         THE (1,1) GRID LOCATION OF THE WIND VEL     COORDINATE SYSTEM IS AT  69.000003 DEGREES LONGITUDE AND  61.250000 DEGREES LATITUDE


                                                   U       VALUES IN UNITS OF     M/SEC
         Y                                                   X ELEMENTS
       ELEMENTS  1

         1      9.


                                                   V       VALUES IN UNITS OF     M/SEC
         Y                                                   X ELEMENTS
       ELEMENTS  1

         1      0.0
```

Figure VIII.-2. Output from READATA; Wind Speed and Direction

```
INPUT PARAMETERS
                1     NPUTS
                1     PO
                1     [illegible]
               10     NUM
                1     PD
                2     ISCAL
```

```
                              OTID CURRENT INPUT DATA      0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

 THE OTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED    0.357E-01DEGREES  APART
                      AND     14 DIVISIONS IN Y SPACED    0.357E-01DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE OTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.369991 DEGREES LATITUDE.

ALL VALUES  FOR PRINTOUT HAVE BEEN DIVIDED BY 10** -6

                              U        VALUES IN UNITS OF M/S

  Y                                     X ELEMENTS
ELEMENTS  1      2      3      4      5      6      7      8      9      10     11     12     13     14

   14    0.019  0.019  0.019  0.283  0.275  0.525  0.787  0.763  0.792  0.708  0.737  0.551  0.131  0.085
   13    0.018  0.018  0.018  0.304  0.423  0.750  0.714  0.857  0.781  0.751  0.620  0.688  0.220  0.098
   12    0.016  0.016  0.016  0.250  0.307  0.487  0.670  0.703  0.772  0.626  0.555  0.494  0.111  0.059
   11    0.014  0.014  0.600  0.120  0.194  0.225  0.604  0.627  0.778  0.600  0.533  0.391  0.354  0.637
   10    0.013  0.013  0.013  0.013  0.259  0.122  0.553  0.580  0.715  0.514  0.610  0.574  0.454  0.490
    9    0.011  0.011  0.011  0.011  0.322  0.019  0.526  0.524  0.704  0.505  0.702  0.726  0.587  0.375
    8    0.009  0.009  0.009  0.009  0.219  0.018  0.461  0.501  0.440  0.479  0.612  0.587  0.514  0.351
    7    0.048  0.554  0.120 -0.142  0.157  0.053  0.184  0.029  0.417  0.413  0.471  0.448  0.108  0.128
    6    0.058  0.300  0.160 -0.081  0.029 -0.060  0.197  0.170  0.225  0.183  0.284  0.409  0.125  0.336
    5    0.089  0.086  0.199 -0.020 -0.100 -0.159 -0.150 -0.217 -0.551 -0.307  0.019  0.190  0.224  0.294
    4    0.072  0.073  0.181  0.027 -0.071 -0.213 -0.012 -0.111 -0.118 -0.134  0.018  0.110  0.119  0.170
    3    0.097  0.100  0.087  0.071 -0.041 -0.071  0.085 -0.004 -0.089  0.039  0.049  0.029  0.014  0.044
    2    0.109  0.099  0.075  0.070  0.029  0.014  0.081  0.016 -0.019  0.016  0.013  0.079  0.032  0.060
    1    0.123  0.096  0.063  0.064  0.098  0.097  0.082  0.019  0.007 -0.007  0.016  0.012  0.051  0.071
                              OTID CURRENT INPUT DATA      0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

 THE OTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED    0.357E-01DEGREES  APART
                      AND     14 DIVISIONS IN Y SPACED    0.357E-01DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE OTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.369991 DEGREES LATITUDE.

ALL VALUES  FOR PRINTOUT HAVE BEEN DIVIDED BY 10** -6

                              U        VALUES IN UNITS OF M/S

  Y                                     X ELEMENTS
ELEMENTS  1      2      3      4      5      6      7      8      9      10     11     12     13     14

   14    0.609  0.609  0.609  0.433  0.465  0.718  0.974  0.957  0.981  0.848  0.976  0.740  0.122  0.215
   13    0.606  0.606  0.606  0.574  0.611  0.918  0.925  1.044  0.971  0.919  0.817  0.816  0.409  0.287
   12    0.604  0.604  0.604  0.482  0.495  0.675  0.858  0.890  0.960  0.818  0.763  0.688  0.499  0.646
   11    0.601  0.601  0.827  0.311  0.181  0.412  0.791  0.818  0.965  0.787  0.720  0.578  0.503  0.470
   10    0.599  0.599  0.599  0.599  0.485  0.309  0.739  0.766  0.921  0.720  0.796  0.760  0.483  0.676
    9    0.597  0.597  0.597  0.597  0.507  0.205  0.711  0.710  0.890  0.691  0.887  0.911  0.773  0.561
    8    0.594  0.594  0.594  0.594  0.424  0.203  0.648  0.686  0.805  0.664  0.797  0.772  0.499  0.516
    7    0.252  0.700  0.308  0.082  0.381  0.237  0.571  0.614  0.801  0.597  0.655  0.669  0.578  0.512
    6    0.262  0.484  0.381  0.102  0.212  0.128  0.180  0.157  0.409  0.327  0.447  0.592  0.509  0.520
    5    0.211  0.229  0.382  0.161  0.083 -0.176  0.011 -0.038 -0.170 -0.125  0.202  0.376  0.408  0.478
    4    0.250  0.255  0.325  0.209  0.111 -0.031  0.150  0.071 -0.136  0.048  0.196  0.292  0.302  0.352
    3    0.278  0.282  0.269  0.255  0.180  0.111  0.266  0.176  0.097  0.220  0.191  0.210  0.196  0.277
    2    0.290  0.279  0.256  0.251  0.210  0.195  0.264  0.197  0.182  0.197  0.198  0.210  0.212  0.241
    1    0.301  0.276  0.291  0.248  0.278  0.277  0.262  0.219  0.187  0.171  0.197  0.212  0.232  0.251
```

Figure VIII.-3. Output from READATA; x-direction currents

```
                              UTID CURRENT INPUT DATA       0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

 .THE UTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED     0.357E-01DEGREES  APART
                     AND       14 DIVISIONS IN Y SPACED     0.357E-01DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE UTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  43.189991 DEGREES LATITUDE.

 ALL VALUES  FOR PRINTOUT HAVE BEEN DIVIDED BY 10** -6

                                          U       VALUES IN UNITS OF M/S

   Y                                               X ELEMENTS
ELEMENTS  1       2       3       4       5       6       7       8       9      10      11      12      13      14

   14       0.139   0.139   0.139  -0.017  -0.005   0.245   0.507   0.487   0.512   0.428   0.456   0.271  -0.148  -0.215

   13       0.138   0.138   0.138   0.107   0.141   0.470   0.457   0.578   0.503   0.472   0.149   0.369  -0.058  -0.181

   12       0.138   0.138   0.138  -0.028   0.029   0.209   0.192   0.428   0.498   0.348   0.277   0.218   0.011   0.181

   11       0.137   0.137   0.363  -0.153  -0.081  -0.052   0.327   0.350   0.501   0.321   0.256   0.118   0.079   0.160

   10       0.137   0.137   0.137   0.137  -0.017  -0.154   0.277   0.104   0.459   0.258   0.338   0.298   0.180   0.218

    9       0.136   0.136   0.136   0.136   0.047  -0.256   0.251   0.250   0.429   0.230   0.427   0.451   0.312   0.100

    8       0.136   0.136   0.136   0.136  -0.035  -0.256   0.190   0.227   0.387   0.205   0.339   0.313   0.240   0.077

    7      -0.205   0.283  -0.153  -0.415  -0.116  -0.220   0.118   0.157   0.188   0.140   0.199   0.212   0.121   0.055

    6      -0.213   0.029  -0.112  -0.351  -0.241  -0.331  -0.075  -0.098  -0.086  -0.129   0.012   0.117   0.058   0.068

    5      -0.222  -0.228  -0.071  -0.291  -0.370  -0.629  -0.420  -0.488  -0.428  -0.578  -0.252  -0.077  -0.005   0.025

    4      -0.198  -0.196  -0.127  -0.242  -0.381  -0.481  -0.102  -0.381  -0.588  -0.401  -0.255  -0.160  -0.150  -0.099

    3      -0.172  -0.164  -0.181  -0.196  -0.310  -0.339  -0.188  -0.275  -0.153  -0.230  -0.259  -0.240  -0.255  -0.221

    2      -0.158  -0.169  -0.193  -0.197  -0.218  -0.258  -0.198  -0.251  -0.108  -0.251  -0.255  -0.218  -0.236  -0.208

    1      -0.188  -0.171  -0.208  -0.199  -0.168  -0.170  -0.185  -0.228  -0.260  -0.278  -0.250  -0.215  -0.215  -0.198
```

Figure VIII.-3. Output from READATA; x-direction currents

```
INPUT PARAMETERS
          1     NDATA
          1     NU
          1     NV
         10     NUM
          1     ND
          2     ISCAL

                                        VTID CURRENT INPUT DATA       0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

  THE VTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED    0.1578-01DEGREES  APART
                          AND   14 DIVISIONS IN Y SPACED    0.1578-01DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE VTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.349991 DEGREES LATITUDE.

 ALL VALUES  FOR PRINTOUT HAVE BEEN DIVIDED BY 10** -6

                                             V       VALUES IN UNITS OF M/S

     Y                                                X ELEMENTS
ELEMENTS  1        2        3        4        5        6        7        8        9        10       11       12       13       14

   14      0.256    0.256    0.256   -0.315   -0.125   -0.018    0.114    0.387    0.553    0.621    0.719    0.911    0.771    0.805

   13      0.256    0.256    0.256   -0.397   -0.197    0.064    0.209    0.456    0.511    0.624    0.578    0.887    0.810    0.751

   12      0.256    0.256    0.256   -0.344   -0.183    0.104    0.192    0.326    0.423    0.468    0.508    0.721    0.655    0.690

   11      0.256    0.256   -0.315   -0.291   -0.169    0.185    0.174    0.261    0.377    0.416    0.487    0.620    0.576    0.659

   10      0.256    0.256    0.256    0.256   -0.187    0.026    0.166    0.212    0.218    0.226    0.226    0.310    0.231    0.291

    9      0.256    0.256    0.256    0.256   -0.125   -0.092    0.159    0.174    0.066    0.062   -0.022   -0.020   -0.136   -0.096

    8      0.256    0.256    0.256    0.256   -0.096   -0.021    0.191    0.140    0.090    0.087   -0.014    0.019   -0.126   -0.100

    7     -0.158    0.629    0.780    0.270   -0.067   -0.007    0.087    0.091    0.019    0.083   -0.089   -0.104   -0.056   -0.061

    6      0.067    0.351    0.589    0.260    0.305    0.187   -0.026   -0.018    0.126    0.187   -0.076   -0.081   -0.059   -0.061

    5      0.298    0.071    0.418    0.250    0.676    0.503   -0.249   -0.201    0.342    0.414   -0.104   -0.031   -0.036   -0.055

    4      0.110    0.017    0.201    0.109    0.268    0.192   -0.224   -0.145    0.116    0.202   -0.080    0.082    0.067    0.072

    3     -0.035   -0.040   -0.018   -0.032   -0.140   -0.120   -0.198   -0.088,  -0.109   -0.010    0.025    0.115    0.159    0.199

    2     -0.012   -0.004    0.015    0.017   -0.092   -0.085   -0.121   -0.049   -0.041    0.029    0.040    0.094    0.127    0.159

    1      0.012    0.011    0.068    0.067   -0.041   -0.051   -0.041   -0.010    0.026    0.064    0.056    0.071    0.098    0.120
                                        VTID CURRENT INPUT DATA       0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

  THE VTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED    0.1578-01DEGREES  APART
                          AND   14 DIVISIONS IN Y SPACED    0.1578-01DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE VTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.349991 DEGREES LATITUDE.

 ALL VALUES  FOR PRINTOUT HAVE BEEN DIVIDED BY 10** -6

                                             V       VALUES IN UNITS OF M/S

     Y                                                X ELEMENTS
ELEMENTS  1        2        3        4        5        6        7        8        9        10       11       12       13       14

   14      0.285    0.285    0.285   -0.126   -0.137   -0.030    0.122    0.375    0.541    0.610    0.728    0.901    0.759    0.594

   13      0.285    0.285    0.285   -0.408   -0.209    0.052    0.197    0.444    0.522    0.612    0.567    0.875    0.799    0.739

   12      0.285    0.285    0.285   -0.356   -0.195    0.093    0.180    0.318    0.411    0.456    0.496    0.711    0.691    0.678

   11      0.285    0.285   -0.326   -0.303   -0.181    0.131    0.162    0.251    0.165    0.405    0.475    0.608    0.565    0.688

   10      0.285    0.285    0.285    0.285   -0.159    0.014    0.155    0.201    0.206    0.214    0.214    0.299    0.219    0.281

    9      0.285    0.285    0.285    0.285   -0.137   -0.103    0.147    0.162    0.054    0.050   -0.031   -0.011   -0.147   -0.108

    8      0.285    0.285    0.285    0.285   -0.108   -0.032    0.182    0.129    0.078    0.015   -0.026    0.007   -0.118   -0.112

    7     -0.170    0.617    0.728    0.258   -0.078   -0.019    0.076    0.081    0.007    0.071   -0.060   -0.116   -0.067   -0.071

    6      0.056    0.319    0.577    0.248    0.291    0.136   -0.018   -0.030    0.114    0.175   -0.087   -0.094   -0.071   -0.075

    5      0.282    0.061    0.426    0.218    0.665    0.491   -0.261   -0.211    0.110    0.402   -0.116   -0.082   -0.098   -0.067

    4      0.118    0.005    0.189    0.097    0.256    0.180   -0.216   -0.156    0.104    0.191   -0.051    0.011    0.050    0.060

    3     -0.047   -0.051   -0.049   -0.044   -0.152   -0.111   -0.210   -0.100   -0.121   -0.022    0.013    0.103    0.187    0.187

    2     -0.023   -0.016    0.004    0.005   -0.101   -0.097   -0.112   -0.060   -0.053    0.016    0.029    0.081    0.115    0.187

    1      0.0      0.019    0.057    0.055   -0.055   -0.061   -0.055   -0.022    0.014    0.052    0.044    0.061    0.081    0.108
```

Figure VIII.-4. Output from READATA; y-direction currents

```
                              VTID CURRENT INPUT DATA       0.0   HOURS  AFTER THE BEGINNING OF THE SPILL

 .  THE VTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED    0.357E-01DEGREES  APART
                          AND     14 DIVISIONS IN Y SPACED    0.357E-01DEGREES  APART.

    THE (1,1) GRID LOCATION OF THE VTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  61.169991 DEGREES LATITUDE.

   ALL VALUES  FOR PRINTOUT HAVE BEEN DIVIDED BY 10** -6

                                                  V       VALUES IN UNITS OF M/S

    Y                                                     X ELEMENTS
ELEMENTS  1       2       3       4       5       6       7       8       9       10      11      12      13      14

   14    -0.181  -0.181  -0.181  -0.752  -0.562  -0.455  -0.101  -0.050   0.116   0.188   0.102   0.076   0.310   0.168
   13    -0.181  -0.181  -0.181  -0.810  -0.630  -0.173  -0.228   0.019   0.096   0.187   0.181   0.450   0.371   0.318
   12    -0.181  -0.181  -0.181  -0.782  -0.621  -0.333  -0.246  -0.112  -0.010   0.031   0.071   0.286   0.218   0.251
   11    -0.181  -0.181  -0.752  -0.728  -0.606  -0.292  -0.268  -0.178  -0.060  -0.021   0.049   0.183   0.139   0.222
   10    -0.181  -0.181  -0.181  -0.181  -0.585  -0.411  -0.271  -0.225  -0.219  -0.211  -0.211  -0.127  -0.206  -0.188
    9    -0.181  -0.181  -0.181  -0.181  -0.542  -0.529  -0.278  -0.268  -0.371  -0.375  -0.459  -0.457  -0.573  -0.533
    8    -0.181  -0.181  -0.181  -0.181  -0.533  -0.458  -0.288  -0.297  -0.367  -0.390  -0.453  -0.438  -0.567  -0.537
    7    -0.595   0.192   0.301  -0.167  -0.508  -0.448  -0.350  -0.388  -0.418  -0.358  -0.486  -0.581  -0.483  -0.488
    6    -0.370  -0.086   0.152  -0.137  -0.132  -0.290  -0.461  -0.455  -0.333  -0.250  -0.513  -0.520  -0.496  -0.500
    5    -0.183  -0.368   0.001  -0.187   0.239   0.066  -0.686  -0.639  -0.095  -0.021  -0.381  -0.468  -0.473  -0.492
    4    -0.308  -0.470  -0.337  -0.378  -0.169  -0.246  -0.661  -0.582  -0.321  -0.235  -0.477  -0.395  -0.375  -0.365
    3    -0.472  -0.477  -0.475  -0.469  -0.577  -0.557  -0.635  -0.525  -0.546  -0.487  -0.412  -0.327  -0.278  -0.238
    2    -0.489  -0.482  -0.422  -0.430  -0.529  -0.521  -0.558  -0.486  -0.478  -0.409  -0.397  -0.383  -0.310  -0.278
    1    -0.425  -0.406  -0.369  -0.311  -0.480  -0.488  -0.480  -0.487  -0.411  -0.371  -0.381  -0.368  -0.383  -0.337
```

Figure VIII.-4. Output from READATA; y-direction currents

```
/80
         0       NSTRT
         0       NSTPR
         1       NSUMR
         0       NPOR
       350       IDAY
         1       NPRT
   3.0           DT
  10.0           TIMMAX
         2       ISCAL
         1       NPPTA
         1       NPPTC
         5       NP
         5       NCD
         4       NCO
         5       NDD
         3       NDO
         5       NFD
         3       NFO
         5       NRD
         3       NRO
         5       NSD
         3       NSO
        13       NTDD
        14       NTDV
         1       NTUD
         1       NTUV
        12       NVD
         3       NVO
         5       NCND
         5       NCLO
         5       NSND
         5       NSPD
       500       NMAX
       200       NTCLAS
       200       NURCL
   1.00          IMSPAR
        10       NAISPL
 100.00          CORR
         8       NSPIL
         1       NSPPRD
         1       NSPPPP
         1       NOSP
         3       NUPS
        10       NUCW
        11       NUPT
        19       NUTL
        15       NUPS
         8       NUPP
         9       NULT
         0       NSHOR
   1.111         POWX
   1.111         POWY
   0.050         EXX
   0.050         EYY
         1       NTPARS
 10.0            DXX
 10.0            DYY
   0.00001       DZZ
```

```
       0.00001          DX
       0.00001          DY
       0.11             DZ
                 5      IMSUB
                 5      JMSUB
                 1      KMSUB
                 0      NSUB
                 1      NDIFF
               200      NCPIT
                 1      NPTTP
      0.5               DEPC
        4.0             PORIN
     0.5                APPAC
     2.0                RIPPAC
     2.0                ROPPAC
     50.0               NEWT
       0.001            DDIANT
         0.0            DTFLZT
                 1      NPTSUB
                 1      NPPTAS
                 1      KPPTV
                 1      KPPTC
                 1      KPPTP
                 1      NPPD
                 0      NPPV
                 1      NPPC
                 1      NPPP
BATHYMETRY   DEPTH      METERS
   14    14     0.0      67.000     41.350  0000.0157 0000.0157DEGREES
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  1.00  1.00  1.00  1.00  1.00
CORP CELL
   14    14     0.0      67.000     41.350  0000.0157 0000.0157DEGREES
   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2
```

Figure VIII.-5. Data Input to Main Simulation

```
  2 101 101 101 101 101 101 101 101 101 101 101 101   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101   1   1   1   1   1   1   1   1   1   1   1   2
  2 101 101 101 101 101 101 101 101 101 101 101 101   2
  2   2   2   2   2   2   2   2   2   2   2   2   2   2   2
   1     1     1     1     1     1     0     0
TEMPERATURE TEMP.   DEGREES C
   1     1      0.0 .    67.000    41.350  0000.0357 0000.0357DEGREES
 20.0
SEA STATE   HEIGHT  METERS       PERIOD  SECONDS
   1     1      0.0      67.000    41.350  0000.0357 0000.0157DEGREES
  1.0
 10.0
TIDE LEVEL            METERS
   14    14     0.0      67.000    41.350  0000.0157 0000.0357DEGREES
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   0.00  0.00  0.00  0.00  0.00
    0.000    0.877  25.000   10.000    0.900    1.0001.00E 00  66.820  41.670
 0.05 0.10 0.11 0.05 0.10 0.08 0.21 0.30
    1     1     0     0     0     1     0     0
    0.000    0.877  25.000   10.000    0.900    1.0001.00E 00  66.820  41.670
 0.05 0.10 0.11 0.05 0.10 0.08 0.21 0.30
    1     1     0     0     0     0     0
    0     0     0     0     0     0     0
    0     0     0     0     0     0     1
    12.0       6.0       50.0     10000.0     100.0      66.77     41.62
```

```
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0     1
     21.300      1.000        0.250 10000.000        60.000
     10.000   1000.000        1.000    66.760        41.620
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
     0      0      0      0      0      0      0
//FT01F001 DD DSN=UPI.EFA1.DEBUG.SWD150,DISP=SHR
//FT03F001 DD DSN=UPI.EFA1.DEBUG.RESTART,DISP=SHR
//FT06F001 DD DUMMY
//FT08F001 DD DUMMY
//FT09F001 DD DUMMY
//FT10F001 DD DSN=UPI.EFA1.DEBUG.CWD150,DISP=SHR
//FT11F001 DD DSN=UPI.EFA1.DEBUG.PWD150,DISP=SHR
//FT12F001 DD DSN=UPI.EFA1.WIND.ISCAL2,DISP=SHR,
//    DCB=BUFNO=1
//FT13F001 DD DSN=UPI.EFA1.ISCAL2.UDIR,DISP=SHR,
//    DCB=BUFNO=1
//FT14F001 DD DSN=UPI.EFA1.ISCAL2.VDIR,DISP=SHR,
//    DCB=BUFNO=1
//FT15F001 DD DSN=UPI.EFA1.DEBUG.WWD150,DISP=SHR
```

Figure VIII.-5. Data Input to Main Simulation

```
INPUT CONTROL PARAMETERS

        0     NSTRT
        0     NSTPR
        1     NSURR
        1     NRUN
      350     IDAY
        1     NENV
  3.00000     DT
 18.00000     TIMMAX
        2     ISCAL
        1     NPRTA
        1     NPRTC
        5     NP
        5     NCD
        4     NCO
        5     NDD
        3     NDO
        5     NED
        3     NEO
        5     NFD
        3     NRO
        5     NSD
        3     NSO
       13     NTDU
       14     NTDV
        1     NTOU
        1     NTOV
       12     NOD
        3     NVO
        5     NCRD
        5     NCLD
        5     NSRD
        5     NSPD
      500     NMAX
      200     NTCLAS
      200     NORCL
  1.00000     INSPAR
       10     NAXSPL
100.00000     CONR
        8     NSPIL
        1     NSPPRD
        1     NSPPRP
        1     NOSP
        3     NURS
       10     NOCN
       11     NOPT
       19     NOVL
       15     NOMS
        8     NODP
        9     NOLT
        0     NSHOR

INPUT STREAM FOR THE SUBSURFACE PORTION OF THE MODEL

  1.33300     POWX
  1.33300     POWY
  0.05000     EXX
  0.05000     EYY
        0     NTRANS
 10.00000     DXX
 10.00000     DYY
  0.00001     DZZ
  0.00001     DX
  0.00001     DY
  0.31000     DZ
        5     INSUR
        5     JNSUR
        3     KNSUR
        0     NSUR
        1     NDIFF
      200     NCRIT
        1     NEITR
  0.90000     DEPC
  8.00000     PORIN
  0.50000     AFRAC
  2.00000     DIFFAC
  2.00000     ROFFAC
 50.00000     RFWT
  0.00100     DDIANT
  0.00000     DTELET
        1     NPTSUB
        1     NPPTRS
        1     NPPTV
        1     NPPTC
        1     NPRTP
        1     NPPD
        0     NPPV
        1     NPPC
        1     NPPP
```

```
                              BATHYMETRY   INPUT DATA       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

 THE BATHYMETRY   GRID HAS    14 DIVISIONS IN X SPACED       0.0157 DEGREES  APART
                       AND    14 DIVISIONS IN Y SPACED       0.0157 DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE BATHYMETRY   COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.350000 DEGREES LATITUDE


                                        DEPTH    VALUES IN UNITS OF METERS

    Y                                                  X ELEMENTS
ELEMENTS    1       2       3       4       5       6       7       8       9       10      11      12      13      14

   14     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

   13     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

   12     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

   11     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

   10     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    9     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    8     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    7     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    6     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    5     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    4     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    3     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    2     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

    1     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
                                  COMP CELL    INPUT DATA       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

.. THE COMP CELL    GRID HAS    14 DIVISIONS IN X SPACED       0.0157 DEGREES  APART
                         AND    14 DIVISIONS IN Y SPACED       0.0157 DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE COMP CELL    COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.350000 DEGREES LATITUDE


                                              VALUES IN UNITS OF

    Y                                                  X ELEMENTS
ELEMENTS    1       2       3       4       5       6       7       8       9       10      11      12      13      14
   14       2       2       2       2       2       2       2       2       2       2       2       2       2       2
   13       2     101     101     101     101     101     101     101     101     101     101     101     101       2
   12       2     101       1       1       1       1       1       1       1       1       1       1       1       2
   11       2     101       1       1       1       1       1       1       1       1       1       1       1       2
   10       2     101       1       1       1       1       1       1       1       1       1       1       1       2
    9       2     101       1       1       1       1       1       1       1       1       1       1       1       2
    8       2     101       1       1       1       1       1       1       1       1       1       1       1       2
    7       2     101       1       1       1       1       1       1       1       1       1       1       1       2
    6       2     101       1       1       1       1       1       1       1       1       1       1       1       2
    5       2     101       1       1       1       1       1       1       1       1       1       1       1       2
    4       2     101       1       1       1       1       1       1       1       1       1       1       1       2
    3       2     101       1       1       1       1       1       1       1       1       1       1       1       2
    2       2     101     101     101     101     101     101     101     101     101     101     101     101       2
    1       2       2       2       2       2       2       2       2       2       2       2       2       2       2
....................................................................................................................

                         SPILL_CONTROL_PARAMETERS___0.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL_

    ENVIRONMENTAL DATA READ THIS STEP: WIND         CURRENT          TEMPERATURE            SEA STATE    TIDAL HEIGHTS

    ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  1 SPILLETS;    0 CLEANUP EFFORTS;    0 TREATMENT EFFORTS.

....................................................................................................................
```

Figure VIII.-6. Output from Preview Run

```
                              WIND VEL     INPUT DATA       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

 THE WIND VEL      GRID HAS      1 DIVISIONS IN X SPACED       0.5000 DEGREES  APART
                        AND      1 DIVISIONS IN Y SPACED       0.2500 DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE WIND VEL     COORDINATE SYSTEM IS AT  68.000000 DEGREES LONGITUDE AND  61.250000 DEGREES LATITUDE


                                         U       VALUES IN UNITS OF    M/SEC

   Y                                              X ELEMENTS
ELEMENTS    1

   1       0.000


                                         V       VALUES IN UNITS OF    M/SEC

   Y                                              X ELEMENTS
ELEMENTS    1

   1      -6.100
                               TEMPERATURE  INPUT DATA       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

 THE TEMPERATURE  GRID HAS      1 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                        AND      1 DIVISIONS IN Y SPACED       0.0157 DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE TEMPERATURE  COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  61.350000 DEGREES LATITUDE


                                       TEMP.    VALUES IN UNITS OF DEGREES C

   Y                                              X ELEMENTS
ELEMENTS    1

   1       20.000
                               SEA STATE    INPUT DATA       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

 THE SEA STATE     GRID HAS      1 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                        AND      1 DIVISIONS IN Y SPACED       0.0157 DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE SEA STATE    COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  61.350000 DEGREES LATITUDE


                                       HEIGHT   VALUES IN UNITS OF METERS

   Y                                              X ELEMENTS
ELEMENTS    1

   1        1.000


                                       PERIOD   VALUES IN UNITS OF SECONDS

   Y                                              X ELEMENTS
ELEMENTS    1

   1       10.000
```

Figure VIII.-6. Output from Preview Run

```
                                   UTID CURRENT INPUT DATA        0.00  HOURS  AFTER THE BEGINNING OF THE SPELL

   THE UTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED        0.0357 DEGREES  APART
                         AND     14 DIVISIONS IN Y SPACED        0.0157 DEGREES  APART.

   THE (1,1) GRID LOCATION OF THE UTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  61.349990 DEGREES LATITUDE

 ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                       U        VALUES IN UNITS OF M/S

   Y                                                     X ELEMENTS
ELEMENTS     1       2       3       4       5       6       7       8       9      10      11      12      13      14

   14      0.419   0.419   0.419   0.243   0.275   0.525   0.787   0.767   0.792   0.708   0.737   0.551   0.133   0.085

   13      0.418   0.418   0.418   0.386   0.423   0.750   0.736   0.857   0.783   0.751   0.628   0.648   0.220   0.098

   12      0.416   0.416   0.416   0.254   0.307   0.487   0.670   0.703   0.772   0.626   0.555   0.496   0.111   0.459

   11      0.414   0.414   0.440   0.124   0.194   0.225   0.604   0.627   0.778   0.600   0.533   0.391   0.156   0.637

   10      0.413   0.413   0.413   0.413   0.259   0.122   0.553   0.580   0.735   0.518   0.610   0.578   0.456   0.490

    9      0.411   0.411   0.411   0.411   0.322   0.019   0.526   0.524   0.704   0.505   0.702   0.726   0.587   0.375

    8      0.409   0.409   0.409   0.409   0.239   0.018   0.463   0.501   0.660   0.479   0.612   0.587   0.514   0.351

    7      0.068   0.556   0.120  -0.142   0.157   0.053   0.384   0.429   0.617   0.413   0.471   0.484   0.394   0.328

    6      0.058   0.300   0.160  -0.081   0.029  -0.060   0.197   0.174   0.225   0.143   0.288   0.409   0.125   0.136

    5      0.049   0.086   0.199  -0.020  -0.100  -0.359  -0.158  -0.217  -0.553  -0.307   0.018   0.198   0.226   0.296

    4      0.072   0.073   0.141   0.027  -0.071  -0.213  -0.032  -0.111  -0.318  -0.118   0.014   0.110   0.119   0.170

    3      0.097   0.100   0.087   0.073  -0.041  -0.071   0.085  -0.006  -0.085   0.019   0.009   0.028   0.018   0.086

    2      0.104   0.099   0.075   0.070   0.029   0.018   0.083   0.016  -0.019   0.016   0.013   0.029   0.032   0.068

    1      0.123   0.096   0.063   0.068   0.098   0.097   0.082   0.019   0.007  -0.007   0.016   0.013   0.051   0.073
                                   VTID CURRENT INPUT DATA        0.00  HOURS  AFTER THE BEGINNING OF THE SPELL

   THE VTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED        0.0357 DEGREES  APART
                         AND     14 DIVISIONS IN Y SPACED        0.0157 DEGREES  APART.

   THE (1,1) GRID LOCATION OF THE VTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  61.349990 DEGREES LATITUDE

 ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                       V        VALUES IN UNITS OF M/S

   Y                                                     X ELEMENTS
ELEMENTS     1       2       3       4       5       6       7       8       9      10      11      12      13      14

   14      0.256   0.256   0.256  -0.315  -0.125  -0.038   0.134   0.387   0.553   0.621   0.739   0.913   0.771   0.605

   13      0.256   0.256   0.256  -0.397  -0.197   0.064   0.209   0.456   0.511   0.679   0.578   0.887   0.810   0.751

   12      0.256   0.256   0.256  -0.384  -0.183   0.104   0.192   0.326   0.421   0.468   0.508   0.723   0.655   0.490

   11      0.256   0.256  -0.315  -0.291  -0.169   0.185   0.174   0.263   0.377   0.416   0.487   0.620   0.576   0.659

   10      0.256   0.256   0.256   0.256  -0.187   0.026   0.166   0.212   0.218   0.226   0.226   0.310   0.231   0.293

    9      0.256   0.256   0.254   0.256  -0.125  -0.092   0.159   0.174   0.066   0.062  -0.022  -0.020  -0.136  -0.096

    8      0.256   0.256   0.256   0.256  -0.096  -0.021   0.193   0.180   0.090   0.047  -0.014   0.019  -0.126  -0.100

    7     -0.158   0.639   0.740   0.270  -0.067  -0.007   0.087   0.093   0.019   0.083  -0.049  -0.184  -0.056  -0.063

    6      0.067   0.351   0.509   0.260   0.105   0.187  -0.026  -0.018   0.126   0.187  -0.076  -0.083  -0.059  -0.063

    5      0.294   0.073   0.438   0.250   0.676   0.501  -0.249  -0.201   0.142   0.414  -0.104  -0.031  -0.036  -0.055

    4      0.130   0.017   0.201   0.109   0.268   0.192  -0.224  -0.145   0.116   0.202  -0.040   0.082   0.062   0.072

    3     -0.035  -0.040  -0.018  -0.032  -0.140  -0.120  -0.198  -0.088  -0.109  -0.010   0.025   0.115   0.159   0.199

    2     -0.012  -0.004   0.015   0.017  -0.092  -0.085  -0.121  -0.049  -0.041   0.028   0.080   0.098   0.127   0.159

    1      0.012   0.031   0.068   0.067  -0.041  -0.051  -0.041  -0.010   0.026   0.059   0.036   0.073   0.094   0.120
```

Figure VIII.-6. Output from Preview Run

```
                              TIDE LEVEL   INPUT DATA       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

THE TIDE LEVEL   GRID HAS     14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                      AND     14 DIVISIONS IN Y SPACED       0.0357 DEGREES  APART.

THE (1,1) GRID LOCATION OF THE TIDE LEVEL   COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.350000 DEGREES LATITUDE


                                                VALUES IN UNITS OF METERS

   Y                                             X ELEMENTS
ELEMENTS   1       2       3       4       5       6       7       8       9      10      11      12      13      14

  14     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

  13     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

  12     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

  11     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

  10     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   9     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   8     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   7     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   6     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   5     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   4     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   3     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   2     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

   1     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

                              EXISTING_SPILLETS____0.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL


                                   NEW SPILLETS ADDED THIS STEP

     THE    1 SPILLET APPEARED      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
     IT IS CENTERED AT LONGITUDE  66.820000 AND LATITUDE  41.669990,
     IS OF RADIUS       25.00 METERS AND IS OF WEIGHT 10000.0000 METRIC TONS.
     SOME PROPERTIES OF THE SPILLED OIL ARE:
                      DENSITY                0.877000 GRAMS/CC
                      INTERFACIAL TENSION   30.000000 DYNES/CM
                      KINEMATIC VISCOSITY    1.000000 CENTISTOKES
     BY WEIGHT THE OIL FRACTIONS ARE:                         PARAFFIN (C6-C12)             0.050000
                                                              PARAFFIN (C13-C22)            0.100000
                                                              CYCLOPARAFFIN (C6-C12)        0.110000
                                                              CYCLOPARAFFIN (C13-C22)       0.050000
                                                              AROMATIC (C6-C11)             0.100000
                                                              AROMATIC (C12-C18)            0.080000
                                                              NAPTHENO-AROMATIC (C9-C25)    0.210000
                                                              RESIDUAL                      0.300000


----------------------------------------------------------------------------------------------------------------


     AT TIME EQUALS       0.000HOURSTHE TOTAL MASS ENTRAINED IS     66.076760METRIC TONS
     THIS RESULTS IN       0.13215TONS PER DROPLET SPREAD          OUT OVER  500PARTICLES

----------------------------------------------------------------------------------------------------------------


                                                MASS_BALANCE

                     TOTAL MASS OF OIL SPILLED         10000.00000  METRIC TONS


       LOCATION OF OIL                                              AMOUNT (METRIC TONS)              PERCENT OF TOTAL
          IN ATMOSPHERE                                                  2273.01600                        22.73
          ON SURFACE                                                     7660.90700                        76.61
          IN WATER COLUMN               0 MARKED PARTICLES                 66.07677                         0.66
          ON BOTTOM                     0 DEPOSITED PARTICLES               0.00000                         0.00
          ON SHORE                                                          0.00000                         0.00
       REMOVAL MECHANISMS
          BIOLOGICALLY CONSUMED                                             0.00000                         0.00
          PHYSICALLY CLEANED UP                                             0.00000                         0.00
          LOST THRU OPEN BOUNDARY       0 LOST PARTICLES                    0.00000                         0.00

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Figure VIII.-6. Output from Preview Run

```
***.*********************************************************************************************************

                        SPILL_CONTROL_PARAMETERS___3.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL.

   ENVIRONMENTAL DATA READ THIS STEP: WIND        CURRENT

   ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  1 SPILLETS;    0 CLEANUP EFFORTS;    0 TREATMENT EFFORTS.

*************************************************************************************************************
 ,                                  WIND VEL     INPUT DATA       3.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE WIND VEL     GRID HAS     1 DIVISIONS IN X SPACED       0.5000 DEGREES  APART
                        AND     1 DIVISIONS IN Y SPACED       0.2500 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE WIND VEL     COORDINATE SYSTEM IS AT  68.000000 DEGREES LONGITUDE AND  41.250000 DEGREES LATITUDE


                                              U       VALUES IN UNITS OF    M/SEC

   Y                                                    X ELEMENTS
ELEMENTS    1

   1       0.000


                                              V       VALUES IN UNITS OF    M/SEC

   Y                                                    X ELEMENTS
ELEMENTS    1

   1      -5.150
                                    UTID CURRENT INPUT DATA       3.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE UTID CURRENT GRID HAS    14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                        AND    14 DIVISIONS IN Y SPACED       0.0357 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE UTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.389990 DEGREES LATITUDE

 ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                              U       VALUES IN UNITS OF M/S

   Y                                                    X ELEMENTS
ELEMENTS    1        2        3        4        5        6        7        8        9        10       11       12       13       14

   14      0.609    0.609    0.609    0.433    0.465    0.714    0.976    0.957    0.981    0.898    0.926    0.740    0.322    0.235

   13      0.606    0.606   -0.606    0.574    0.611    0.938    0.925    1.046    0.971    0.939    0.817    0.836    0.409    0.287

   12      0.604    0.604    0.604    0.442    0.495    0.675    0.858    0.890    0.960    0.814    0.743    0.684    0.499    0.646

   11      0.601   -0.601    0.827    0.311    0.381    0.412    0.791    0.814    0.965    0.787    0.770    0.574    0.561    0.424

   10      0.599    0.599    0.599    0.599    0.445    0.109    0.739    0.766    0.921    0.720    0.796    0.760    0.643    0.676

    9      0.597    0.597    0.597    0.597    0.507    0.205    0.711    0.710    0.890    0.691    0.887    0.911    0.771    0.561

    8      0.594    0.594    0.594    0.594    0.424    0.201    0.648    0.686    0.885    0.664    0.797    0.772    0.699    0.536

    7      0.252    0.740    0.304    0.082    0.341    0.237    0.571    0.614    0.801    0.597    0.655    0.669    0.578    0.512

    6      0.242    0.488    0.343    0.102    0.212    0.124    0.380    0.357    0.409    0.327    0.467    0.592    0.509    0.520

    5      0.231    0.229    0.382    0.161    0.083   -0.176    0.033   -0.034   -0.170   -0.125    0.202    0.376    0.408    0.478

    4      0.254    0.255    0.125    0.209    0.111   -0.011    0.150    0.071   -0.136    0.048    0.196    0.292    0.302    0.352

    3      0.278    0.282    0.269    0.255    0.140    0.111    0.266    0.176    0.097    0.220    0.191    0.210    0.196    0.227

    2      0.290    0.279    0.256    0.251    0.210    0.195    0.264    0.197    0.182    0.197    0.194    0.210    0.212    0.281

    1      0.301    0.276    0.243    0.248    0.278    0.277    0.262    0.219    0.187    0.171    0.197    0.212    0.232    0.253
```

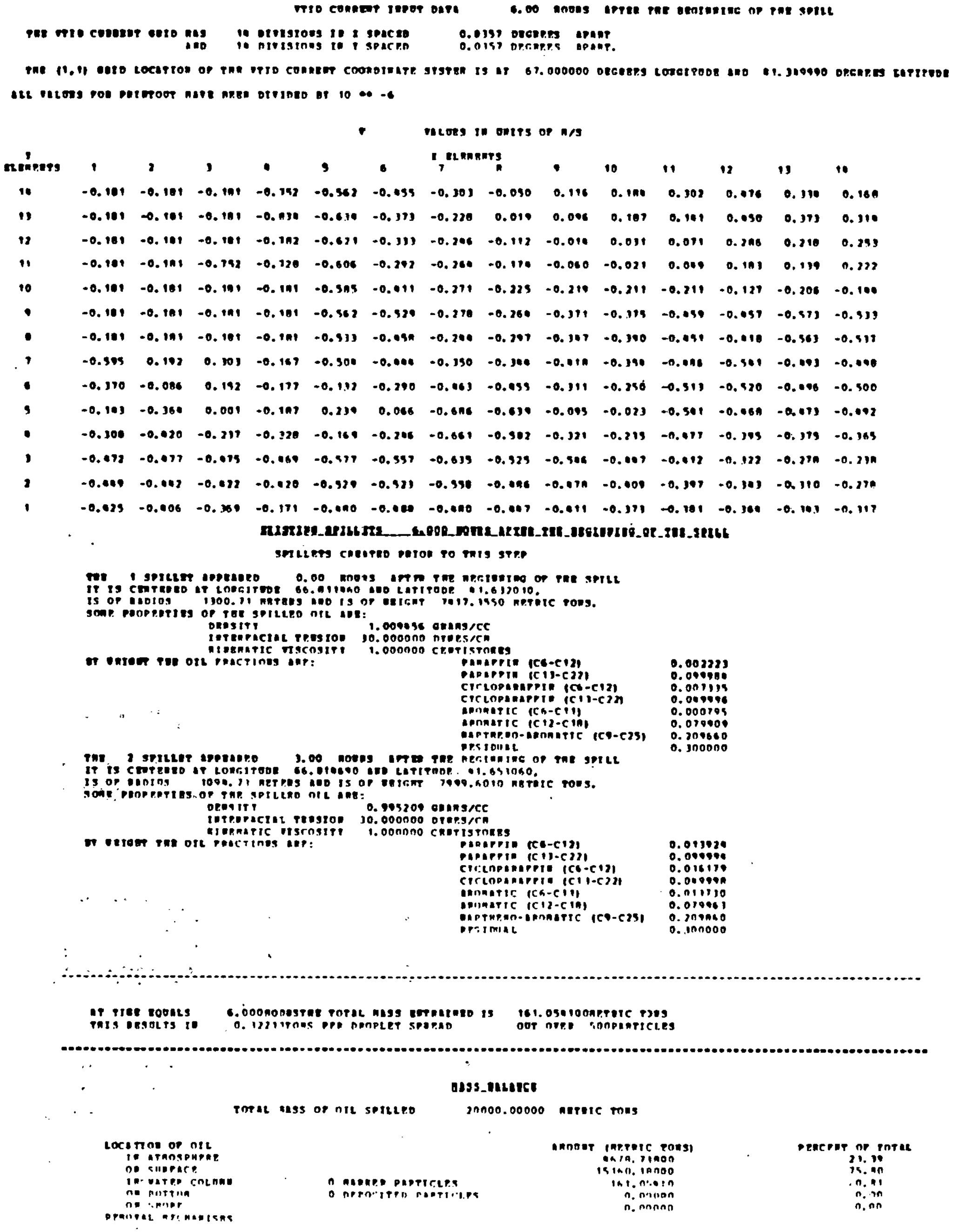
Figure VIII.-6. Output from Preview Run

```
                        TTID CURRENT INPUT DATA       1.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE TTID CURRENT GRID HAS     14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                        AND     14 DIVISIONS IN Y SPACED       0.0357 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE TTID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.349990 DEGREES LATITUDE

 ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                            V        VALUES IN UNITS OF M/S

    Y                                                  X ELEMENTS
 ELEMENTS     1       2       3       4       5       6       7       8       9      10      11      12      13      14

   14       0.285   0.285   0.285  -0.326  -0.137  -0.030   0.122   0.375   0.541   0.618   0.728   0.801   0.759   0.599

   13       0.285   0.285   0.285  -0.408  -0.209   0.052   0.197   0.448   0.522   0.612   0.567   0.875   0.799   0.739

   12       0.285   0.285   0.285  -0.356  -0.195   0.093   0.180   0.318   0.411   0.456   0.496   0.711   0.643   0.670

   11       0.285   0.285  -0.326  -0.303  -0.181   0.131   0.162   0.251   0.365   0.405   0.475   0.608   0.565   0.648

   10       0.285   0.285   0.285   0.285  -0.159   0.018   0.155   0.201   0.206   0.214   0.218   0.299   0.219   0.281

    9       0.285   0.285   0.285   0.285  -0.117  -0.101   0.187   0.162   0.054   0.050  -0.033  -0.011  -0.187  -0.108

    8       0.285   0.285   0.285   0.285  -0.108  -0.032   0.182   0.129   0.078   0.035  -0.026   0.007  -0.138  -0.112

    7      -0.170   0.617   0.728   0.258  -0.078  -0.019   0.076   0.081   0.007   0.071  -0.060  -0.116  -0.067  -0.073

    6       0.056   0.339   0.577   0.248   0.293   0.136  -0.038  -0.010   0.118   0.175  -0.087  -0.048  -0.071  -0.075

    5       0.282   0.061   0.426   0.218   0.665   0.491  -0.261  -0.213   0.330   0.403  -0.116  -0.082  -0.088  -0.067

    4       0.118   0.005   0.189   0.097   0.256   0.180  -0.236  -0.156   0.108   0.191  -0.051   0.031   0.050   0.080

    3      -0.047  -0.051  -0.049  -0.048  -0.152  -0.131  -0.210  -0.108  -0.121  -0.022   0.013   0.103   0.107   0.107

    2      -0.023  -0.016   0.004   0.005  -0.103  -0.097  -0.132  -0.048  -0.051   0.016   0.029   0.083   0.115   0.187

    1       0.000   0.019   0.057   0.055  -0.055  -0.063  -0.055  -0.072   0.018   0.052   0.044   0.061   0.083   0.108
                                   EXISTING_SPILLETS____3.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                                          SPILLETS CREATED PRIOR TO THIS STEP

          THE   1 SPILLET APPEARED      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
          IT IS CENTERED AT LONGITUDE  66.816710 AND LATITUDE  41.649680,
          IS OF RADIUS     1091.99 METERS AND IS OF WEIGHT  7460.9020 METRIC TONS.
          SOME PROPERTIES OF THE SPILLED OIL ARE:
                              DENSITY                  1.003198 GRAMS/CC
                              INTERFACIAL TENSION  30.000000 DYNES/CM
                              KINEMATIC VISCOSITY    1.000000 CENTISTOKES
          BY WEIGHT THE OIL FRACTIONS ARE:                        PARAFFIN (C6-C12)               0.006969
                                                                  PARAFFIN (C13-C22)              0.099990
                                                                  CYCLOPARAFFIN (C6-C12)          0.019816
                                                                  CYCLOPARAFFIN (C13-C22)         0.049997
                                                                  AROMATIC (C6-C11)               0.004686
                                                                  AROMATIC (C12-C18)              0.079943
                                                                  NAPTHENO-AROMATIC (C9-C25)      0.209785
                                                                  RESIDUAL                        0.300000

                                          NEW SPILLETS ADDED THIS STEP

          THE   2 SPILLET APPEARED      3.00  HOURS  AFTER THE BEGINNING OF THE SPILL
          IT IS CENTERED AT LONGITUDE  66.820000 AND LATITUDE  41.669990,
          IS OF RADIUS       25.00 METERS AND IS OF WEIGHT 10000.0000 METRIC TONS.
          SOME PROPERTIES OF THE SPILLED OIL ARE:
                              DENSITY                  0.877000 GRAMS/CC
                              INTERFACIAL TENSION  30.000000 DYNES/CM
                              KINEMATIC VISCOSITY    1.000000 CENTISTOKES
          BY WEIGHT THE OIL FRACTIONS ARE:                        PARAFFIN (C6-C12)               0.050000
                                                                  PARAFFIN (C13-C22)              0.100000
                                                                  CYCLOPARAFFIN (C6-C12)          0.110000
                                                                  CYCLOPARAFFIN (C13-C22)         0.050000
                                                                  AROMATIC (C6-C11)               0.100000
                                                                  AROMATIC (C12-C18)              0.080000
                                                                  NAPTHENO-AROMATIC (C9-C25)      0.210000
                                                                  RESIDUAL                        0.300000


  ----------------------------------------------------------------------------------------------------------------------------

          AT TIME EQUALS      3.000HOURSTHE TOTAL MASS ENTRAINED IS    144.986000METRIC TONS
          THIS RESULTS IN      0.28997TONS PER DROPLET SPREAD         OUT OVER  500PARTICLES

  ----------------------------------------------------------------------------------------------------------------------------


                                                   MASS_BALANCE

                              TOTAL MASS OF OIL SPILLED        20000.00000  METRIC TONS


          LOCATION OF OIL                                              AMOUNT (METRIC TONS)               PERCENT OF TOTAL
             IN ATMOSPHERE                                                  4439.04600                         22.19
             ON SURFACE                                                    15415.95000                         77.08
             IN WATER COLUMN              0 MARKER PARTICLES                 144.98600                          0.72
```

Figure VIII.-6. Output from Preview Run

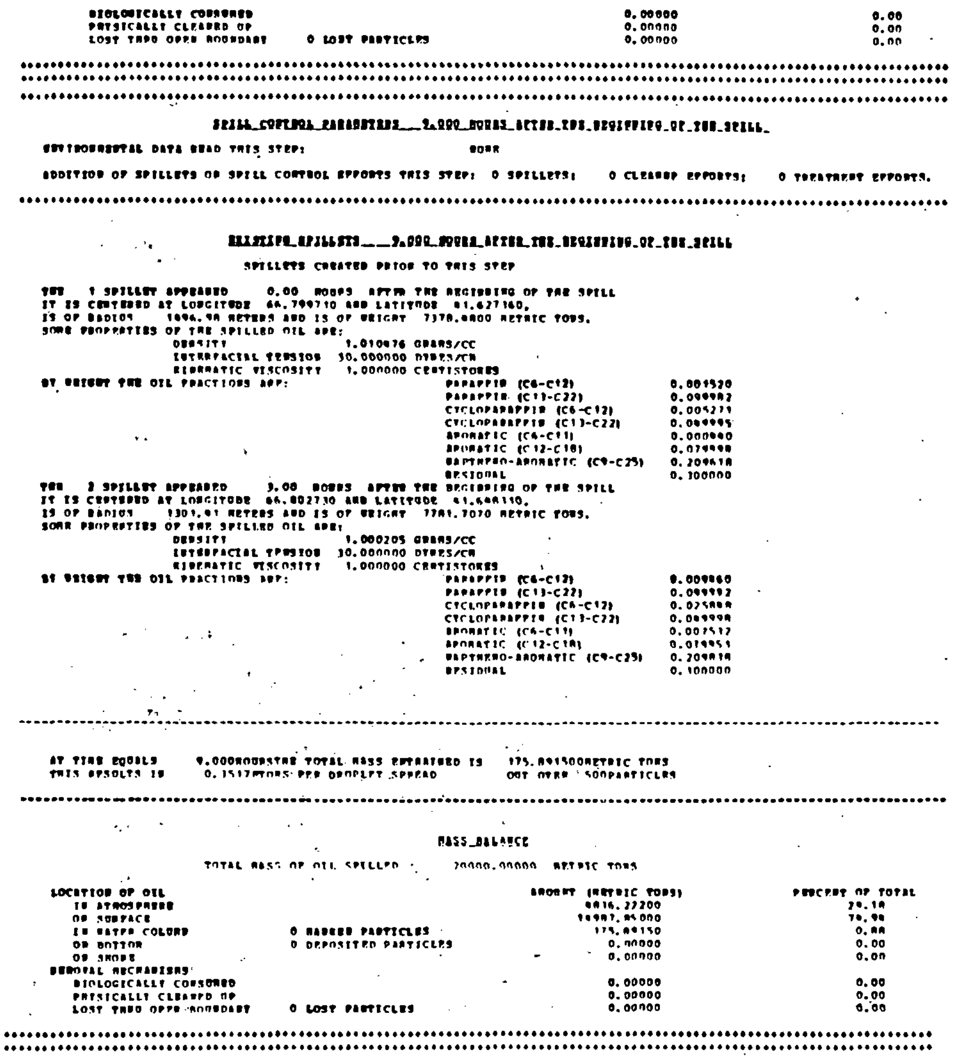
```
      ON BOTTOM                 0 DEPOSITED PARTICLES               0.00000                 0.00
      ON SHORE                                                      0.00000                 0.00
   REMOVAL MECHANISMS
      BIOLOGICALLY CONSUMED                                         0.00000                 0.00
      PHYSICALLY CLEANED UP                                         0.00000                 0.00
      LOST THRU OPEN BOUNDARY   0 LOST PARTICLES                    0.00000                 0.00
*************************************************************************************************
*************************************************************************************************
*************************************************************************************************

             SPILL CONTROL PARAMETERS    6.000 HOURS AFTER THE BEGINNING OF THE SPILL

  ENVIRONMENTAL DATA READ THIS STEP: WIND      CURRENT

  ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  0 SPILLETS:    0 CLEANUP EFFORTS:    0 TREATMENT EFFORTS.

*************************************************************************************************

                                   WIND VEL     INPUT DATA       6.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE WIND VEL      GRID HAS      1 DIVISIONS IN X SPACED       0.5000 DEGREES  APART
                         AND      1 DIVISIONS IN Y SPACED       0.2500 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE WIND VEL     COORDINATE SYSTEM IS AT  68.000000 DEGREES LONGITUDE AND  41.250000 DEGREES LATITUDE


                                          U       VALUES IN UNITS OF     M/SEC

    Y                                              X-ELEMENTS
ELEMENTS    1

    1       2.570

                                          V       VALUES IN UNITS OF     M/SEC

    Y                                              X ELEMENTS
ELEMENTS    1

    1       0.000

                                   UVID CURRENT INPUT DATA      6.00  HOURS  APTER THE BEGINNING OF THE SPILL

  THE UVID CURRENT GRID HAS     14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                         AND    14 DIVISIONS IN Y SPACED       0.0357 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE UVID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.349990 DEGREES LATITUDE

 ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                         U        VALUES IN UNITS OF M/S

    Y                                              X ELEMENTS
ELEMENTS    1       2       3       4       5       6       7       8       9      10      11      12      13      14

   14     0.139   0.139   0.139  -0.017  -0.005   0.295   0.507   0.407   0.512   0.428   0.456   0.271  -0.148  -0.235

   13     0.138   0.138   0.138   0.107   0.143   0.470   0.457   0.578   0.501   0.472   0.349   0.369  -0.059  -0.181

   12     0.138   0.138   0.138  -0.024   0.029   0.209   0.392   0.428   0.490   0.148   0.277   0.218   0.013   0.181

   11     0.137   0.137   0.361  -0.153  -0.083  -0.052   0.127   0.350   0.501   0.323   0.256   0.114   0.079   0.160

   10     0.137   0.137   0.137   0.137  -0.017  -0.154   0.277   0.304   0.459   0.258   0.334   0.298   0.180   0.214

    9     0.136   0.136   0.136   0.136   0.087  -0.256   0.251   0.250   0.429   0.210   0.427   0.451   0.312   0.100

    8     0.136   0.136  -0.136   0.136  -0.015  -0.256   0.190   0.227   0.387   0.205   0.319   0.311   0.240   0.077

    7    -0.205   0.203  -0.151  -0.415  -0.116  -0.220   0.114   0.157   0.344   0.140   0.199   0.212   0.121   0.055

    6    -0.211   0.029  -0.112  -0.351  -0.281  -0.311  -0.075  -0.098  -0.046  -0.129   0.012   0.117   0.054   0.068

    5    -0.222  -0.224  -0.071  -0.291  -0.370  -0.629  -0.420  -0.488  -0.824  -0.578  -0.292  -0.077  -0.045   0.025

    4    -0.198  -0.196  -0.127  -0.242  -0.341  -0.483  -0.302  -0.181  -0.588  -0.401  -0.255  -0.160  -0.150  -0.099

    3    -0.172  -0.168  -0.181  -0.196  -0.310  -0.319  -0.188  -0.275  -0.151  -0.210  -0.259  -0.240  -0.255  -0.271

    2    -0.158  -0.169  -0.191  -0.197  -0.218  -0.254  -0.184  -0.251  -0.106  -0.251  -0.255  -0.218  -0.216  -0.208

    1    -0.144  -0.171  -0.204  -0.199  -0.169  -0.170  -0.185  -0.228  -0.260  -0.274  -0.250  -0.215  -0.215  -0.198
```

Figure VIII.-6. Output from Preview Run



```
                              WIND CURRENT INPUT DATA       6.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE WIND CURRENT GRID HAS     14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                        AND     14 DIVISIONS IN Y SPACED       0.0157 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE WIND CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.389990 DEGREES LATITUDE

 ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                          V        VALUES IN UNITS OF M/S

    Y                                                  X ELEMENTS
 ELEMENTS     1        2        3        4        5        6        7        8        9       10       11       12       13       14

    14     -0.181   -0.181   -0.181   -0.752   -0.562   -0.455   -0.303   -0.050    0.116    0.188    0.302    0.476    0.338    0.168

    13     -0.181   -0.181   -0.181   -0.838   -0.634   -0.373   -0.228    0.019    0.096    0.187    0.181    0.450    0.373    0.318

    12     -0.181   -0.181   -0.181   -0.782   -0.671   -0.333   -0.246   -0.112   -0.014    0.031    0.071    0.286    0.218    0.253

    11     -0.181   -0.181   -0.792   -0.328   -0.606   -0.292   -0.264   -0.174   -0.060   -0.021    0.049    0.183    0.139    0.222

    10     -0.181   -0.181   -0.191   -0.181   -0.585   -0.411   -0.271   -0.225   -0.219   -0.211   -0.211   -0.127   -0.206   -0.144

     9     -0.181   -0.181   -0.181   -0.181   -0.562   -0.529   -0.278   -0.264   -0.371   -0.375   -0.459   -0.457   -0.573   -0.539

     8     -0.181   -0.181   -0.181   -0.181   -0.533   -0.458   -0.244   -0.297   -0.347   -0.390   -0.451   -0.418   -0.563   -0.537

     7     -0.595    0.192    0.303   -0.167   -0.504   -0.444   -0.350   -0.344   -0.418   -0.394   -0.486   -0.541   -0.493   -0.498

     6     -0.370   -0.086    0.192   -0.177   -0.132   -0.290   -0.463   -0.455   -0.311   -0.256   -0.513   -0.520   -0.496   -0.500

     5     -0.183   -0.364    0.001   -0.187    0.239    0.066   -0.686   -0.639   -0.095   -0.023   -0.501   -0.468   -0.473   -0.492

     4     -0.308   -0.420   -0.217   -0.328   -0.169   -0.246   -0.661   -0.582   -0.321   -0.215   -0.477   -0.395   -0.379   -0.365

     3     -0.472   -0.477   -0.475   -0.469   -0.577   -0.557   -0.635   -0.525   -0.586   -0.447   -0.412   -0.322   -0.278   -0.238

     2     -0.449   -0.442   -0.422   -0.420   -0.529   -0.523   -0.558   -0.486   -0.478   -0.409   -0.397   -0.383   -0.310   -0.278

     1     -0.425   -0.406   -0.369   -0.171   -0.480   -0.488   -0.480   -0.447   -0.411   -0.371   -0.181   -0.364   -0.303   -0.317
                                    EXISTING_SPILLETS____6.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                                           SPILLETS CREATED PRIOR TO THIS STEP

          THE   1 SPILLET APPEARED       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
          IT IS CENTERED AT LONGITUDE  66.811860 AND LATITUDE  41.632010,
          IS OF RADIUS     1300.71 METERS AND IS OF WEIGHT  7817.1550 METRIC TONS.
          SOME PROPERTIES OF THE SPILLED OIL ARE:
                         DENSITY                  1.009456 GRAMS/CC
                         INTERFACIAL TENSION  30.000000 DYNES/CM
                         KINEMATIC VISCOSITY   1.000000 CENTISTOKES
          BY WEIGHT THE OIL FRACTIONS ARE:                          PARAFFIN (C6-C12)                 0.002223
                                                                    PARAFFIN (C13-C22)                0.099980
                                                                    CYCLOPARAFFIN (C6-C12)            0.007335
                                                                    CYCLOPARAFFIN (C13-C22)           0.049996
                                                                    AROMATIC (C6-C11)                 0.000795
                                                                    AROMATIC (C12-C18)                0.079909
                                                                    NAPTHENO-AROMATIC (C9-C25)        0.209660
                                                                    RESIDUAL                          0.300000
          THE   2 SPILLET APPEARED       3.00  HOURS  AFTER THE BEGINNING OF THE SPILL
          IT IS CENTERED AT LONGITUDE  66.810690 AND LATITUDE  41.651060,
          IS OF RADIUS     1098.71 METERS AND IS OF WEIGHT  7999.6010 METRIC TONS.
          SOME PROPERTIES OF THE SPILLED OIL ARE:
                         DENSITY                  0.995209 GRAMS/CC
                         INTERFACIAL TENSION  30.000000 DYNES/CM
                         KINEMATIC VISCOSITY   1.000000 CENTISTOKES
          BY WEIGHT THE OIL FRACTIONS ARE:                          PARAFFIN (C6-C12)                 0.013924
                                                                    PARAFFIN (C13-C22)                0.099994
                                                                    CYCLOPARAFFIN (C6-C12)            0.016179
                                                                    CYCLOPARAFFIN (C13-C22)           0.049998
                                                                    AROMATIC (C6-C11)                 0.011730
                                                                    AROMATIC (C12-C18)                0.079961
                                                                    NAPTHENO-AROMATIC (C9-C25)        0.209860
                                                                    RESIDUAL                          0.300000


        ----------------------------------------------------------------------------------------------------------


          AT TIME EQUALS     6.000HOURSTHE TOTAL MASS ENTRAINED IS    161.058100METRIC TONS
          THIS RESULTS IN     0.32211TONS PER DROPLET SPREAD          OUT OVER  500PARTICLES

        ----------------------------------------------------------------------------------------------------------


                                                    MASS_BALANCE

                           TOTAL MASS OF OIL SPILLED        20000.00000  METRIC TONS


           LOCATION OF OIL                                                      AMOUNT (METRIC TONS)             PERCENT OF TOTAL
              IN ATMOSPHERE                                                          4678.71800                        23.39
              ON SURFACE                                                            15160.18000                        75.80
              IN WATER COLUMN               0 NABBED PARTICLES                        161.05810                         0.81
              ON BOTTOM                     0 DEPOSITED PARTICLES                       0.00000                         0.00
              ON SHORE                                                                  0.00000                         0.00
           REMOVAL MECHANISMS
```

Figure VIII.-6. Output from Preview Run



```
        BIOLOGICALLY CONSUMED                                                 0.00000                 0.00
        PHYSICALLY CLEANED UP                                                 0.00000                 0.00
        LOST THRU OPEN BOUNDARY      0 LOST PARTICLES                         0.00000                 0.00

**************************************************************************************************************
**************************************************************************************************************
**************************************************************************************************************

                   SPILL_CONTROL_PARAMETERS___9.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL_

   ENVIRONMENTAL DATA READ THIS STEP:                         NONE

   ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  0 SPILLETS;    0 CLEANUP EFFORTS;    0 TREATMENT EFFORTS.

**************************************************************************************************************

                      EXISTING_SPILLETS___9.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                        SPILLETS CREATED PRIOR TO THIS STEP

   THE    1 SPILLET APPEARED      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
   IT IS CENTERED AT LONGITUDE  66.799710 AND LATITUDE  41.627160,
   IS OF RADIUS     1896.98 METERS AND IS OF WEIGHT  7378.0800 METRIC TONS.
   SOME PROPERTIES OF THE SPILLED OIL ARE:
                    DENSITY                1.010476 GRAMS/CC
                    INTERFACIAL TENSION   30.000000 DYNES/CM
                    KINEMATIC VISCOSITY    1.000000 CENTISTOKES
   BY WEIGHT THE OIL FRACTIONS ARE:                         PARAFFIN (C6-C12)              0.001520
                                                            PARAFFIN (C13-C22)             0.099982
                                                            CYCLOPARAFFIN (C6-C12)         0.005271
                                                            CYCLOPARAFFIN (C13-C22)        0.049995
                                                            AROMATIC (C6-C11)              0.000940
                                                            AROMATIC (C12-C18)             0.079998
                                                            NAPTHENO-AROMATIC (C9-C25)     0.209618
                                                            RESIDUAL                       0.100000
   THE    2 SPILLET APPEARED      3.00  HOURS  AFTER THE BEGINNING OF THE SPILL
   IT IS CENTERED AT LONGITUDE  66.802730 AND LATITUDE  41.648110,
   IS OF RADIUS     1301.91 METERS AND IS OF WEIGHT  7781.7070 METRIC TONS.
   SOME PROPERTIES OF THE SPILLED OIL ARE:
                    DENSITY                1.000205 GRAMS/CC
                    INTERFACIAL TENSION   30.000000 DYNES/CM
                    KINEMATIC VISCOSITY    1.000000 CENTISTOKES
   BY WEIGHT THE OIL FRACTIONS ARE:                         PARAFFIN (C6-C12)              0.009860
                                                            PARAFFIN (C13-C22)             0.099992
                                                            CYCLOPARAFFIN (C6-C12)         0.025888
                                                            CYCLOPARAFFIN (C13-C22)        0.049998
                                                            AROMATIC (C6-C11)              0.007512
                                                            AROMATIC (C12-C18)             0.019951
                                                            NAPTHENO-AROMATIC (C9-C25)     0.209818
                                                            RESIDUAL                       0.100000

--------------------------------------------------------------------------------------------------------------

    AT TIME EQUALS      9.000HOURSTHE TOTAL MASS ENTRAINED IS    175.891500METRIC TONS
    THIS RESULTS IN      0.3517MTONS PER DROPLET SPREAD          OUT OVER  500PARTICLES

**************************************************************************************************************

                                              MASS_BALANCE

                         TOTAL MASS OF OIL SPILLED      20000.00000  METRIC TONS

    LOCATION OF OIL                                               AMOUNT (METRIC TONS)           PERCENT OF TOTAL
       IN ATMOSPHERE                                                   5816.22200                     29.08
       ON SURFACE                                                     14007.85000                     70.04
       IN WATER COLUMN            0 NABBED PARTICLES                    175.89150                      0.88
       ON BOTTOM                  0 DEPOSITED PARTICLES                   0.00000                      0.00
       ON SHORE                                                           0.00000                      0.00
    REMOVAL MECHANISMS
       BIOLOGICALLY CONSUMED                                              0.00000                      0.00
       PHYSICALLY CLEANED UP                                              0.00000                      0.00
       LOST THRU OPEN BOUNDARY    0 LOST PARTICLES                        0.00000                      0.00

**************************************************************************************************************
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```
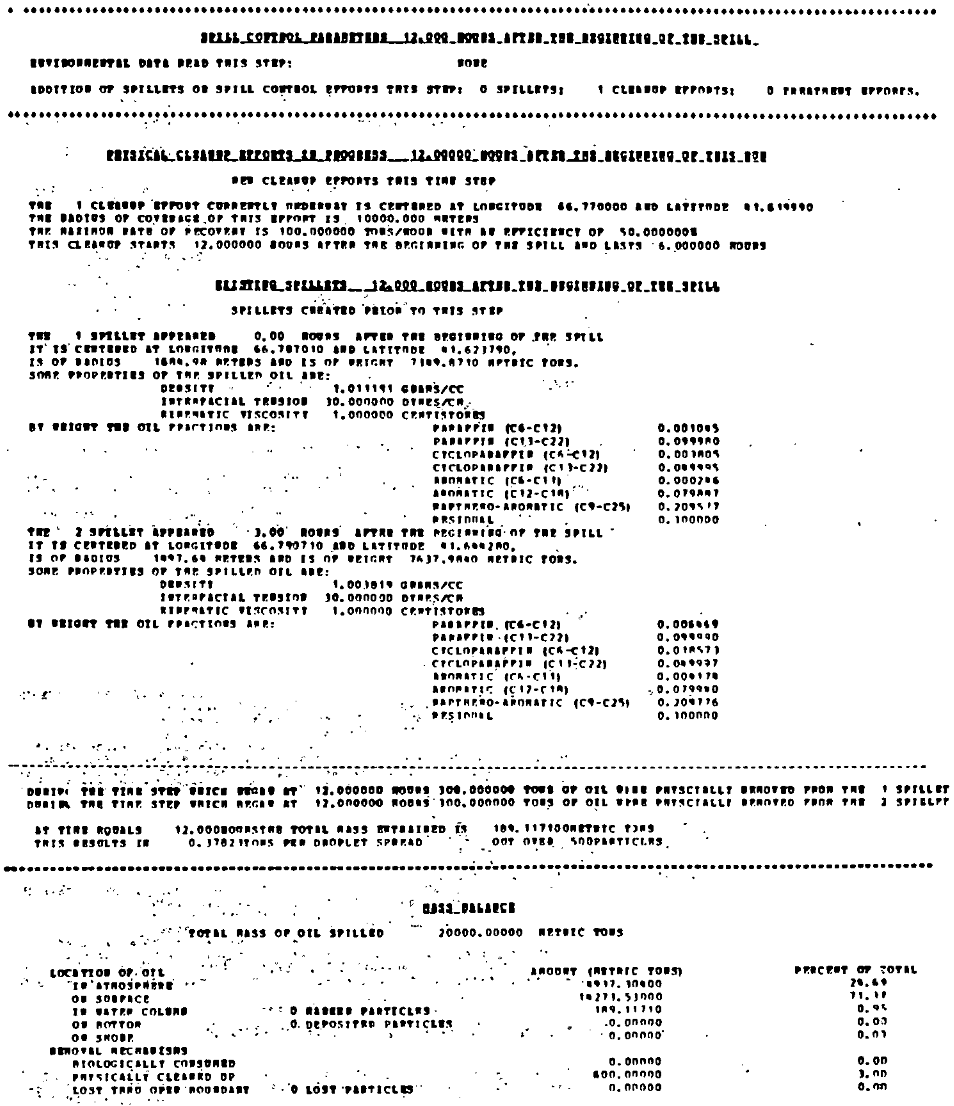

Figure VIII.-6. Output from Preview Run



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* ******************************************************************************************************

                SPILL CONTROL PARAMETERS   12.000 HOURS AFTER THE BEGINNING OF THE SPILL

   ENVIRONMENTAL DATA READ THIS STEP:                        NONE

   ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  0 SPILLETS;    1 CLEANUP EFFORTS;    0 TREATMENT EFFORTS.

*******************************************************************************************************

          PHYSICAL CLEANUP EFFORTS IN PROGRESS   12.00000 HOURS AFTER THE BEGINNING OF THIS RUN

                        NEW CLEANUP EFFORTS THIS TIME STEP

   THE   1 CLEANUP EFFORT CURRENTLY UNDERWAY IS CENTERED AT LONGITUDE  66.770000 AND LATITUDE  41.619990
   THE RADIUS OF COVERAGE OF THIS EFFORT IS  10000.000 METERS
   THE MAXIMUM RATE OF RECOVERY IS 100.000000 TONS/HOUR WITH AN EFFICIENCY OF  50.0000000%
   THIS CLEANUP STARTS  12.000000 HOURS AFTER THE BEGINNING OF THE SPILL AND LASTS  6.000000 HOURS

                EXISTING SPILLETS   12.000 HOURS AFTER THE BEGINNING OF THE SPILL

                        SPILLETS CREATED PRIOR TO THIS STEP

   THE   1 SPILLET APPEARED      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
   IT IS CENTERED AT LONGITUDE  66.787010 AND LATITUDE  41.623790,
   IS OF RADIUS    1684.98 METERS AND IS OF WEIGHT  7189.8710 METRIC TONS.
   SOME PROPERTIES OF THE SPILLED OIL ARE:
                   DENSITY                 1.011191 GRAMS/CC
                   INTERFACIAL TENSION   30.000000 DYNES/CM
                   KINEMATIC VISCOSITY    1.000000 CENTISTOKES
   BY WEIGHT THE OIL FRACTIONS ARE:                          PARAFFIN (C6-C12)                 0.001045
                                                             PARAFFIN (C13-C22)                0.099980
                                                             CYCLOPARAFFIN (C6-C12)            0.003805
                                                             CYCLOPARAFFIN (C13-C22)           0.089995
                                                             AROMATIC (C6-C11)                 0.000246
                                                             AROMATIC (C12-C18)                0.079887
                                                             NAPTHENO-AROMATIC (C9-C25)        0.209517
                                                             RESIDUAL                          0.100000
   THE   2 SPILLET APPEARED      3.00  HOURS  AFTER THE BEGINNING OF THE SPILL
   IT IS CENTERED AT LONGITUDE  66.790710 AND LATITUDE  41.604280,
   IS OF RADIUS    1897.64 METERS AND IS OF WEIGHT  7637.9840 METRIC TONS.
   SOME PROPERTIES OF THE SPILLED OIL ARE:
                   DENSITY                 1.003819 GRAMS/CC
                   INTERFACIAL TENSION   30.000000 DYNES/CM
                   KINEMATIC VISCOSITY    1.000000 CENTISTOKES
   BY WEIGHT THE OIL FRACTIONS ARE:                          PARAFFIN (C6-C12)                 0.006469
                                                             PARAFFIN (C13-C22)                0.099990
                                                             CYCLOPARAFFIN (C6-C12)            0.018571
                                                             CYCLOPARAFFIN (C13-C22)           0.089997
                                                             AROMATIC (C6-C11)                 0.004174
                                                             AROMATIC (C12-C18)                0.079990
                                                             NAPTHENO-AROMATIC (C9-C25)        0.209776
                                                             RESIDUAL                          0.100000

-------------------------------------------------------------------------------------------------------

   DURING THE TIME STEP WHICH BEGAN AT  12.000000 HOURS 300.000000 TONS OF OIL WERE PHYSICALLY REMOVED FROM THE  1 SPILLET
   DURING THE TIME STEP WHICH BEGAN AT  12.000000 HOURS 300.000000 TONS OF OIL WERE PHYSICALLY REMOVED FROM THE  2 SPILLET

    AT TIME EQUALS    12.000HOURSTHE TOTAL MASS ENTRAINED IS   189.117100METRIC TONS
    THIS RESULTS IN     0.37823TONS PER DROPLET SPREAD         OUT OVER  500PARTICLES

*******************************************************************************************************

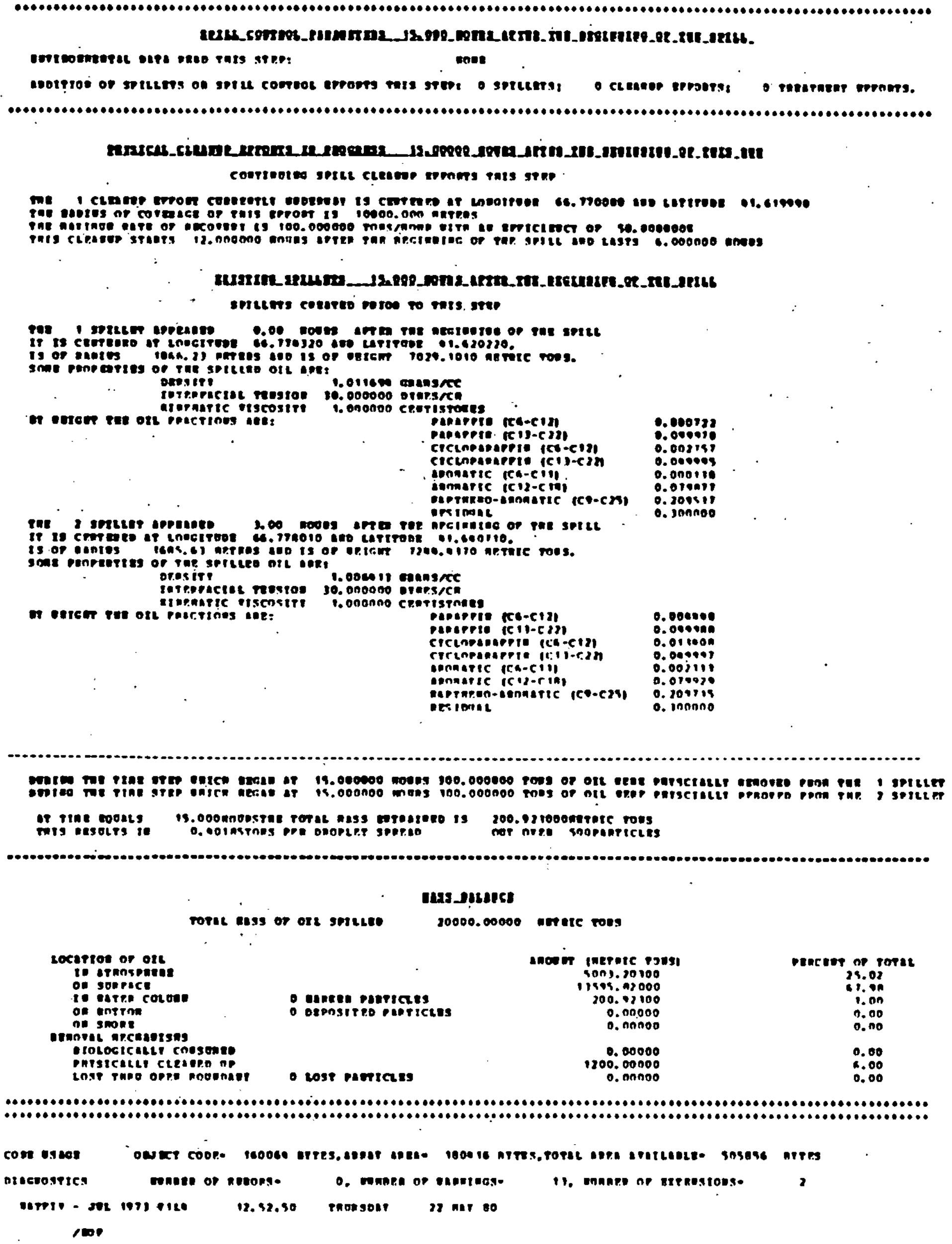
                                        MASS BALANCE

                     TOTAL MASS OF OIL SPILLED          20000.00000  METRIC TONS

     LOCATION OF OIL                                           AMOUNT (METRIC TONS)              PERCENT OF TOTAL
       IN ATMOSPHERE                                              4937.30400                        24.69
       ON SURFACE                                                14271.53000                        71.36
       IN WATER COLUMN          0 NUMBER PARTICLES                 189.11710                         0.95
       ON BOTTOM                0 DEPOSITED PARTICLES                0.00000                         0.00
       ON SHORE                                                      0.00000                         0.00
     REMOVAL MECHANISMS
       BIOLOGICALLY CONSUMED                                         0.00000                         0.00
       PHYSICALLY CLEANED UP                                       600.00000                         3.00
       LOST THRU OPEN BOUNDARY   0 LOST PARTICLES                    0.00000                         0.00

*******************************************************************************************************
*******************************************************************************************************
```

Figure VIII.-6. Output from Preview Run



```
*****************************************************************************************************

                 SPILL_CONTROL_PARAMETERS__15.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL.

  ENVIRONMENTAL DATA READ THIS STEP:                           NONE

  ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  0 SPILLETS;    0 CLEANUP EFFORTS;    0 TREATMENT EFFORTS.

*****************************************************************************************************

          PHYSICAL_CLEANUP_EFFORTS_IN_PROGRESS___15.00000_HOURS_AFTER_THE_BEGINNING_OF_THIS_RUN

                            CONTINUING SPILL CLEANUP EFFORTS THIS STEP

  THE    1 CLEANUP EFFORT CURRENTLY UNDERWAY IS CENTERED AT LONGITUDE  66.770000 AND LATITUDE  61.619990
  THE RADIUS OF COVERAGE OF THIS EFFORT IS  10000.000 METERS
  THE MAXIMUM RATE OF RECOVERY IS 100.000000 TONS/HOUR WITH AN EFFICIENCY OF  50.000000%
  THIS CLEANUP STARTS  12.000000 HOURS AFTER THE BEGINNING OF THE SPILL AND LASTS  6.000000 HOURS

                     EXISTING_SPILLETS___15.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                            SPILLETS CREATED PRIOR TO THIS STEP

  THE    1 SPILLET APPEARED       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
  IT IS CENTERED AT LONGITUDE  66.770320 AND LATITUDE  61.620220,
  IS OF RADIUS     1066.23 METERS AND IS OF WEIGHT  7029.1010 METRIC TONS.
  SOME PROPERTIES OF THE SPILLED OIL ARE:
                 DENSITY                1.011690 GRAMS/CC
                 INTERFACIAL TENSION  30.000000 DYNES/CM
                 KINEMATIC VISCOSITY   1.000000 CENTISTOKES
  BY WEIGHT THE OIL FRACTIONS ARE:                         PARAFFIN (C6-C12)               0.000722
                                                           PARAFFIN (C13-C22)              0.099970
                                                           CYCLOPARAFFIN (C6-C12)          0.002757
                                                           CYCLOPARAFFIN (C13-C22)         0.099995
                                                           AROMATIC (C6-C11)               0.000110
                                                           AROMATIC (C12-C18)              0.079877
                                                           NAPTHENO-AROMATIC (C9-C25)      0.209517
                                                           RESIDUAL                        0.300000
  THE    2 SPILLET APPEARED       3.00  HOURS  AFTER THE BEGINNING OF THE SPILL
  IT IS CENTERED AT LONGITUDE  66.778010 AND LATITUDE  61.660710,
  IS OF RADIUS     1605.63 METERS AND IS OF WEIGHT  7288.4170 METRIC TONS.
  SOME PROPERTIES OF THE SPILLED OIL ARE:
                 DENSITY                1.008613 GRAMS/CC
                 INTERFACIAL TENSION  30.000000 DYNES/CM
                 KINEMATIC VISCOSITY   1.000000 CENTISTOKES
  BY WEIGHT THE OIL FRACTIONS ARE:                         PARAFFIN (C6-C12)               0.004900
                                                           PARAFFIN (C13-C22)              0.099988
                                                           CYCLOPARAFFIN (C6-C12)          0.011408
                                                           CYCLOPARAFFIN (C13-C22)         0.099997
                                                           AROMATIC (C6-C11)               0.002111
                                                           AROMATIC (C12-C18)              0.079929
                                                           NAPTHENO-AROMATIC (C9-C25)      0.209715
                                                           RESIDUAL                        0.100000


-----------------------------------------------------------------------------------------------------

  DURING THE TIME STEP WHICH BEGAN AT  15.000000 HOURS 100.000000 TONS OF OIL WERE PHYSICALLY REMOVED FROM THE  1 SPILLET
  DURING THE TIME STEP WHICH BEGAN AT  15.000000 HOURS 100.000000 TONS OF OIL WERE PHYSICALLY REMOVED FROM THE  2 SPILLET

   AT TIME EQUALS    15.000HOURSTHE TOTAL MASS ENTRAINED IS   200.921000METRIC TONS
   THIS RESULTS IN     0.40184TONS PER DROPLET SPREAD         OUT OVER  500PARTICLES

*****************************************************************************************************

                                         MASS_BALANCE

                  TOTAL MASS OF OIL SPILLED        20000.00000  METRIC TONS

     LOCATION OF OIL                                            AMOUNT (METRIC TONS)          PERCENT OF TOTAL
        IN ATMOSPHERE                                                5003.20300                   25.02
        ON SURFACE                                                  13595.87000                   67.98
        IN WATER COLUMN          0 MARKER PARTICLES                  200.92100                    1.00
        ON BOTTOM                0 DEPOSITED PARTICLES                 0.00000                    0.00
        ON SHORE                                                       0.00000                    0.00
     REMOVAL MECHANISMS
        BIOLOGICALLY CONSUMED                                          0.00000                    0.00
        PHYSICALLY CLEANED UP                                       1200.00000                    6.00
        LOST THRU OPEN BOUNDARY    0 LOST PARTICLES                    0.00000                    0.00

*****************************************************************************************************
*****************************************************************************************************

CORE USAGE       OBJECT CODE=  160069 BYTES,ARRAY AREA=  180416 BYTES,TOTAL AREA AVAILABLE=  505856  BYTES

DIAGNOSTICS         NUMBER OF ERRORS=       0, NUMBER OF WARNINGS=       11, NUMBER OF EXTENSIONS=       2

  WATFIV - JUL 1973 V1L0       12.52.50    THURSDAY     22 MAY 80

       /EOF
```

Figure VIII.-6. Output from Preview Run

```
INPUT CONTROL PARAMETERS   INPUT STREAM FOR THE SUBSURFACE PORTION OF THE MODEL

         0    NSTRT
        -1    NSTEP               1.33300    DOWX
         1    NCHEM               1.33300    DOWY
         0    NPUN                0.05000    PTX
       150    IDAT                0.05000    PTY
         1    NPRT                      0    NTRANS
   1.00000    DT                 10.00000    DTX
  16.00000    TIMMAX             10.00000    DTY
         2    ISCAL               0.00001    DTZ
         1    NPDATA              0.00001    DX
         1    NPRTC               0.00001    DY
         5    NP                  0.33000    DZ
         5    NSD                       5    IMSOR
         4    NCD                       5    JMSOR
         5    NPD                       1    KMSOR
         3    NPD                       0    NSOR
         4    NPD                       1    NDIFF
         1    NPD                     200    NCRIT
         5    NPD                       1    NTITP
         3    NPD                 0.50000    DEPC
         5    NSD                 4.00000    PORIN
         3    NSD                 0.50000    APHAC
        13    NTDR                2.00000    DIFFAC
        14    NTDY                2.00000    DZFFAC
         1    NTHO               50.00000    HPRT
         1    NTHY                0.00100    DDIART
        12    NUN                 0.00000    DTPLZT
         3    NUN                       1    NPTSOR
         5    NCRD                      1    NPRTRS
         5    NCLD                      1    KPRTV
         5    NSRD                      1    KPRTC
         5    NSPD                      1    KPRTP
       500    NPAR                      1    NPRD
       200    NTCLAS                    0    NPRT
       200    NPACI                     1    NPRC
   1.00000    TPSPAR                    1    NPRP
        10    NAISPL
 100.00000    ZONA
         8    NSPIL
         1    NSPRED
         1    NSPPPP
         1    NDSP
         1    NOPS
        10    NUCN
        13    NUCP
        14    NUVL
        15    NUHS
         8    NODP
         9    NULT
         0    NCHOP
```

```
                              BATHYMETRY   INPUT DATA        0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

THE BATHYMETRY   GRID HAS    14 DIVISIONS IN X SPACED        0.0357 DEGREES  APART
                      AND    14 DIVISIONS IN Y SPACED        0.0357 DEGREES  APART.

THE (1,1) GRID LOCATION OF THE BATHYMETRY   COORDINATE SYSTEM IS AT  67.000003 DEGREES LONGITUDE AND  41.350003 DEGREES LATITUDE

                                   DEPTH    VALUES IN UNITS OF METERS

   Y                                          X ELEMENTS
ELEMENTS    1      2      3      4      5      6      7      8      9      10     11     12     13     14

  14      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

  13      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

  12      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

  11      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

  10      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   9      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   8      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   7      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   6      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   5      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   4      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   3      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   2      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000

   1      1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
```

```
                              COMP CELL    INPUT DATA        0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

THE COMP CELL    GRID HAS    14 DIVISIONS IN X SPACED        0.0357 DEGREES  APART
                      AND    14 DIVISIONS IN Y SPACED        0.0357 DEGREES  APART.

THE (1,1) GRID LOCATION OF THE COMP CELL   COORDINATE SYSTEM IS AT  67.000003 DEGREES LONGITUDE AND  41.350003 DEGREES LATITUDE

                                        VALUES IN UNITS OF

   Y                                    X ELEMENTS
ELEMENTS   1      2      3      4      5      6      7      8      9     10     11     12     13     14
  14       2      2      2      2      2      2      2      2      2      2      2      2      2      2
  13       2    101    101    101    101    101    101    101    101    101    101    101    101      2
  12       2    101      1      1      1      1      1      1      1      1      1      1      1      2
  11       2    101      1      1      1      1      1      1      1      1      1      1      1      2
  10       2    101      1      1      1      1      1      1      1      1      1      1      1      2
   9       2    101      1      1      1      1      1      1      1      1      1      1      1      2
   8       2    101      1      1      1      1      1      1      1      1      1      1      1      2
   7       2    101      1      1      1      1      1      1      1      1      1      1      1      2
   6       2    101      1      1      1      1      1      1      1      1      1      1      1      2
   5       2    101      1      1      1      1      1      1      1      1      1      1      1      2
   4       2    101      1      1      1      1      1      1      1      1      1      1      1      2
   3       2    101      1      1      1      1      1      1      1      1      1      1      1      2
   2       2    101    101    101    101    101    101    101    101    101    101    101    101      2
   1       2      2      2      2      2      2      2      2      2      2      2      2      2      2
```

Figure VIII.-7. Output from Main Simulation

```
** *****************************************************************************************************

                          SPILL CONTROL PARAMETERS   0.000 HOURS AFTER THE BEGINNING OF THE SPILL
   ENVIRONMENTAL DATA READ THIS STEP: WIND        CURRENT         TEMPERATURE          SEA STATE    FINAL REPORTS
   ADDITION OF SPILLETS OR SPILL CONTROL REPORTS THIS STEP:  1 SPILLETS:    0 CLEANUP REPORTS:    0 TREATMENT REPORTS .
*******************************************************************************************************


                                         WIND VEL     INPUT DATA       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE WIND VEL     GRID HAS     1 DIVISIONS IN X SPACED       0.5000 DEGREES  APART
                        AND     1 DIVISIONS IN Y SPACED       0.2500 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE WIND VEL     COORDINATE SYSTEM IS AT  60.000003 DEGREES LONGITUDE AND  81.250000 DEGREES LATITUDE

                                              U       VALUES IN UNITS OF    M/SEC

                                                        X ELEMENTS
   Y
ELEMENTS    1

   1       0.000

                                              V       VALUES IN UNITS OF    M/SEC

                                                        X ELEMENTS
   Y
ELEMENTS    1

   1      -6.180


                                        TEMPERATURE  INPUT DATA       0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE TEMPERATURE  GRID HAS     1 DIVISIONS IN X SPACED      0.0357 DEGREES  APART
                        AND     1 DIVISIONS IN Y SPACED      0.0357 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE TEMPERATURE  COORDINATE SYSTEM IS AT  67.000003 DEGREES LONGITUDE AND  81.350003 DEGREES LATITUDE

                                             TEMP.    VALUES IN UNITS OF DEGREES C

                                                        X ELEMENTS
   Y
ELEMENTS    1

   1      20.000


                                        SEA STATE    INPUT DATA      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE SEA STATE    GRID HAS     1 DIVISIONS IN X SPACED      0.0357 DEGREES  APART
                        AND     1 DIVISIONS IN Y SPACED      0.0357 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE SEA STATE    COORDINATE SYSTEM IS AT  67.000003 DEGREES LONGITUDE AND  81.350000 DEGREES LATITUDE

                                             HEIGHT   VALUES IN UNITS OF METERS

                                                        X ELEMENTS
   Y
ELEMENTS    1

   1       1.000

                                             PERIOD   VALUES IN UNITS OF SECONDS

                                                        X ELEMENTS
   Y
ELEMENTS    1

   1      10.000
```

Figure VIII.-7. Output from Main Simulation

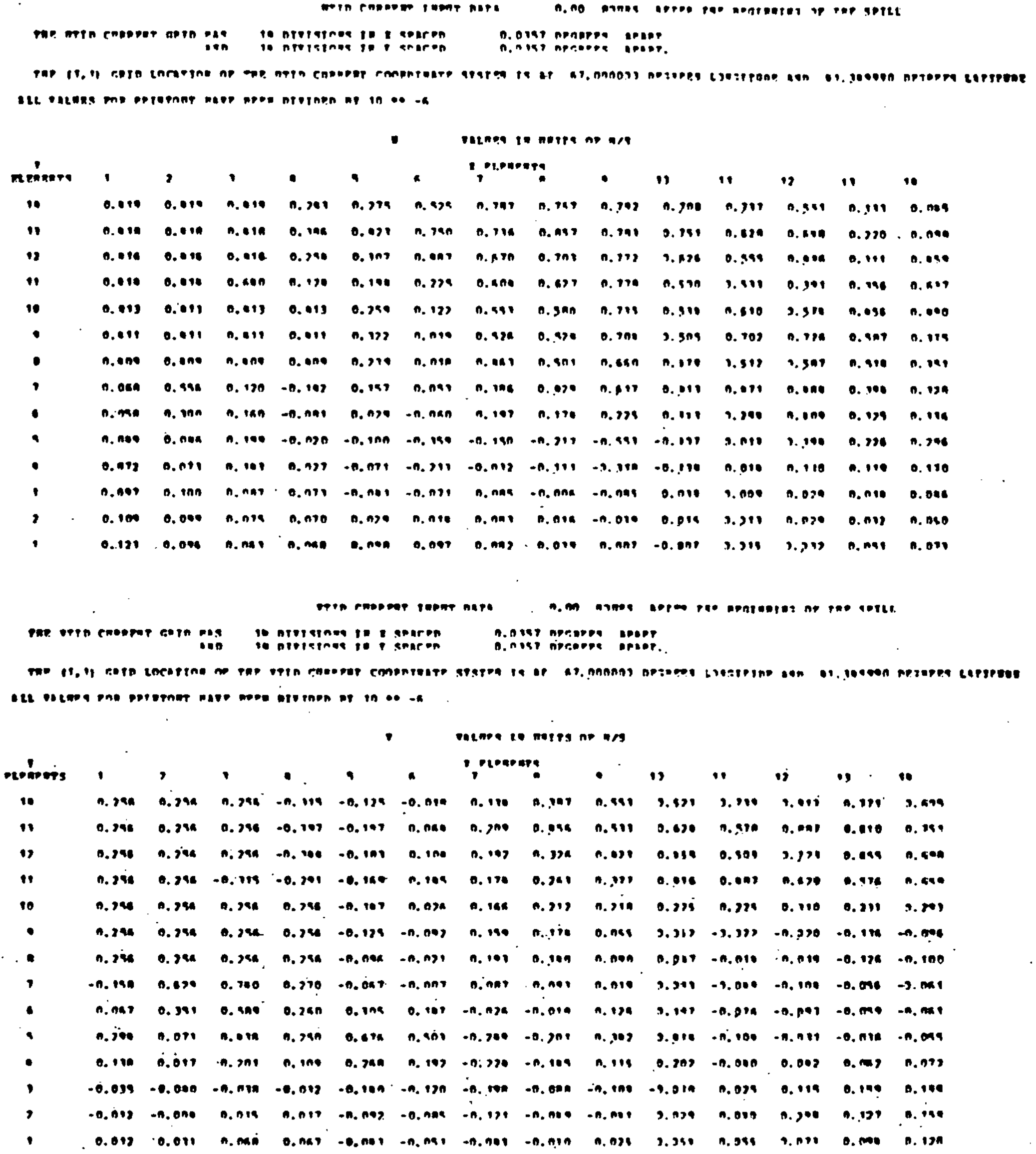


Figure VIII.-7. Output from Main Simulation

```
                         TIDE LEVEL   INPUT DATA      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL

 THE TIDE LEVEL   GRID HAS    14 DIVISIONS IN X SPACED      0.0357 DEGREES  APART
                       AND    14 DIVISIONS IN Y SPACED      0.0157 DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE TIDE LEVEL   COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  81.350000 DEGREES LATITUDE


                                        VALUES IN UNITS OF METERS

    Y                                           X ELEMENTS
ELEMENTS    1      2      3      4      5      6      7      8      9     10     11     12     13     14
   14     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.330  0.000  0.000  0.000  0.000
   13     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.030  0.070  0.303  0.000  0.000
   12     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
   11     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.330  0.033  0.300  0.030  0.000
   10     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.300  0.000  0.000  0.000  0.000
    9     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.333  0.300  0.000  0.000
    8     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.003  0.300  0.000  0.000  0.000  0.000
    7     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  3.333  0.000  0.000  0.000  0.000
    6     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.330  0.300  0.000  0.000
    5     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
    4     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.033  0.000  0.000  0.000  0.000
    3     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.300  0.000  0.000  0.000  0.000
    2     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.333  0.333  0.300  0.000  0.000
    1     0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.030  0.300  0.000  0.000  0.000  0.000


                 EXISTING_SPILLETS____0.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                         NEW SPILLETS ADDED THIS STEP

     THE   1 SPILLET APPEARED     0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
     IT IS CENTERED AT LONGITUDE  66.820000 AND LATITUDE  81.660990,
     IS OF RADIUS      25.00 METERS AND IS OF WEIGHT 10000.0000 METRIC TONS.
     SOME PROPERTIES OF THE SPILLED OIL ARE:
                         DENSITY                0.877000 GRAMS/CC
                         INTERFACIAL TENSION   10.000000 DYNES/CM
                         KINEMATIC VISCOSITY    1.000000 CENTISTOKES
     BY WEIGHT THE OIL FRACTIONS ARE:                     PARAFFIN (C6-C12)                0.053330
                                                          PARAFFIN (C13-C22)               0.100030
                                                          CYCLOPARAFFIN (C6-C12)           0.110333
                                                          CYCLOPARAFFIN (C13-C22)          0.053330
                                                          AROMATIC (C6-C11)                0.133333
                                                          AROMATIC (C12-C18)               0.000330
                                                          NAPTHENO-AROMATIC (C9-C25)       0.213333
                                                          RESIDUAL                         0.100330

  ------------------------------------------------------------------------------------------------------------------------

                          FLOATING_GRID_DEFINITION_AND_PARTICLE_LOCATION_STATISTICS

  ORIGIN OF FLOATING GRID IS AT (     0.2150,      0.1550) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED UPPER GRID
  THE NEW GRID SEPERATION IN THE FLOATING SYSTEM IS      0.0001220 DEGREES  IN X AND       0.0001310 DEGREES  IN Y
  THE GRID SEPERATION IN THE FIXED SYSTEM IS       0.036 DEGREES  IN X AND     0.016 DEGREES  IN Y

  THE AVERAGE VALUES OF X, Y AND Z ARE          0.000295          0.000287          0.171321
  THE STANDARD DEVIATIONS ARE            0.000081          0.000038          1.006805
            HORIZONTAL X-Y SCALE DEPENDENT DIFFUSION COEFF.=      0.2511E-08      0.2058E-08
      XAVG= 0.295E-01      YAVG= 0.285E-01      ZAVG= 0.716           SIGX= 0.800E-08SIGY= 0.808E-08
```

Figure VIII.-7. Output from Main Simulation

```
U & V HORIZONTAL VELOCITIES ARE MULTIPLIED BY 1000

        U VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    1
         0.36     0.36     0.36     0.36     0.36
  0.2      0.065    0.065    0.065    0.065    0.065
  0.2      0.066    0.066    0.066    0.066    0.067
  0.2      0.068    0.068    0.068    0.068    0.068
  0.2      0.070    0.070    0.070    0.070    0.070
  0.2      0.071    0.072    0.072    0.072    0.072

        U VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    2
         0.36     0.36     0.36     0.36     0.36
  0.2      0.065    0.065    0.065    0.065    0.065
  0.2      0.066    0.066    0.066    0.066    0.067
  0.2      0.068    0.068    0.068    0.068    0.068
  0.2      0.070    0.070    0.070    0.070    0.070
  0.2      0.071    0.072    0.072    0.072    0.072

        U VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    3
         0.36     0.36     0.36     0.36     0.36
  0.2      0.065    0.065    0.065    0.065    0.065
  0.2      0.066    0.066    0.066    0.066    0.067
  0.2      0.068    0.068    0.068    0.068    0.068
  0.2      0.070    0.070    0.070    0.070    0.070
  0.2      0.071    0.072    0.072    0.072    0.072

        V VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    1
         0.36     0.36     0.36     0.36     0.36
  0.2     -0.076   -0.076   -0.076   -0.076   -0.076
  0.2     -0.075   -0.075   -0.075   -0.075   -0.075
  0.2     -0.074   -0.074   -0.074   -0.074   -0.074
  0.2     -0.073   -0.073   -0.073   -0.073   -0.073
  0.2     -0.072   -0.072   -0.072   -0.072   -0.072

        V VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    2
         0.36     0.36     0.36     0.36     0.36
  0.2     -0.076   -0.076   -0.076   -0.076   -0.076
  0.2     -0.075   -0.075   -0.075   -0.075   -0.075
  0.2     -0.074   -0.074   -0.074   -0.074   -0.074
  0.2     -0.073   -0.073   -0.073   -0.073   -0.073
  0.2     -0.072   -0.072   -0.072   -0.072   -0.072

        V VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    3
         0.36     0.36     0.36     0.36     0.36
  0.2     -0.076   -0.076   -0.076   -0.076   -0.076
  0.2     -0.075   -0.075   -0.075   -0.075   -0.075
  0.2     -0.074   -0.074   -0.074   -0.074   -0.074
  0.2     -0.073   -0.073   -0.073   -0.073   -0.073
  0.2     -0.072   -0.072   -0.072   -0.072   -0.072

        W VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    1
         0.36     0.36     0.36     0.36     0.36
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000

        W VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    2
         0.36     0.36     0.36     0.36     0.36
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000

        W VELOCITY FIELD      STEP NUMBER   0      TIME          0.00  LEVEL    3
         0.36     0.36     0.36     0.36     0.36
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000
  0.2      0.000    0.000    0.000    0.000    0.000

                      FLOATING GRID DEFINITION AND PARTICLE LOCATION STATISTICS

ORIGIN OF FLOATING GRID IS AT (     0.2162,       0.3567) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED FRAME GRID
THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS       0.0001156 DEGREES  IN X AND       0.0303973 DEGREES  IN Y
THE GRID SEPARATION IN THE FIXED SYSTEM IS      0.036 DEGREES  IN X AND     0.036 DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE          0.000271          0.030210          0.736025
THE STANDARD DEVIATIONS ARE                 0.000046         0.000060          0.163850


       CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   1     TIME          0.00  LEVEL    1

         0.36     0.36     0.36     0.36     0.36
  0.22    0.00000 0.00000 0.00000 0.00000 0.00000
  0.22    0.00000 0.67011 6.11235 0.65889 0.00000
  0.22    0.0000018.2751836.01509 5.22510 0.00000
  0.22    0.00000 1.05509 0.26118 0.00798 0.00000
  0.22    0.00000 0.00000 0.00000 0.00000 0.00000

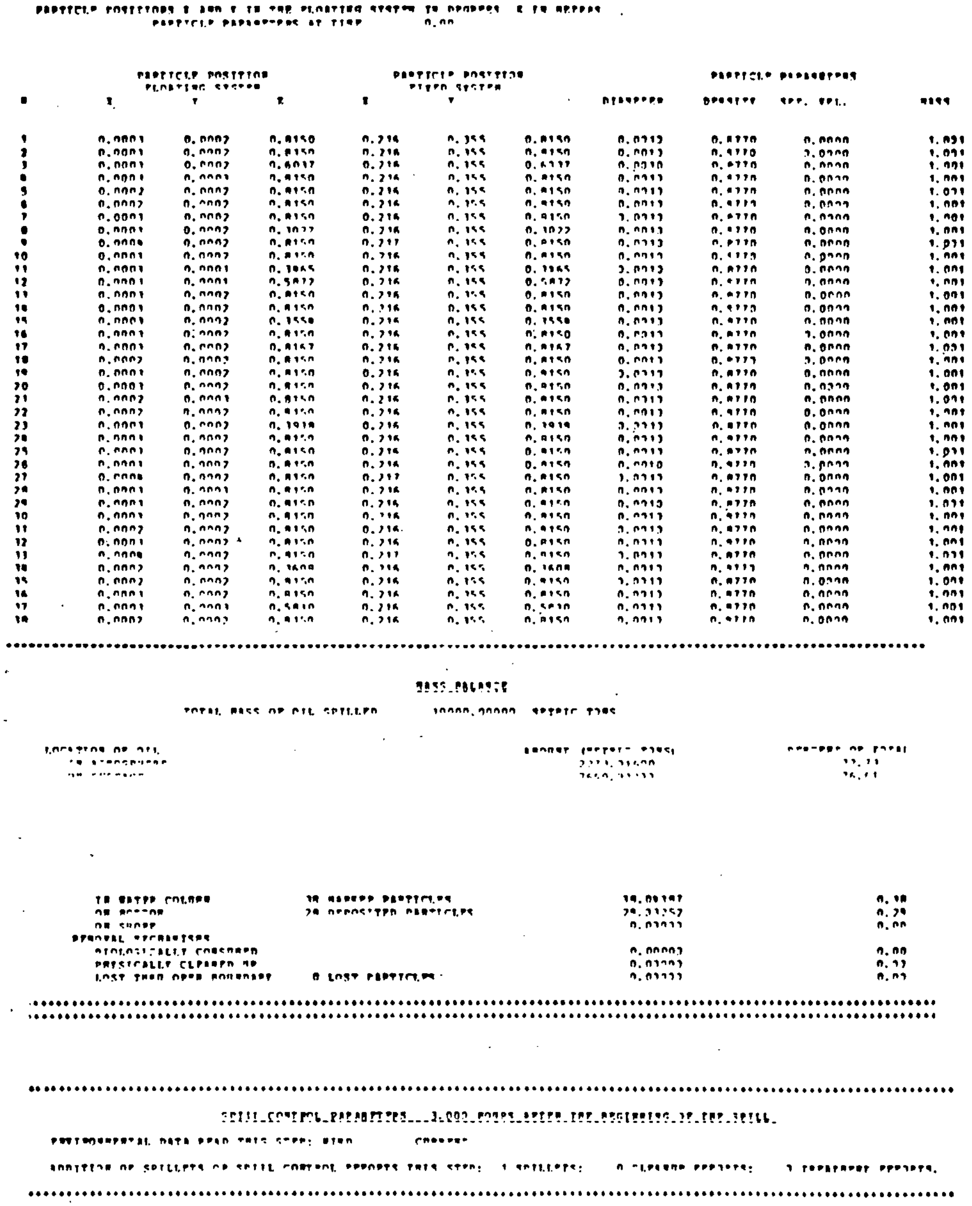
       CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   1     TIME          0.00  LEVEL    2

         0.36     0.36     0.36     0.36     0.36
  0.22    0.00000 0.00000 0.00000 0.00000 0.00000
  0.22    0.00000 0.0787817.51773 2.36165 0.00000
  0.22    0.0000081.0192880.2859020.55174 0.00002
  0.22    0.00000 7.07107 5.00586 2.81191 0.00002
  0.22    0.00000 0.00018 0.00050 0.00000 0.00000

       CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   1     TIME          0.00  LEVEL    3

         0.36     0.36     0.36     0.36     0.36
  0.22    0.00000 0.00000 0.00000 0.00000 0.00000
  0.22    0.0000010.05787*********86.01199 0.00000
  0.22    0.0000063.99999********************* 0.02610
  0.22    0.0000012.9169751.36821 7.91202 0.00067
  0.22    0.00000 0.01077 0.01588 0.00000 0.00000
```

Figure VIII.-7. Output from Main Simulation



```
PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
                 PARTICLE PARAMETERS AT TIME        0.00

                 PARTICLE POSITION                    PARTICLE POSITION                              PARTICLE PARAMETERS
                  FLOATING SYSTEM                       FIXED SYSTEM
 N          X           Y           Z          X          Y                    DIAMETER     DENSITY    SPE. VOL.         MASS

 1       0.0001      0.0002      0.8150      0.216      0.355      0.8150      0.0013      0.8770      0.0000         1.001
 2       0.0001      0.0002      0.8150      0.216      0.355      0.8150      0.0013      0.8770      0.0000         1.001
 3       0.0001      0.0002      0.6017      0.216      0.155      0.6017      0.0010      0.8770      0.0000         1.001
 4       0.0001      0.0001      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
 5       0.0002      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
 6       0.0002      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
 7       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
 8       0.0001      0.0002      0.3022      0.216      0.155      0.3022      0.0013      0.8770      0.0000         1.001
 9       0.0004      0.0002      0.8150      0.217      0.155      0.8150      0.0013      0.8770      0.0000         1.001
10       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
11       0.0001      0.0001      0.3865      0.216      0.155      0.3865      0.0013      0.8770      0.0000         1.001
12       0.0001      0.0001      0.5872      0.216      0.155      0.5872      0.0013      0.8770      0.0000         1.001
13       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
14       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
15       0.0001      0.0002      0.3558      0.216      0.155      0.3558      0.0013      0.8770      0.0000         1.001
16       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
17       0.0001      0.0002      0.8167      0.216      0.355      0.8167      0.0013      0.8770      0.0000         1.001
18       0.0002      0.0002      0.8150      0.216      0.355      0.8150      0.0013      0.8770      0.0000         1.001
19       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
20       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
21       0.0002      0.0001      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
22       0.0002      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
23       0.0001      0.0002      0.3939      0.216      0.155      0.3939      0.0013      0.8770      0.0000         1.001
24       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
25       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
26       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0010      0.8770      0.0000         1.001
27       0.0004      0.0002      0.8150      0.217      0.155      0.8150      0.0013      0.8770      0.0000         1.001
28       0.0001      0.0001      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
29       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
30       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
31       0.0002      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
32       0.0001      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
33       0.0004      0.0002      0.8150      0.217      0.155      0.8150      0.0013      0.8770      0.0000         1.001
34       0.0002      0.0002      0.3608      0.216      0.155      0.3608      0.0013      0.8770      0.0000         1.001
35       0.0002      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001
36       0.0001      0.0002      0.8150      0.216      0.355      0.8150      0.0013      0.8770      0.0000         1.001
37       0.0001      0.0001      0.5810      0.216      0.155      0.5810      0.0013      0.8770      0.0000         1.001
38       0.0002      0.0002      0.8150      0.216      0.155      0.8150      0.0013      0.8770      0.0000         1.001

******************************************************************************************************************

                                              MASS BALANCE

                         TOTAL MASS OF OIL SPILLED        10000.00000  METRIC TONS

   LOCATION OF OIL                                                   AMOUNT (METRIC TONS)            PERCENT OF TOTAL
      IN ATMOSPHERE                                                     2273.31600                         22.73
      ON SURFACE                                                        7650.33333                         76.51



        IN WATER COLUMN          38 MARKED PARTICLES                      38.08387                          0.38
        ON BOTTOM                29 DEPOSITED PARTICLES                   29.31252                          0.29
        ON SHORE                                                           0.03033                          0.00
     REMOVAL MECHANISMS
        BIOLOGICALLY CONSUMED                                              0.00003                          0.00
        PHYSICALLY CLEANED UP                                              0.03303                          0.33
        LOST THRU OPEN BOUNDARY     0 LOST PARTICLES                       0.03333                          0.03

  ******************************************************************************************************************
  ******************************************************************************************************************


  ********************************************************************************************************************

                    SPILL_CONTROL_PARAMETERS___3.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL_

    ENVIRONMENTAL DATA READ THIS STEP: WIND        CURRENT

    ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:   1 SPILLETS:     0 CLEANUP EFFORTS:    0 TREATMENT EFFORTS.

  ********************************************************************************************************************
```

Figure VIII.-7. Output from Main Simulation

```
                              WIND FEL     INPUT DATA       1.00  HOURS  AFTER THE BEGINNING OF THE SPILL

  THE WIND FEL    GRID HAS     1 DIVISIONS IN X SPACED      0.5000 DEGREES  APART
                       AND     1 DIVISIONS IN Y SPACED      0.2500 DEGREES  APART.

  THE (1,1) GRID LOCATION OF THE WIND FEL     COORDINATE SYSTEM IS AT  58.000000 DEGREES LONGITUDE AND  61.250000 DEGREES LATITUDE

                                            U       VALUES IN UNITS OF    M/SEC
  Y
ELEMENTS    1                                          X ELEMENTS

  1       0.000

                                            V       VALUES IN UNITS OF    M/SEC
  Y
ELEMENTS    1                                          X ELEMENTS

  1      -5.150


                              TIDE CURRENT INPUT DATA       1.00  HOURS  AFTER THE BEGINNING OF THE SPILL

 THE TIDE CURRENT GRID HAS    14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                       AND    14 DIVISIONS IN Y SPACED       0.0357 DEGREES  APART.

 THE (1,1) GRID LOCATION OF THE TIDE CURRENT COORDINATE SYSTEM IS AT  57.000011 DEGREES LONGITUDE AND  61.388893 DEGREES LATITUDE

ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                         U        VALUES IN UNITS OF M/S
  Y                                                 X ELEMENTS
ELEMENTS    1       2       3       4       5       6       7       8       9      10      11      12      13      14

  14      0.609   0.609   0.609   0.611   0.665   0.710   0.976   0.957   0.991   0.899   1.025   1.100   0.122   1.239

  13      0.606   0.606   0.606   0.578   0.611   0.938   0.925   1.066   0.971   0.939   0.817   0.836   0.809   0.787

  12      0.608   0.608   0.608   0.683   0.695   0.675   0.858   0.890   0.950   0.918   0.783   0.680   0.699   0.686

  11      0.601   0.601   0.027   0.119   0.181   0.612   0.791   0.810   0.965   0.797   0.720   0.578   0.593   0.420

  10      0.599   0.599   0.599   0.598   0.665   0.109   0.719   0.766   0.921   0.720   1.795   1.760   0.683   0.678

   9      0.597   0.597   0.597   0.597   0.507   0.205   0.711   0.710   0.890   1.691   0.887   0.911   0.771   0.561

   8      0.598   0.598   0.598   0.598   0.620   0.203   0.688   0.686   0.895   1.658   0.787   0.772   0.699   1.516

   7      0.252   0.780   0.108   0.082   0.181   0.217   0.571   0.610   0.801   0.597   0.555   1.569   0.570   0.512

   6      0.282   0.888   0.181   0.102   0.212   0.120   0.180   0.357   0.809   0.327   0.887   0.592   0.509   0.520

   5      0.231   0.229   0.182   0.161   0.081  -0.176   0.011  -0.010  -0.110  -0.125   0.202   0.176   0.808   0.070

   4      0.250   0.255   0.125   0.209   0.111  -0.011   0.150   0.071  -0.116   1.089   0.196   0.292   0.102   0.152

   3      0.270   0.297   0.269   0.255   0.180   0.111   0.266   0.176   0.097   0.221   0.191   1.210   0.196   0.227

   2      0.290   0.279   0.256   0.251   0.210   0.195   0.268   0.197   0.102   1.197   0.198   1.210   0.212   0.201

   1      0.303   0.275   0.281   0.288   0.278   0.277   0.262   0.219   0.187   1.171   0.197   0.212   0.212   0.253
```

Figure VIII.-7. Output from Main Simulation

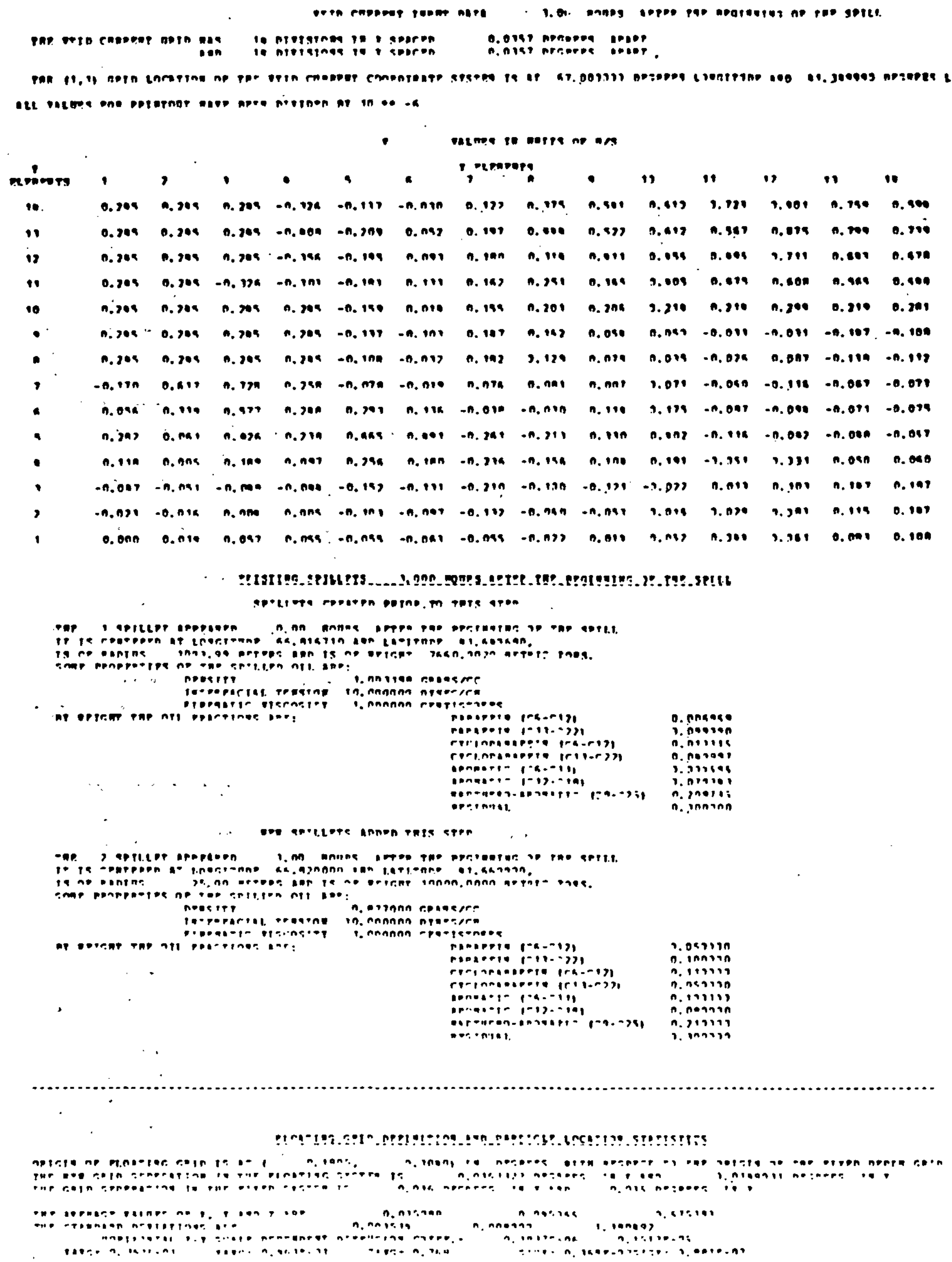


Figure VIII.-7. Output from Main Simulation

```
ALL HORIZONTAL VELOCITIES ARE MULTIPLIED BY 10**6

        U VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   1
         0.31    0.33    0.34    0.36    0.37
  0.2     0.312   0.366   0.409   0.452   0.418
  0.2     0.211   0.228   0.271   0.318   0.352
  0.2     0.419   0.426   0.437   0.489   0.511
  0.2     0.601   0.657   0.669   0.681   0.710
  0.1     0.679   0.718   0.702   0.765   0.767

        U VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   2
         0.31    0.33    0.34    0.36    0.37
  0.2     0.312   0.366   0.409   0.452   0.418
  0.2     0.211   0.228   0.271   0.318   0.352
  0.2     0.419   0.426   0.437   0.489   0.511
  0.2     0.601   0.657   0.669   0.681   0.710
  0.1     0.679   0.718   0.702   0.765   0.767

        U VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   3
         0.31    0.33    0.34    0.36    0.37
  0.2     0.312   0.366   0.409   0.452   0.418
  0.2     0.211   0.228   0.271   0.318   0.352
  0.2     0.419   0.426   0.437   0.489   0.511
  0.2     0.601   0.657   0.669   0.681   0.710
  0.1     0.679   0.718   0.702   0.765   0.767

        V VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   1
         0.31    0.33    0.34    0.36    0.37
  0.2    -0.152  -0.087  -0.038  -0.009  -0.080
  0.2    -0.118  -0.071  -0.023  -0.010   0.080
  0.2    -0.021  -0.051  -0.048   0.048   0.087
  0.2     0.077   0.068   0.067   0.108   0.111
  0.1     0.207   0.162   0.179   0.169   0.190

        V VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   2
         0.31    0.33    0.34    0.36    0.37
  0.2    -0.152  -0.087  -0.038  -0.009  -0.080
  0.2    -0.118  -0.071  -0.023  -0.010   0.080
  0.2    -0.021  -0.051  -0.048   0.048   0.087
  0.2     0.077   0.068   0.067   0.108   0.111
  0.1     0.207   0.162   0.179   0.169   0.190

        V VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   3
         0.31    0.33    0.34    0.36    0.37
  0.2    -0.152  -0.087  -0.038  -0.009  -0.080
  0.2    -0.118  -0.071  -0.023  -0.010   0.080
  0.2    -0.021  -0.051  -0.048   0.048   0.087
  0.2     0.077   0.068   0.067   0.108   0.111
  0.1     0.207   0.162   0.179   0.169   0.190

        W VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   1
         0.31    0.33    0.34    0.36    0.37
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.1     0.000   0.000   0.000   0.000   0.000

        W VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   2


         0.31    0.33    0.34    0.36    0.37
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.1     0.000   0.000   0.000   0.000   0.000

        W VELOCITY FIELD      STEP NUMBER   1      TIME      10800.00  LEVEL   3
         0.31    0.33    0.34    0.36    0.37
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.2     0.000   0.000   0.000   0.000   0.000
  0.1     0.000   0.000   0.000   0.000   0.000

                    FLOATING_GRID_DEFINITION_AND_PARTICLE_LOCATION_STATISTICS

ORIGIN OF FLOATING GRID IS AT (      0.1877,       0.3012) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED UPPER GRID
THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS        0.0178033 DEGREES  IN X AND       0.0188982 DEGREES  IN Y
THE GRID SEPARATION IN THE FIXED SYSTEM IS      0.036 DEGREES  IN X AND     0.016 DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE          0.017680          0.086860          0.768287
THE STANDARD DEVIATIONS ARE                 0.003908          0.008871          0.121089
```

Figure VIII.-7. Output from Main Simulation

```
        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   1     TIME    10800.00  LEVEL   1

         0.31     0.33     0.34     0.36     0.37
 0.19    0.00000 0.00000 0.00000 0.00000 0.00000
 0.21    0.00000 0.00000 0.00006 0.00002 0.00000
 0.22    0.00000 0.00000 0.00011 0.00170 0.00000
 0.24    0.00000 0.00000 0.00000 0.00000 0.00000
 0.25    0.00000 0.00000 0.00000 0.00000 0.00000

        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   1     TIME    10800.00  LEVEL   2

         0.31     0.33     0.34     0.36     0.37
 0.19    0.00000 0.00000 0.00000 0.00000 0.00000
 0.21    0.00000 0.00012 0.00033 0.00801 0.00000
 0.22    0.00000 0.00027 0.00058 0.00688 0.00000
 0.24    0.00000 0.00002 0.00008 0.00000 0.00000
 0.25    0.00000 0.00000 0.00000 0.00000 0.00000

        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   1     TIME    10800.00  LEVEL   3

         0.31     0.33     0.34     0.36     0.37
 0.19    0.00000 0.00000 0.00000 0.00000 0.00000
 0.21    0.00000 0.00108 0.00538 0.02111 0.00000
 0.22    0.00000 0.00633 0.01058 0.03791 0.00000
 0.24    0.00000 0.00051 0.00134 0.00000 0.00000
 0.25    0.00000 0.00000 0.00000 0.00000 0.00000

*** ************************************************************************************************

              SPILL_CONTROL_PARAMETERS___3.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL_

  ENVIRONMENTAL DATA READ THIS STEP:                          NONE

  ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  0 SPILLETS:    0 CLEANUP EFFORTS:    0 TREATMENT EFFORTS..
****************************************************************************************************

              EXISTING_SPILLETS____3.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                     SPILLETS CREATED PRIOR TO THIS STEP

  THE    1 SPILLET APPEARED      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
  IT IS CENTERED AT LONGITUDE  66.799710 AND LATITUDE  41.627160,
  IS OF RADIUS    1696.90 METERS AND IS OF WEIGHT  7178.6900 METRIC TONS.
  SOME PROPERTIES OF THE SPILLED OIL ARE:
                    DENSITY                1.010876 GRAMS/CC
                    INTERFACIAL TENSION   30.000000 DYNES/CM
                    KINEMATIC VISCOSITY    1.000000 CENTISTOKES
  BY WEIGHT THE OIL FRACTIONS ARE:                            PARAFFIN (C6-C12)              0.001333
                                                              PARAFFIN (C13-C22)             0.099992
                                                              CYCLOPARAFFIN (C6-C12)         0.005271
                                                              CYCLOPARAFFIN (C13-C22)        0.049905
                                                              AROMATIC (C6-C11)              0.000010
                                                              AROMATIC (C12-C18)             0.079979
                                                              NAPHTHENO-AROMATIC (C9-C25)    0.209618
                                                              RESIDUAL                       0.103333
  THE    2 SPILLET APPEARED      1.00  HOURS  AFTER THE BEGINNING OF THE SPILL
  IT IS CENTERED AT LONGITUDE  66.802710 AND LATITUDE  41.608110,
  IS OF RADIUS    1101.81 METERS AND IS OF WEIGHT  7781.7070 METRIC TONS.
  SOME PROPERTIES OF THE SPILLED OIL ARE:
                    DENSITY                1.000205 GRAMS/CC
                    INTERFACIAL TENSION   30.000000 DYNES/CM
                    KINEMATIC VISCOSITY    1.000000 CENTISTOKES
  BY WEIGHT THE OIL FRACTIONS ARE:                            PARAFFIN (C6-C12)              0.008153
                                                              PARAFFIN (C13-C22)             0.099992
                                                              CYCLOPARAFFIN (C6-C12)         0.025908
                                                              CYCLOPARAFFIN (C13-C22)        0.013333
                                                              AROMATIC (C6-C11)              0.007512
                                                              AROMATIC (C12-C18)             0.079351
                                                              NAPHTHENO-AROMATIC (C9-C25)    0.209910
                                                              RESIDUAL                       0.103333

----------------------------------------------------------------------------------------------------


              FLOATING_GRID_DEFINITION_AND_PARTICLE_LOCATION_STATISTICS

ORIGIN OF FLOATING GRID IS AT (     0.1782,  -    0.2623) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED ORDER GRID
THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS        [illegible] DEGREES  IN X AND       [illegible] DEGREES  IN Y
THE GRID SEPARATION IN THE FIXED SYSTEM IS       0.016 DEGREES  IN X AND     0.015 DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE          [illegible]          [illegible]          [illegible]
THE STANDARD DEVIATIONS ARE              [illegible]        [illegible]        [illegible]
```

Figure VIII.-7. Output from Main Simulation

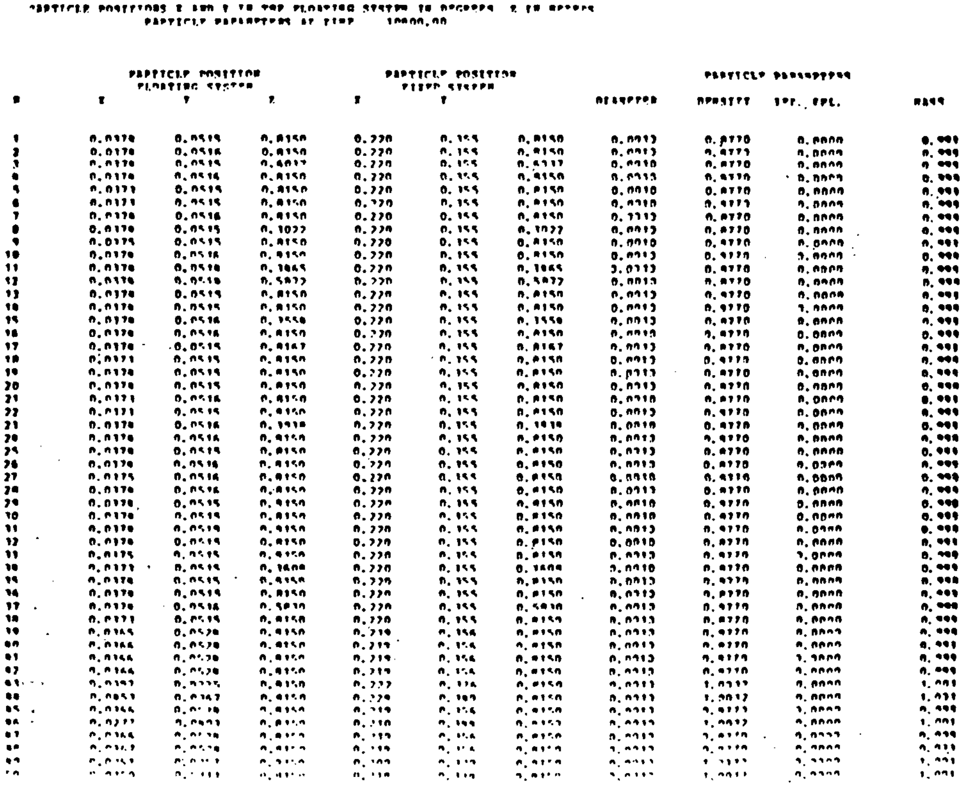


Figure VIII.-7. Output from Main Simulation

```
 51      0.0191    0.0037    0.8150    0.222    0.107    0.8150    0.0013    1.0012    0.0000       1.001
 52      0.0197    0.0316    0.8150    0.222    0.115    0.8150    0.0013    1.0012    0.0000       1.001
 53      0.0412    0.0319    0.8150    0.224    0.115    0.8150    0.0013    1.0012    0.0000       1.001
 54      0.0191    0.0316    0.8150    0.222    0.115    0.8150    0.0013    1.0012    0.0000       1.001
 55      0.0166    0.0528    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 56      0.0155    0.0521    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 57      0.0176    0.0386    0.8150    0.220    0.102    0.8150    0.0013    1.0012    0.0000       1.001
 58      0.0166    0.0528    0.5717    0.219    0.156    0.5717    0.0010    0.8770    0.0000       0.998
 59      0.0609    0.0101    0.8150    0.244    0.118    0.8150    0.0013    1.0012    0.0000       1.011
 60      0.0901    0.0111    0.8150    0.221    0.118    0.8150    0.0013    1.0012    0.0000       1.001
 61      0.0262    0.0325    0.8150    0.209    0.116    0.8150    0.0013    1.0012    0.0000       1.001
 62      0.0155    0.0528    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 63      0.0186    0.0281    0.8150    0.221    0.111    0.8150    0.0013    1.0012    0.0000       1.031
 64      0.0507    0.0101    0.8150    0.213    0.111    0.8150    0.0013    1.0012    0.0000       1.001
 65      0.0195    0.0108    0.8150    0.222    0.118    0.8150    0.0010    1.0012    0.0000       1.001
 66      0.0817    0.0288    0.8150    0.228    0.112    0.8150    0.0013    1.0012    0.0000       1.001
 67      0.0166    0.0521    0.8786    0.219    0.156    0.8786    0.0013    0.8770    0.0000       0.999
 68      0.0192    0.0107    0.7611    0.222    0.118    0.7611    0.0013    1.0012    0.0000       1.001
 69      0.0804    0.0312    0.8150    0.221    0.116    0.8150    0.0013    1.0012    0.0000       1.001
 70      0.0191    0.0285    0.8150    0.222    0.112    0.8150    0.0013    1.0012    0.0000       1.001
 71      0.0812    0.0327    0.8150    0.228    0.116    0.8150    0.0013    1.0012    0.0000       1.001
 72      0.0165    0.0528    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 73      0.0165    0.0528    0.7679    0.219    0.156    0.7679    0.0013    0.8770    0.0000       0.999
 74      0.0166    0.0528    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 75      0.0165    0.0528    0.7887    0.219    0.156    0.7887    0.0010    0.8770    0.0000       0.999
 76      0.0166    0.0528    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 77      0.0165    0.0528    0.8150    0.219    0.156    0.8150    0.0010    0.8770    0.0000       0.999
 78      0.0166    0.0528    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 79      0.0165    0.0521    0.7275    0.219    0.156    0.7275    0.0013    0.8771    0.0000       0.999
 80      0.0165    0.0521    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 81      0.0166    0.0528    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.998
 82      0.0166    0.0528    0.8150    0.219    0.156    0.8150    0.0013    0.8770    0.0000       0.999
 83      0.0166    0.0528    0.7111    0.219    0.156    0.7111    0.0010    0.8770    0.0000       0.999

****************************************************************************************************

                                          MASS_BALANCE

               TOTAL MASS OF OIL SPILLED        20000.00000  METRIC TONS

      LOCATION OF OIL                                          AMOUNT (METRIC TONS)          PERCENT OF TOTAL
         IN ATMOSPHERE                                             4438.06400                     22.19
         ON SURFACE                                               15416.95000                     77.08
         IN WATER COLUMN          83 MASSED PARTICLES                82.99915                      0.41
         ON BOTTOM                62 DEPOSITED PARTICLES             61.98656                      0.31
         ON SHORE                                                     0.00000                      0.00
      REMOVAL MECHANISMS
         BIOLOGICALLY CONSUMED                                        0.00000                      0.00
         PHYSICALLY CLEANED UP                                        0.00000                      0.00
         LOST THRU OPEN BOUNDARY    0 LOST PARTICLES                  0.00000                      0.00

****************************************************************************************************
****************************************************************************************************

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                    SPILL_CONTROL_PARAMETERS___6.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL_

      ENVIRONMENTAL DATA READ THIS STEP: WIND       CURRENT

      ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  0 SPILLETS;   0 CLEANUP EFFORTS;   0 TREATMENT EFFORTS.

  ****************************************************************************************************


                         WIND VEL     INPUT DATA       6.00  HOURS  AFTER THE BEGINNING OF THE SPILL

THE WIND VEL     GRID HAS     1 DIVISIONS IN X SPACED       0.5000 DEGREES  APART
                      AND     1 DIVISIONS IN Y SPACED       0.2500 DEGREES  APART.

THE (1,1) GRID LOCATION OF THE WIND VEL   COORDINATE SYSTEM IS AT  68.000000 DEGREES LONGITUDE AND  61.250000 DEGREES LATITUDE


                                  U    VALUES IN UNITS OF    M/SEC

   Y                                       X ELEMENTS
ELEMENTS     1

   1       2.570


                                       V   VALUES IN UNITS OF    M/SEC

   Y                                       X ELEMENTS
ELEMENTS     1

   1       0.000
```

Figure VIII.-7. Output from Main Simulation

```
                                GRID CURRENT INPUT DATA      6.00  HOURS  AFTER THE BEGINNING OF THE SPILL

   THE GRID CURRENT GRID HAS     14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                         AND     14 DIVISIONS IN Y SPACED       0.0357 DEGREES  APART.

   THE (1,1) GRID LOCATION OF THE GRID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  61.166660 DEGREES LATITUDE

  ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                          U        VALUES IN UNITS OF M/S

     Y                                                     X ELEMENTS
  ELEMENTS    1       2       3       4       5       6       7       8       9      10      11      12      13      14

     14     0.139   0.139   0.139  -0.037  -0.005   0.285   0.507   0.897   0.512   1.028   0.855   0.271  -0.188  -0.235
     13     0.138   0.138   0.138   0.107   0.183   0.870   0.857   0.578   0.503   0.872   0.389   0.169  -0.059  -0.181
     12     0.138   0.138   0.138  -0.028   0.029   0.209   0.392   0.828   0.898   0.388   0.277   0.218   0.031   0.191
     11     0.137   0.137   0.163  -0.153  -0.083  -0.052   0.327   0.350   0.503   0.373   1.255   1.318   0.079   0.160
     10     0.137   0.137   0.137   0.137  -0.017  -0.158   0.277   0.308   0.859   0.259   0.338   0.298   0.188   0.218
      9     0.136   0.136   0.136   0.136   0.087  -0.256   0.251   0.250   0.829   0.310   0.827   0.891   0.312   0.188
      8     0.136   0.136   0.136   0.136  -0.035  -0.256   0.190   0.227   0.187   0.205   0.338   1.313   0.288   0.077
      7    -0.205   0.281  -0.151  -0.815  -0.116  -0.220   0.118   0.157   0.188   0.380   0.199   0.212   0.123   0.055
      6    -0.213   0.029  -0.112  -0.353  -0.283  -0.333  -0.075  -0.099  -0.088  -0.129   0.012   0.137   0.059   0.058
      5    -0.222  -0.228  -0.071  -0.291  -0.370  -0.629  -0.820  -0.888  -0.828  -0.579  -3.252  -1.077  -0.085   0.025
      4    -0.198  -0.196  -0.127  -0.282  -0.383  -0.883  -0.302  -0.393  -0.588  -1.803  -0.255  -0.160  -0.150  -0.099
      3    -0.172  -0.168  -0.181  -0.196  -0.330  -0.339  -0.188  -0.275  -0.353  -0.330  -0.259  -0.280  -0.255  -0.223
      2    -0.158  -0.169  -0.193  -0.197  -0.218  -0.258  -0.188  -0.251  -0.305  -1.351  -0.255  -1.238  -0.238  -0.208
      1    -0.188  -0.171  -0.208  -0.199  -0.168  -0.170  -0.185  -0.228  -0.260  -0.278  -0.250  -0.235  -0.215  -0.198


                                GRID CURRENT INPUT DATA      6.00  HOURS  AFTER THE BEGINNING OF THE SPILL

   THE GRID CURRENT GRID HAS     14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
                         AND     14 DIVISIONS IN Y SPACED       0.0357 DEGREES  APART.

   THE (1,1) GRID LOCATION OF THE GRID CURRENT COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  61.166660 DEGREES LATITUDE

  ALL VALUES FOR PRINTOUT HAVE BEEN DIVIDED BY 10 ** -6

                                          V        VALUES IN UNITS OF M/S

     Y                                                     X ELEMENTS
  ELEMENTS    1       2       3       4       5       6       7       8       9      10      11      12      13      14

     14    -0.181  -0.181  -0.181  -0.752  -0.562  -0.855  -0.103  -0.050   0.115   0.198   1.302   0.878   0.331   0.158
     13    -0.181  -0.181  -0.181  -0.838  -0.638  -0.373  -0.228   0.018   0.095   0.197   0.181   0.850   0.373   0.318
     12    -0.181  -0.181  -0.181  -0.782  -0.621  -0.333  -0.286  -0.112  -0.018   0.031   0.071   0.288   0.218   0.253
     11    -0.181  -0.181  -0.752  -0.728  -0.606  -0.292  -0.268  -0.178  -0.058  -0.021   3.088   3.183   0.139   0.222
     10    -0.181  -0.181  -0.181  -0.181  -0.585  -0.833  -0.273  -0.225  -0.219  -0.211  -0.211  -1.327  -0.208  -0.188
      9    -0.181  -0.181  -0.181  -0.181  -0.562  -0.529  -0.278  -0.268  -0.371  -0.379  -0.858  -0.857  -0.573  -0.533
      8    -0.181  -0.181  -0.181  -0.181  -0.533  -0.858  -0.288  -0.297  -0.387  -0.390  -0.853  -0.838  -0.563  -0.537
      7    -0.595   0.192   0.303  -0.167  -0.508  -0.888  -0.350  -0.388  -0.818  -0.358  -0.896  -0.583  -0.893  -0.898
      6    -0.370  -0.086   0.152  -0.177  -0.112  -0.290  -0.863  -0.855  -0.313  -0.250  -0.533  -0.520  -0.898  -0.500
      5    -0.183  -0.368   0.003  -0.187   0.239   0.066  -0.686  -0.638  -0.095  -0.023  -0.583  -0.868  -0.873  -0.892
      4    -0.308  -0.820  -0.237  -0.328  -0.169  -0.286  -0.661  -0.582  -0.323  -0.335  -0.877  -0.395  -0.375  -0.365
      3    -0.872  -0.877  -0.875  -0.869  -0.577  -0.557  -0.635  -0.525  -0.585  -3.317  -0.812  -1.322  -0.278  -0.238
      2    -0.889  -0.887  -0.822  -0.820  -0.528  -0.523  -0.558  -0.886  -0.878  -0.388  -0.387  -0.383  -0.338  -0.278
      1    -0.825  -0.806  -0.369  -0.373  -0.880  -0.888  -0.888  -0.887  -0.833  -3.373  -0.383  -0.368  -0.383  -0.317
```

Figure VIII.-7. Output from Main Simulation

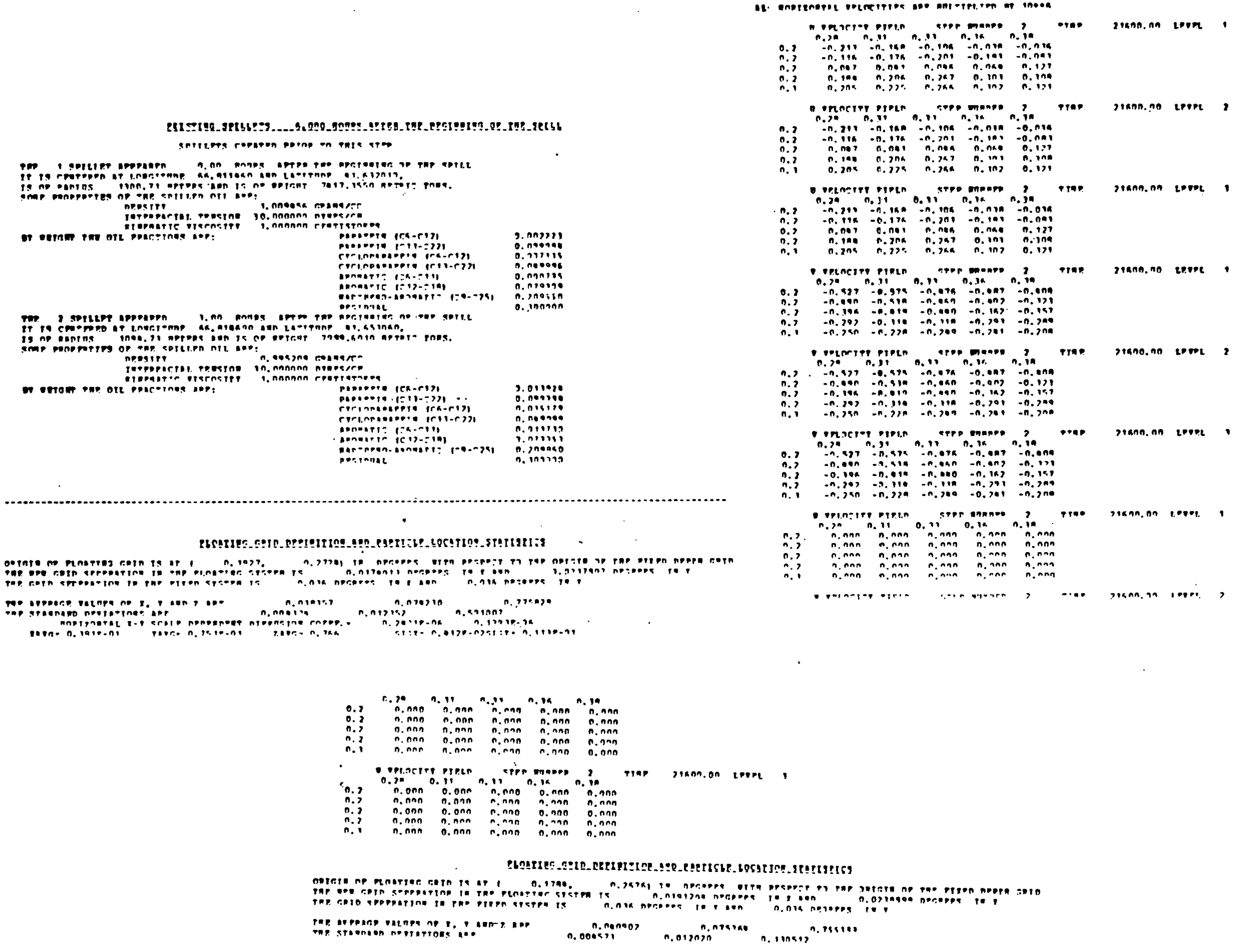

Figure VIII.-7. Output from Main Simulation

```
          CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   2     TIME    21599.99  LEVEL   1

           0.28     0.31     0.33     0.36     0.38
  0.19     0.00000 0.00000 0.00000 0.00000 0.00000
  0.21     0.00000 0.00000 0.00015 0.00069 0.00000
  0.23     0.00000 0.00000 0.00017 0.00105 0.00000
  0.24     0.00000 0.00000 0.00000 0.00000 0.00000
  0.26     0.00000 0.00000 0.00000 0.00000 0.00000

          CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   2     TIME    21600.00  LEVEL   2

           0.28     0.31     0.33     0.36     0.38
  0.19     0.00000 0.00000 0.00000 0.00000 0.00000
  0.21     0.00000 0.00007 0.00028 0.00270 0.00000
  0.23     0.00000 0.00016 0.00053 0.00171 0.00000
  0.24     0.00000 0.00000 0.00001 0.00001 0.00000
  0.26     0.00000 0.00000 0.00000 0.00000 0.00000

          CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   2     TIME    21600.00  LEVEL   3

           0.28     0.31     0.33     0.36     0.38
  0.19     0.00000 0.00000 0.00000 0.00000 0.00000
  0.21     0.00000 0.00096 0.00837 0.01610 0.00000
  0.23     0.00000 0.00218 0.00982 0.02283 0.00000
  0.24     0.00000 0.00000 0.00105 0.00036 0.00000
  0.26     0.00000 0.00000 0.00000 0.00000 0.00000


PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
              PARTICLE PARAMETERS AT TIME     21600.00


               PARTICLE POSITION                      PARTICLE POSITION                                PARTICLE PARAMETERS
                FLOATING SYSTEM                         FIXED SYSTEM
 N          X          Y          Z          X          Y          Z         DIAMETER    DENSITY   SET. VEL.         MASS

 1       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0013      0.8720     0.0000           0.998
 2       0.0001     0.0827     0.8150     0.219      0.150      0.8150      0.0013      0.8720     0.0000           0.999
 3       0.0001     0.0827     0.6033     0.218      0.150      0.6033      0.0013      0.8710     0.0000           0.998
 4       0.0001     0.0828     0.8150     0.219      0.150      0.8150      0.0013      0.8720     0.0000           0.999
 5       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0013      0.8710     0.0000           0.998
 6       0.0000     0.0826     0.8150     0.218      0.150      0.8150      0.0010      0.8710     0.0000           0.991
 7       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0010      0.8710     0.0000           0.998
 8       0.0001     0.0827     0.3022     0.219      0.150      0.3022      0.0013      0.8710     0.0000           0.999
 9       0.0002     0.0827     0.8150     0.219      0.150      0.8150      0.0013      0.8710     0.0000           0.998
10       0.0001     0.0827     0.8150     0.219      0.150      0.8150      0.0013      0.8720     0.0000           0.991
11       0.0001     0.0826     0.1865     0.219      0.150      0.1865      0.0013      0.8710     0.0000           0.999
12       0.0001     0.0826     0.5822     0.219      0.150      0.5822      0.0013      0.8710     0.0000           0.999
13       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0013      0.8710     0.0000           0.991
14       0.0000     0.0826     0.8150     0.218      0.150      0.8150      0.0013      0.8710     0.0000           0.999
15       0.0000     0.0827     0.1558     0.218      0.150      0.1558      0.0013      0.8710     0.0000           0.999
16       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0013      0.8710     0.0000           0.998
17       0.0000     0.0827     0.8167     0.218      0.150      0.8167      0.0011      0.8710     0.0000           0.991
18       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0013      0.8720     0.0000           0.998
19       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0010      0.8720     0.0000           0.998
20       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0010      0.8720     0.0000           0.998
21       0.0199     0.0828     0.8150     0.218      0.150      0.8150      0.0010      0.8720     0.0000           0.999
22       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0013      0.8723     0.0100           0.998
23       0.0001     0.0827     0.3938     0.219      0.150      0.3938      0.0010      0.8720     0.0000           0.999
24       0.0001     0.0827     0.8150     0.219      0.150      0.8150      0.0013      0.8720     0.0000           0.998
25       0.0000     0.0827     0.8150     0.219      0.150      0.8150      0.0013      0.8720     0.0000           0.991
26       0.0001     0.0827     0.8150     0.219      0.150      0.8150      0.0013      0.8720     0.0000           0.999
27       0.0002     0.0827     0.8150     0.219      0.150      0.8150      0.0010      0.8720     0.0000           0.999
28       0.0001     0.0828     0.8150     0.219      0.150      0.8150      0.0013      0.8710     0.0000           0.998
29       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0013      0.8770     0.0000           0.991
30       0.0001     0.0827     0.8153     0.219      0.150      0.8150      0.0013      0.8719     0.0000           0.998
31       0.0000     0.0827     0.8153     0.218      0.150      0.8150      0.0010      0.8770     0.0000           0.999
32       0.0001     0.0827     0.8153     0.219      0.150      0.8150      0.0013      0.8770     0.0000           0.998
33       0.0002     0.0826     0.8150     0.219      0.150      0.8150      0.0013      0.8770     0.0000           0.991
34       0.0000     0.0826     0.1608     0.218      0.150      0.1608      0.0010      0.8720     0.0000           0.999
35       0.0000     0.0827     0.8153     0.218      0.150      0.8150      0.0010      0.8720     0.0000           0.998
36       0.0000     0.0827     0.8150     0.218      0.150      0.8150      0.0013      0.8720     0.0000           0.998
37       0.0001     0.0827     0.5813     0.219      0.150      0.5810      0.0013      0.8720     0.0000           0.991
38       0.0000     0.0827     0.8150     0.219      0.150      0.8150      0.0013      0.8710     0.0000           0.999
39       0.0130     0.0826     0.8150     0.217      0.151      0.8150      0.0010      0.8710     0.0000           0.998
40       0.0102     0.0815     0.8150     0.218      0.151      0.8150      0.0013      0.8713     0.0000           0.998
41       0.0102     0.0815     0.8150     0.218      0.151      0.8150      0.0013      0.8713     0.0000           0.991
42       0.0103     0.0815     0.8150     0.219      0.151      0.8150      0.0013      0.8713     0.0000           0.999
43       0.0826     0.0533     0.8150     0.221      0.131      0.8150      0.0010      1.0012     0.0000           1.001
44       0.0899     0.0618     0.8150     0.227      0.115      0.8150      0.0011      1.0012     0.0000           1.001
45       0.0103     0.0815     0.8150     0.218      0.151      0.8150      0.0013      0.8713     0.0000           0.999
46       0.0109     0.0700     0.8150     0.209      0.119      0.8150      0.0011      1.1112     0.0000           1.001
47       0.0121     0.0816     0.8150     0.219      0.151      0.8150      0.0010      0.8710     0.0000           0.991
48       0.0131     0.0816     0.8150     0.210      0.151      0.8150      0.0013      0.8713     0.0000           0.998
49       0.0107     0.0829     0.8150     0.201      0.151      0.8150      0.0013      1.0013     0.0000           1.011
50       0.0111     [illegible] 0.8150    0.216      0.150      0.8150      0.0011      1.1111     0.0000           1.011
```

Figure VIII.-7. Output from Main

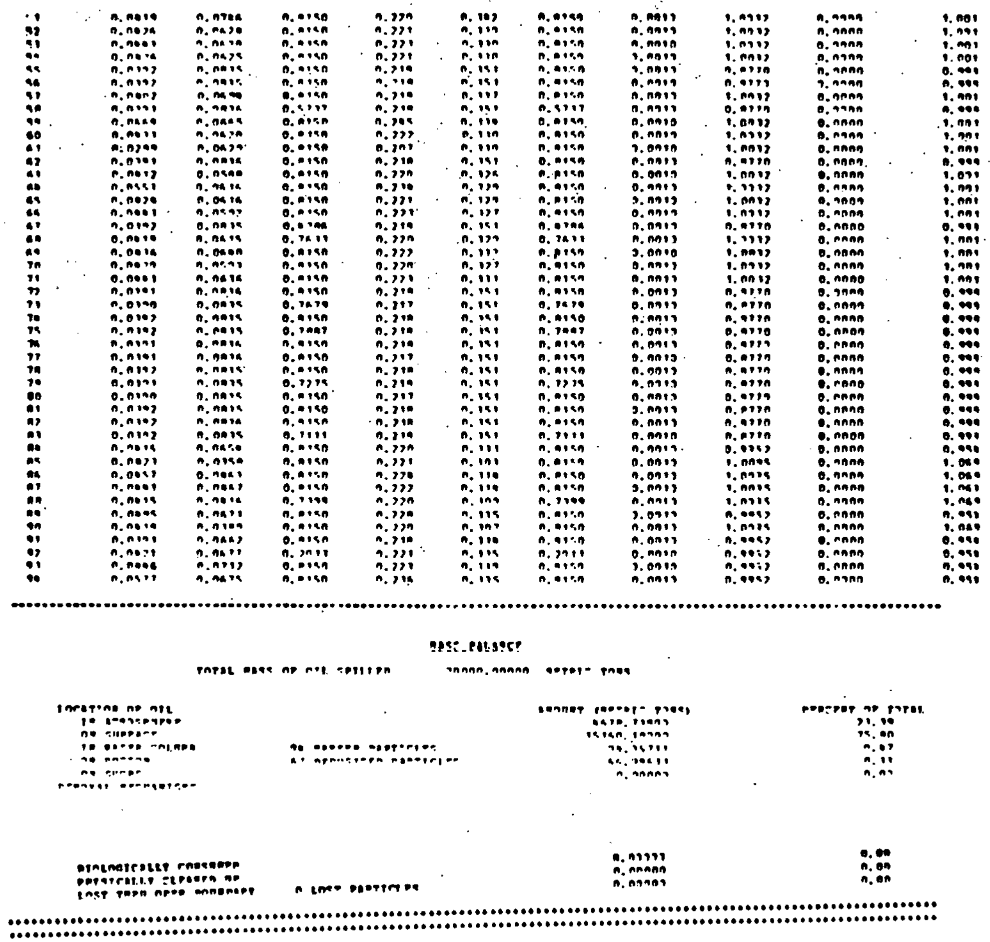

Figure VIII.-7. Output from Main

```
ALL HORIZONTAL VELOCITIES ARE MULTIPLIED BY 1000S

       U VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   1
        0.27     0.30     0.33     0.35     0.38
0.2     -0.198   -0.152   -0.101   -0.028   -0.038
0.2     -0.181   -0.199   -0.216   -0.197   -0.095
0.2      0.017    0.082    0.058    0.077    0.119
0.2      0.169    0.225    0.257    0.296    0.307
0.3      0.193    0.225    0.257    0.295    0.321

       U VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   2
        0.27     0.30     0.33     0.35     0.38
0.2     -0.198   -0.152   -0.101   -0.028   -0.038
0.2     -0.181   -0.199   -0.216   -0.197   -0.095
0.2      0.017    0.082    0.058    0.077    0.118
0.2      0.169    0.205    0.257    0.296    0.307
0.3      0.193    0.225    0.257    0.295    0.321

       U VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   3
        0.27     0.30     0.33     0.35     0.38
0.2     -0.198   -0.152   -0.101   -0.029   -0.038
0.2     -0.181   -0.199   -0.216   -0.197   -0.095
0.2      0.017    0.082    0.058    0.077    0.118
0.2      0.169    0.205    0.257    0.296    0.307
0.3      0.193    0.225    0.257    0.295    0.321

       V VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   1
        0.27     0.30     0.33     0.35     0.38
0.2     -0.517   -0.568   -0.897   -0.516   -0.811
0.2     -0.877   -0.527   -0.879   -0.822   -0.118
0.2     -0.188   -0.811   -0.880   -0.362   -0.156
0.2     -0.271   -0.295   -0.308   -0.286   -0.281
0.3     -0.268   -0.281   -0.251   -0.281   -0.206

       V VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   2
        0.27     0.30     0.33     0.35     0.38
0.2     -0.517   -0.568   -0.897   -0.516   -0.811
0.2     -0.877   -0.527   -0.879   -0.822   -0.118
0.2     -0.186   -0.811   -0.880   -0.362   -0.156
0.2     -0.271   -0.295   -0.308   -0.286   -0.281
0.3     -0.258   -0.281   -0.251   -0.281   -0.206

       V VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   3
        0.27     0.30     0.33     0.35     0.38
0.2     -0.517   -0.568   -0.897   -0.516   -0.811
0.2     -0.877   -0.527   -0.879   -0.822   -0.118
0.2     -0.186   -0.811   -0.880   -0.362   -0.156
0.2     -0.271   -0.295   -0.308   -0.286   -0.281
0.3     -0.268   -0.281   -0.251   -0.281   -0.206

       W VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   1
        0.27     0.30     0.33     0.35     0.38
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.3      0.000    0.000    0.000    0.000    0.000

       W VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   2
```

```
        0.27     0.30     0.33     0.35     0.38
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.3      0.000    0.000    0.000    0.000    0.000

       W VELOCITY FIELD      STEP NUMBER    1      TIME      12800.00  LEVEL   3
        0.27     0.30     0.33     0.35     0.38
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.2      0.000    0.000    0.000    0.000    0.000
0.3      0.000    0.000    0.000    0.000    0.000

                         FLOATING_GRID_DEFINITION_AND_PARTICLE_LOCATION_STATISTICS

ORIGIN OF FLOATING GRID IS AT (     0.1700,       0.2629) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED UPPER GRID
THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS        0.1209981 DEGREES  IN X AND        0.0219810 DEGREES  IN Y
THE GRID SEPARATION IN THE FIXED SYSTEM IS       0.036 DEGREES  IN X AND       0.036 DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE           0.088882           0.078707           0.755151
THE STANDARD DEVIATIONS ARE                   0.008791         0.012560          3.182099


         CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER    1      TIME     12800.00  LEVEL   1

          0.27     0.30     0.33     0.35     0.38
0.19      0.00000 0.00000 0.00000 0.00000 0.00000
0.21      0.00000 0.00000 0.00016 0.00031 0.00000
0.23      0.00000 0.00000 0.00050 0.00098 0.00000
0.25      0.00000 0.00000 0.00010 0.00005 0.00000
0.26      0.00000 0.00000 0.00000 0.00000 0.00000

         CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER    1      TIME     12800.00  LEVEL   2

          0.27     0.30     0.33     0.35     0.38
0.19      0.00000 0.00000 0.00000 0.00000 0.00000
0.21      0.00000 0.00008 0.00030 0.00281 0.00000
0.23      0.00000 0.00018 0.00188 0.00188 0.00000
0.25      0.00000 0.00012 0.00098 0.00020 0.00000
0.26      0.00000 0.00000 0.00000 0.00000 0.00000

         CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER    1      TIME     12800.00  LEVEL   3

          0.27     0.30     0.33     0.35     0.38
0.19      0.00000 0.00000 0.00000 0.00000 0.00000
0.21      0.00000 0.00170 0.00538 0.01668 0.00000
0.23      0.00000 0.00207 0.00902 0.01861 0.00000
0.25      0.00000 0.00051 0.03185 0.00036 0.00000
0.26      0.00000 0.00000 0.00000 0.00003 0.00000
```

Figure VIII.-7. Output from Main

```
      PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
                    PARTICLE PARAMETERS AT TIME    12600.00

                 PARTICLE POSITION                  PARTICLE POSITION                               PARTICLE PARAMETERS
                  FLOATING SYSTEM                     FIXED SYSTEM
  N        X           Y           Z           X          Y                     DIAMETER     DENSITY   SET. VEL.           MASS

  1     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
  2     0.0827      0.0829      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.997
  3     0.0827      0.0829      0.6017      0.217      0.186      0.6017      0.0010      0.8770      0.0000          0.999
  4     0.0827      0.0830      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
  5     0.0826      0.0828      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.998
  6     0.0825      0.0828      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.999
  7     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
  8     0.0827      0.0829      0.3022      0.217      0.186      0.3022      0.0013      0.8770      0.0000          0.999
  9     0.0828      0.0828      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.999
 10     0.0827      0.0829      0.8150      0.217      0.185      0.8150      0.0013      0.8770      0.0000          0.999
 11     0.0827      0.0828      0.3065      0.217      0.186      0.3065      0.0013      0.8770      0.0000          0.999
 12     0.0827      0.0828      0.5872      0.217      0.186      0.5872      0.0010      0.8770      0.0000          0.999
 13     0.0828      0.0833      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
 14     0.0824      0.0828      0.8150      0.217      0.185      0.8150      0.0013      0.8770      0.0000          0.999
 15     0.0826      0.0829      0.3558      0.217      0.185      0.3558      0.0010      0.8773      0.0000          0.999
 16     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.999
 17     0.0826      0.0828      0.8167      0.217      0.186      0.8167      0.0010      0.8770      0.0000          0.998
 18     0.0826      0.0829      0.8150      0.217      0.185      0.8150      0.0013      0.8770      0.0000          0.999
 19     0.0826      0.0838      0.8150      0.217      0.186      0.8150      0.0013      0.8773      0.0000          0.999
 20     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.999
 21     0.0825      0.0830      0.8150      0.216      0.185      0.8150      0.0013      0.8770      0.0000          0.999
 22     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.998
 23     0.0827      0.0829      0.3838      0.217      0.186      0.3838      0.0010      0.8770      0.0000          0.999
 24     0.0827      0.0829      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
 25     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.999
 26     0.0827      0.0829      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
 27     0.0828      0.0829      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.999
 28     0.0827      0.0830      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.998
 29     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
 30     0.0827      0.0828      0.8150      0.217      0.185      0.8150      0.0013      0.8773      0.0000          0.999
 31     0.0826      0.0829      0.8150      0.217      0.185      0.8150      0.0010      0.8770      0.0000          0.999
 32     0.0827      0.0828      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.998
 33     0.0828      0.0828      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
 34     0.0826      0.0828      0.3608      0.217      0.185      0.3608      0.0013      0.8773      0.0000          0.999
 35     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
 36     0.0825      0.0829      0.8150      0.217      0.186      0.8150      0.0010      0.8770      0.0000          0.999
 37     0.0827      0.0829      0.5830      0.217      0.186      0.5830      0.0013      0.8770      0.0000          0.999
 38     0.0826      0.0829      0.8150      0.217      0.186      0.8150      0.0013      0.8770      0.0000          0.999
 39     0.0815      0.0818      0.8150      0.215      0.187      0.8150      0.0013      0.8770      0.0000          0.999
 40     0.0816      0.0817      0.8150      0.216      0.187      0.8150      0.0013      0.8770      0.0000          0.998
 41     0.0816      0.0817      0.8150      0.216      0.187      0.8150      0.0013      0.8770      0.0000          0.993
 42     0.0815      0.0817      0.8150      0.216      0.187      0.8150      0.0013      0.8770      0.0000          0.999
 43     0.0858      0.0512      0.8150      0.219      0.116      0.8153      0.0010      1.0012      0.0000          1.001
 44     0.0529      0.0479      0.8150      0.227      0.111      0.8150      0.0013      1.0012      0.0000          1.001
 45     0.0815      0.0817      0.8150      0.216      0.187      0.8150      0.0013      0.8770      0.0000          0.999
 46     0.0332      0.0106      0.8150      0.207      0.111      0.8150      0.0013      1.0112      0.0000          1.001
 47     0.0815      0.0817      0.8150      0.216      0.187      0.8150      0.0013      0.8770      0.0000          0.999
 48     0.0817      0.0818      0.8150      0.216      0.187      0.8150      0.0013      0.8770      0.0000          0.998
 49     0.[illegible]118   [illegible]   0.8150   0.205   0.110   0.8150   0.0013   1.0012   0.0000   1.0[illegible]
 50     [illegible]   [illegible]   [illegible]   [illegible]   0.110   [illegible]   0.0013   [illegible]   0.0000   1.0[illegible]
```

Figure VIII.-7. Output from Main

```
 51      0.0087   0.0786   0.8150   0.219   0.117   0.8150   0.0013   1.0012   0.0000    1.001
 52      0.0850   0.0621   0.8150   0.219   0.125   0.8150   0.0010   1.0012   0.0000    1.001
 53      0.0870   0.0628   0.8150   0.221   0.126   0.8150   0.0011   1.0112   0.0000    1.001
 54      0.0850   0.0628   0.8150   0.219   0.125   0.8150   0.0013   1.0012   0.0000    1.001
 55      0.0816   0.0817   0.8150   0.216   0.107   0.8150   0.0010   0.8770   0.0000    0.999
 56      0.0816   0.0816   0.8150   0.216   0.107   0.8150   0.0013   0.8770   0.0000    0.999
 57      0.0824   0.0691   0.8150   0.213   0.117   0.8150   0.0013   1.0112   0.0000    1.001
 58      0.0816   0.0817   0.5717   0.216   0.107   0.5717   0.0013   0.8770   0.0000    0.999
 59      0.0717   0.0680   0.8150   0.207   0.111   0.8150   0.0013   1.0112   0.0000    1.001
 60      0.0862   0.0619   0.8150   0.220   0.125   0.8150   0.0010   1.0012   0.0000    1.001
 61      0.0117   0.0621   0.8150   0.206   0.125   0.8150   0.0013   1.0112   0.0000    1.031
 62      0.0816   0.0817   0.8150   0.216   0.107   0.8150   0.0010   1.0112   0.0000    1.001
 63      0.0810   0.0587   0.8150   0.210   0.122   0.8150   0.0010   0.8770   0.0000    0.999
 64      0.0680   0.0621   0.8150   0.210   0.125   0.8150   0.0010   1.0012   0.0000    1.031
 65      0.0852   0.0615   0.8150   0.219   0.124   0.8150   0.0010   1.0112   0.0000    1.001
 66      0.0870   0.0597   0.8150   0.221   0.122   0.8150   0.0013   1.0012   0.0000    1.001
 67      0.0816   0.0816   0.0786   0.216   0.106   0.0786   0.0013   1.0112   0.0000    1.001
 68      0.0087   0.0618   0.7633   0.219   0.120   0.7633   0.0013   0.8770   0.0000    0.999
 69      0.0866   0.0680   0.8150   0.221   0.127   0.8150   0.0010   1.0112   0.0000    1.001
 70      0.0087   0.0597   0.8150   0.210   0.122   0.8150   0.0011   1.0012   0.0000    1.001
 71      0.0876   0.0635   0.8150   0.221   0.124   0.8150   0.0010   1.0112   0.0000    1.001
 72      0.0815   0.0810   0.8150   0.215   0.107   0.8150   0.0013   1.0012   0.0000    1.031
 73      0.0815   0.0817   0.7670   0.215   0.107   0.7579   0.0013   0.8773   0.0000    0.999
 74      0.0816   0.0817   0.8150   0.216   0.107   0.8150   0.0010   0.8770   0.0000    0.999
 75      0.0816   0.0817   0.7087   0.216   0.107   0.7087   0.0013   0.8770   0.0000    0.999
 76      0.0815   0.0810   0.8150   0.216   0.107   0.8150   0.0013   0.8770   0.0000    0.999
 77      0.0815   0.0817   0.8150   0.215   0.107   0.8150   0.0013   0.8770   0.0000    0.999
 78      0.0816   0.0817   0.8150   0.216   0.107   0.8150   0.0010   0.8770   0.0000    0.999
 79      0.0815   0.0817   0.7275   0.215   0.107   0.7275   0.0013   0.8770   0.0000    0.999
 80      0.0815   0.0817   0.8150   0.215   0.107   0.8150   0.0013   0.8770   0.0000    0.999
 81      0.0816   0.0817   0.8150   0.216   0.107   0.8150   0.0010   0.8770   0.0000    0.999
 82      0.0816   0.0817   0.8150   0.216   0.107   0.8150   0.0013   0.8770   0.0000    0.999
 83      0.0816   0.0817   0.7111   0.216   0.107   0.7111   0.0010   0.8770   0.0000    0.999
 84      0.0087   0.0653   0.8150   0.210   0.124   0.8150   0.0010   0.9952   0.0000    0.950
 85      0.0851   0.0150   0.8150   0.219   0.209   0.8150   0.0010   1.0095   0.0000    1.060
 86      0.0840   0.0865   0.8150   0.221   0.100   0.8150   0.0013   1.0095   0.0000    1.069
 87      0.0871   0.0867   0.8150   0.223   0.110   0.8150   0.0010   1.0095   0.0000    1.061
 88      0.0087   0.0816   0.7190   0.210   0.100   0.7190   0.0013   1.0115   0.0000    1.069
 89      0.0510   0.0673   0.8150   0.227   0.119   0.8150   0.0010   0.9952   0.0000    0.950
 90      0.0865   0.0100   0.8150   0.219   0.102   0.8150   0.0013   1.0115   0.0000    1.069
 91      0.0815   0.0660   0.8150   0.115   0.129   0.8150   0.0013   0.9952   0.0000    0.950
 92      0.0089   0.0676   0.2011   0.110   0.110   0.2011   0.0013   0.9952   0.0000    0.950
 93      0.0670   0.0111   0.8150   0.222   0.119   0.8150   0.0010   0.9952   0.0000    0.950
 94      0.0629   0.0601   0.8150   0.217   0.111   0.8150   0.0010   0.9952   0.0000    0.950
 95      0.0850   0.0516   0.8150   0.210   0.110   0.8150   0.0013   1.0105   0.0000    0.901
 96      0.0505   0.0691   0.1715   0.211   0.111   0.1715   0.0010   1.3312   0.0100    0.901
 97      0.0711   0.0619   0.8150   0.207   0.115   0.8150   0.0010   1.0105   0.0000    0.902
 98      0.0517   0.0001   0.8150   0.203   0.107   0.8150   0.0013   1.0135   0.0000    0.900
 99      0.0502   0.0650   0.5017   0.211   0.110   0.5017   0.0010   1.0112   0.0000    0.901
100      0.0001   0.0712   0.8150   0.221   0.110   0.8150   0.0013   1.0112   0.0000    0.901
101      0.0502   0.0660   0.8110   0.211   0.110   0.8110   0.0010   1.0002   0.0000    0.901
102      0.0505   0.0670   0.5091   0.212   0.110   0.5091   0.0013   1.0002   0.0000    0.901
**************************************************************************************************

                                    MASS BALANCE
                TOTAL MASS OF OIL SPILLED       20000.00000  METRIC TONS



       LOCATION OF OIL                                          AMOUNT (METRIC TONS)        PERCENT OF TOTAL
         IN ATMOSPHERE                                                4016.77700                  20.10
         ON SURFACE                                                  15847.75000                  79.90
         IN WATER COLUMN          102 MOBILE PARTICLES                 101.96797                   0.51
         ON BOTTOM                 76 DEPOSITED PARTICLES               33.52335                   0.17
         ON SHORE                                                        0.00003                   0.00
       REMOVAL MECHANISMS
         BIOLOGICALLY CONSUMED                                           0.00003                   0.00
         PHYSICALLY CLEANED UP                                           0.00003                   0.00
         LOST THRU OPEN BOUNDARY.   0 LOST PARTICLES                     0.00000                   0.00
**********************************************************************************************************
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Figure VIII.-7. Output from Main

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              SPILL_CONTROL_PARAMETERS__12.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL.

   ENVIRONMENTAL DATA READ THIS STEP:                              NONE

   ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  0 SPILLETS;    1 CLEANUP EFFORTS;    0 TREATMENT EFFORTS.

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          PHYSICAL_CLEANUP_EFFORTS_IN_PROGRESS___12.00000_HOURS_AFTER_THE_BEGINNING_OF_THIS_RUN

                        NEW CLEANUP EFFORTS THIS TIME STEP

   THE   1 CLEANUP EFFORT CURRENTLY UNDERWAY IS CENTERED AT LONGITUDE  56.770300 AND LATITUDE  61.619990
   THE RADIUS OF COVERAGE OF THIS EFFORT IS  10000.000 METERS
   THE MAXIMUM RATE OF RECOVERY IS 100.000000 TONS/HOUR WITH AN EFFICIENCY OF  50.0037008
   THIS CLEANUP STARTS  12.000000 HOURS AFTER THE BEGINNING OF THE SPILL AND LASTS  5.000333 HOURS

                  EXISTING_SPILLETS___12.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                        SPILLETS CREATED PRIOR TO THIS STEP

   THE   1 SPILLET APPEARED     0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
   IT IS CENTERED AT LONGITUDE  66.787010 AND LATITUDE  61.621790,
   IS OF RADIUS     1688.98 METERS AND IS OF WEIGHT  7189.8710 METRIC TONS.
   SOME PROPERTIES OF THE SPILLED OIL ARE:
                  DENSITY                  1.011191 GRAMS/CC
                  INTERFACIAL TENSION     30.000000 DYNES/CM
                  KINEMATIC VISCOSITY      1.000000 CENTISTOKES
   BY WEIGHT THE OIL FRACTIONS ARE:                              PARAFFIN (C6-C12)              0.001095
                                                                 PARAFFIN (C13-C22)             0.049990
                                                                 CYCLOPARAFFIN (C6-C12)         0.001975
                                                                 CYCLOPARAFFIN (C13-C22)        0.049995
                                                                 AROMATIC (C6-C11)              0.000215
                                                                 AROMATIC (C12-C18)             0.073997
                                                                 NAPHTHENO-AROMATIC (C9-C25)    0.799577
                                                                 RESIDUAL                       0.100000
   THE   2 SPILLET APPEARED     1.00  HOURS  AFTER THE BEGINNING OF THE SPILL
   IT IS CENTERED AT LONGITUDE  66.790710 AND LATITUDE  61.600290,
   IS OF RADIUS     1097.60 METERS AND IS OF WEIGHT  7617.9800 METRIC TONS.
   SOME PROPERTIES OF THE SPILLED OIL ARE:
                  DENSITY                  1.001819 GRAMS/CC
                  INTERFACIAL TENSION     30.000000 DYNES/CM
                  KINEMATIC VISCOSITY      1.000000 CENTISTOKES
   BY WEIGHT THE OIL FRACTIONS ARE:                              PARAFFIN (C6-C12)              0.006159
                                                                 PARAFFIN (C13-C22)             0.099930
                                                                 CYCLOPARAFFIN (C6-C12)         0.019511
                                                                 CYCLOPARAFFIN (C13-C22)        0.089997
                                                                 AROMATIC (C6-C11)              0.000119
                                                                 AROMATIC (C12-C18)             0.019990
                                                                 NAPHTHENO-AROMATIC (C9-C25)    0.309715
                                                                 RESIDUAL                       0.100333

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   DURING THE TIME STEP WHICH BEGAN AT  12.000000 HOURS 100.000000 TONS OF OIL WERE PHYSICALLY REMOVED FROM THE  1 SPILLET
   DURING THE TIME STEP WHICH BEGAN AT  12.000000 HOURS 100.000000 TONS OF OIL WERE PHYSICALLY REMOVED FROM THE  2 SPILLET

                     FLOATING_GRID_DEFINITION_AND_PARTICLE_LOCATION_STATISTICS

 ORIGIN OF FLOATING GRID IS AT (    0.1661,      0.2629) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
 THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS       0.0261712 DEGREES  IN X AND       0.0219810 DEGREES  IN Y
 THE GRID SEPARATION IN THE FIXED SYSTEM IS     0.036 DEGREES  IN X AND     0.035 DEGREES  IN Y

 THE AVERAGE VALUES OF X, Y AND Z ARE          0.055861          0.072689          0.729208
 THE STANDARD DEVIATIONS ARE                  0.011817          0.011819          0.663359
          HORIZONTAL X-Y SCALE DEPENDENT DIFFUSION COEFF.=      0.6658E-05      0.3551E-36
     XAVG= 0.581E-01     YAVG= 0.717E-01     ZAVG= 0.758        SIGX= 0.965E-02SIGY= 0.121E-01
```

Figure VIII.-7. Output from Main

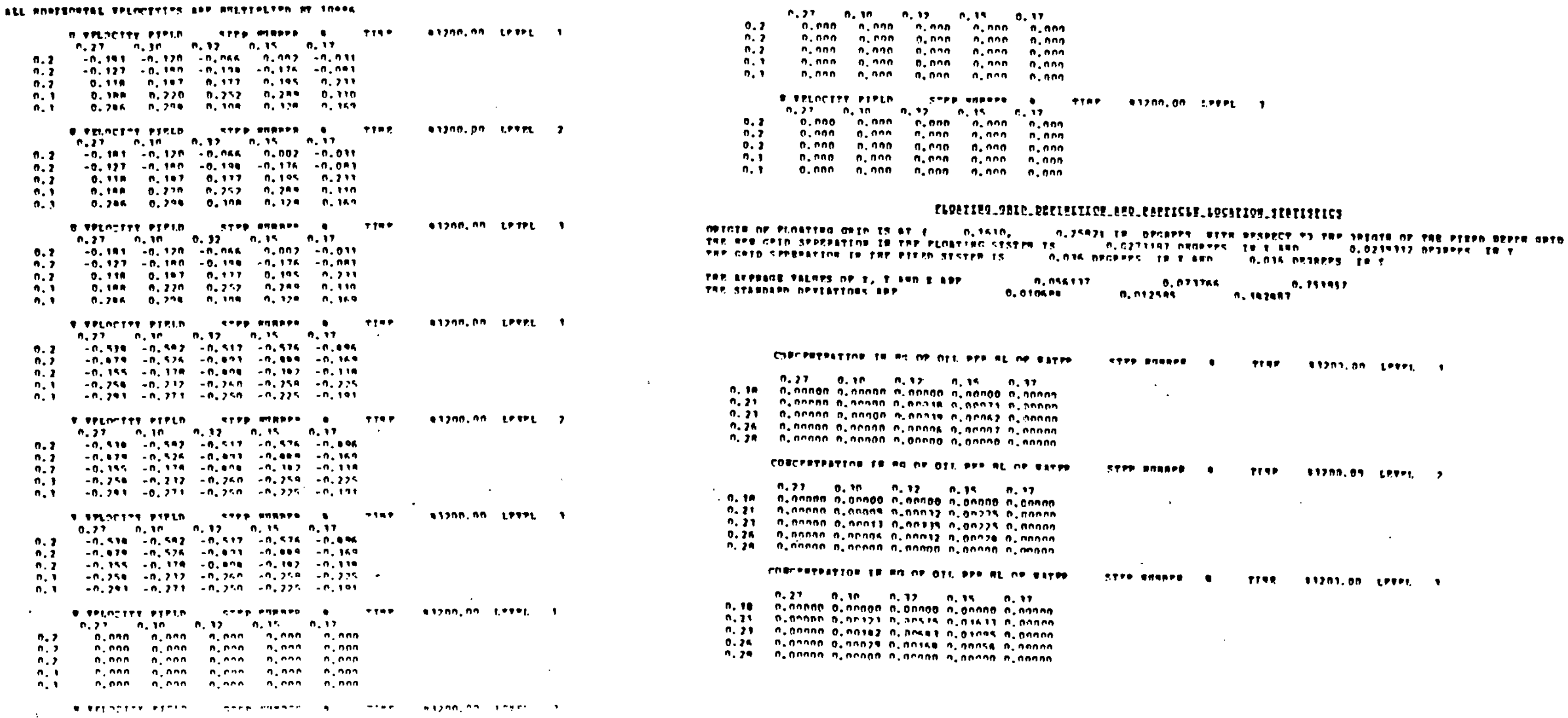

Figure VIII.-7. Output from Main

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 PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
              PARTICLE PARAMETERS AT TIME    43200.00

                PARTICLE POSITION                 PARTICLE POSITION                          PARTICLE PARAMETERS
                 FLOATING SYSTEM                    FIXED SYSTEM
  N       X          Y          Z          X          Y                  DIAMETER    DENSITY   SET. VEL.        MASS

  1    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
  2    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
  3    0.0519     0.0829     0.6317     0.215     0.181     0.6317     0.0010     0.8770     0.0000          0.999
  4    0.0519     0.0830     0.8150     0.215     0.181     0.8150     0.0010     0.8770     0.0000          0.999
  5    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
  6    0.0518     0.0828     0.8150     0.215     0.181     0.8150     0.0010     0.8770     0.0000          0.999
  7    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
  8    0.0519     0.0829     0.3022     0.215     0.181     0.3022     0.0013     0.8770     0.0000          0.999
  9    0.0521     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 10    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 11    0.0519     0.0828     0.3065     0.215     0.181     0.3065     0.0010     0.8770     0.0000          0.999
 12    0.0519     0.0828     0.5872     0.215     0.181     0.5872     0.0010     0.8770     0.0000          0.999
 13    0.0519     0.0827     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 14    0.0519     0.0828     0.8150     0.215     0.181     0.8150     0.0010     0.8770     0.0000          0.999
 15    0.0519     0.0829     0.3558     0.215     0.181     0.3558     0.0010     0.8770     0.0000          0.999
 16    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.998
 17    0.0519     0.0829     0.8167     0.215     0.181     0.8167     0.0013     0.8770     0.0000          0.999
 18    0.0518     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 19    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 20    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 21    0.0518     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 22    0.0518     0.0829     0.8150     0.215     0.181     0.8150     0.0010     0.8770     0.0000          0.999
 23    0.0519     0.0829     0.3938     0.215     0.181     0.3938     0.0010     0.8770     0.0000          0.999
 24    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 25    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 26    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0010     0.8770     0.0000          0.999
 27    0.0520     0.0829     0.8150     0.215     0.181     0.8150     0.0010     0.8770     0.0000          0.999
 28    0.0519     0.0830     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.998
 29    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 30    0.0520     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 31    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 32    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 33    0.0520     0.0828     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 34    0.0518     0.0828     0.3608     0.215     0.181     0.3608     0.0010     0.8770     0.0000          0.999
 35    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0010     0.8770     0.0000          0.999
 36    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.998
 37    0.0519     0.0829     0.5810     0.215     0.181     0.5810     0.0013     0.8770     0.0000          0.999
 38    0.0519     0.0829     0.8150     0.215     0.181     0.8150     0.0013     0.8770     0.0000          0.999
 39    0.0509     0.0837     0.8150     0.218     0.182     0.8150     0.0013     0.8770     0.0000          0.999
 40    0.0509     0.0837     0.8150     0.218     0.182     0.8150     0.0013     0.8770     0.0000          0.999
 41    0.0509     0.0837     0.8150     0.218     0.182     0.8150     0.0010     0.8770     0.0000          0.999
 42    0.0509     0.0837     0.8150     0.218     0.182     0.8150     0.0013     0.8770     0.0000          0.998
 43    0.0585     0.0511     0.8150     0.237     0.111     0.8150     0.0013     1.0032     0.0000          1.001
 44    0.0533     0.0680     0.8150     0.226     0.136     0.8150     0.0013     1.0032     0.0000          1.001
 45    0.0519     0.0837     0.8150     0.218     0.182     0.8150     0.0010     0.8770     0.0000          0.999
 46    0.0489     0.0699     0.8150     0.206     0.139     0.8150     0.0013     1.0032     0.0000          1.001
 47    0.0509     0.0837     0.8150     0.218     0.182     0.8150     0.0013     0.8770     0.0000          0.999
 48    0.0513     0.0837     0.8150     0.218     0.181     0.8150     0.0013     0.8770     0.0000          0.998
 49    0.0489     0.0582     0.8150     0.209     0.112     0.8150     0.0013     1.0032     0.0000          1.001
 50    0.0496     0.0610     0.8150     0.212     0.119     0.8150     0.0013     1.0032     0.0000          1.001
```

Figure VIII.-7. Output from Main

```
 51      0.0510    0.0705    0.8150    0.217    0.111    0.8150    0.0013    1.0012    0.0000        1.001
 52      0.0505    0.0621    0.8150    0.217    0.120    0.8150    0.0010    1.0012    0.0000        1.001
 53      0.0548    0.0627    0.8150    0.220    0.121    0.8150    0.0013    1.0012    0.0000        1.001
 54      0.0508    0.0622    0.8150    0.217    0.120    0.8150    0.0013    1.0012    0.0000        1.001
 55      0.0509    0.0817    0.8150    0.218    0.102    0.8150    0.0013    0.8770    0.0000        0.991
 56      0.0509    0.0816    0.8150    0.218    0.102    0.8150    0.0010    0.8770    0.0000        0.999
 57      0.0510    0.0690    0.8150    0.215    0.122    0.8150    0.0010    1.0012    0.0000        1.001
 58      0.0509    0.0817    0.5717    0.218    0.102    0.5717    0.0013    0.8770    0.0000        0.998
 59      0.0862    0.0692    0.8150    0.209    0.121    0.8150    0.0010    1.0012    0.0000        1.001
 60      0.0550    0.0619    0.8150    0.218    0.120    0.8150    0.0013    1.0012    0.0000        1.001
 61      0.0818    0.0615    0.8150    0.208    0.120    0.8150    0.0010    1.0012    0.0000        1.001
 62      0.0503    0.0817    0.8150    0.218    0.102    0.8150    0.0013    0.8770    0.0000        0.999
 63      0.0529    0.0585    0.8150    0.216    0.117    0.8150    0.0010    1.0012    0.0000        1.001
 64      0.0711    0.0628    0.8150    0.218    0.121    0.8150    0.0010    1.0012    0.0000        1.001
 65      0.0502    0.0611    0.8150    0.217    0.120    0.8150    0.0010    1.0012    0.0000        1.001
 66      0.0547    0.0592    0.8150    0.220    0.117    0.8150    0.0010    1.0012    0.0000        1.001
 67      0.0507    0.0816    0.6786    0.218    0.102    0.6786    0.0010    0.8770    0.0000        0.999
 68      0.0516    0.0612    0.7611    0.217    0.119    0.7611    0.0010    1.0012    0.0000        1.001
 69      0.0558    0.0619    0.8150    0.219    0.122    0.8150    0.0010    1.0012    0.0000        1.001
 70      0.0517    0.0590    0.8150    0.217    0.117    0.8150    0.0010    1.0012    0.0000        1.001
 71      0.0549    0.0618    0.8150    0.220    0.122    0.8150    0.0013    1.0012    0.0000        1.001
 72      0.0509    0.0818    0.8150    0.218    0.102    0.8150    0.0010    0.8770    0.0000        0.999
 73      0.0509    0.0817    0.7579    0.218    0.102    0.7579    0.0010    0.8770    0.0000        0.999
 74      0.0509    0.0817    0.8150    0.218    0.102    0.8150    0.0013    0.8770    0.0000        0.999
 75      0.0509    0.0817    0.7887    0.218    0.102    0.7887    0.0010    0.8770    0.0000        0.999
 76      0.0509    0.0817    0.8150    0.218    0.102    0.8150    0.0010    0.8770    0.0000        0.999
 77      0.0508    0.0817    0.8150    0.218    0.102    0.8150    0.0010    0.8770    0.0000        0.999
 78      0.0507    0.0817    0.8150    0.218    0.102    0.8150    0.0013    0.8770    0.0000        0.998
 79      0.0508    0.0816    0.7275    0.218    0.102    0.7275    0.0011    0.8770    0.0000        0.999
 80      0.0508    0.0816    0.8150    0.218    0.102    0.8150    0.0010    0.8770    0.0000        0.995
 81      0.0510    0.0817    0.8150    0.218    0.102    0.8150    0.0010    0.8770    0.0000        0.999
 82      0.0503    0.0817    0.8150    0.218    0.102    0.8150    0.0013    0.8770    0.0000        0.998
 83      0.0509    0.0817    0.7111    0.218    0.102    0.7111    0.0010    0.8770    0.0000        0.999
 84      0.0512    0.0651    0.8150    0.216    0.121    0.8150    0.0010    0.9352    0.0000        0.958
 85      0.0581    0.0159    0.8150    0.217    0.298    0.8150    0.0010    1.0095    0.0000        1.048
 86      0.0587    0.0865    0.8150    0.222    0.105    0.8150    0.0013    1.0095    0.0000        1.069
 87      0.0565    0.0867    0.8150    0.219    0.105    0.8150    0.0013    1.0095    0.0000        1.063
 88      0.0512    0.0818    0.7199    0.216    0.100    0.7199    0.0010    1.0135    0.0000        1.059
 89      0.0617    0.0678    0.8150    0.227    0.126    0.8150    0.0013    0.9952    0.0000        0.958
 90      0.0536    0.0109    0.8150    0.217    0.221    0.8150    0.0011    1.0035    0.0000        1.069
 91      0.0506    0.0657    0.8150    0.218    0.128    0.8150    0.0010    0.9952    0.0000        0.958
 92      0.0510    0.0678    0.2011    0.217    0.126    0.2011    0.0019    1.3352    0.0000        0.958
 93      0.0571    0.0710    0.8150    0.220    0.129    0.8159    0.0010    0.9952    0.0000        0.958
 94      0.0787    0.0689    0.8150    0.218    0.127    0.8150    0.0011    0.9952    0.0000        0.958
 95      0.0585    0.0510    0.8150    0.218    0.110    0.8150    0.0013    1.0105    0.0000        0.993
 96      0.0597    0.0687    0.1215    0.211    0.117    0.1215    0.0010    1.1002    0.0000        0.991
 97      0.0862    0.0511    0.8150    0.209    0.112    0.8150    0.0011    1.0135    0.0000        0.999
 98      0.0709    0.0855    0.8150    0.201    0.108    0.8150    0.0010    1.0105    0.0000        0.991
 99      0.0705    0.0678    0.5017    0.211    0.126    0.5017    0.0010    1.1112    0.0000        0.991
100      0.0599    0.0713    0.8150    0.222    0.129    0.8150    0.0010    1.0002    0.0000        0.991
101      0.0708    0.0678    0.8118    0.211    0.126    0.8118    0.0018    1.0112    0.0000        0.981
102      0.0625    0.0678    0.5007    0.211    0.126    0.5007    0.0010    1.0002    0.0000        0.991
103      0.0955    0.0619    0.8150    0.259    0.112    0.8150    0.0011    1.0018    0.0000        0.991
104      0.0935    0.0760    0.8150    0.256    0.118    0.8150    0.0010    1.0018    0.0000        0.991
105      0.0931    0.0891    0.6951    0.286    0.106    0.6951    0.0013    1.0112    0.0000        1.086
106      0.0891    0.0600    0.8150    0.252    0.119    0.8150    0.0013    1.0112    0.0000        1.086
107      0.0557    0.0676    0.8150    0.219    0.111    0.8150    0.0013    1.0118    0.0000        0.991
108      0.0938    0.0711    0.8153    0.256    0.111    0.8153    0.0010    1.0018    0.0000        0.991
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                                   MASS_BALANCE

                  TOTAL MASS OF OIL SPILLED      20000.00000  METRIC TONS

LOCATION OF OIL                                          AMOUNT (METRIC TONS)        PERCENT OF TOTAL
   IN ATMOSPHERE                                              4917.10407                  24.59
   ON SURFACE                                                14273.51000                  71.37
   IN WATER COLUMN         108 MARKED PARTICLES                109.03100                   0.55
   ON BOTTOM                81 DEPOSITED PARTICLES              81.08499                   0.41
   ON SHORE                                                      0.09033                   0.00
REMOVAL MECHANISMS
   BIOLOGICALLY CONSUMED                                         0.00000                   0.00
   PHYSICALLY CLEANED UP                                       600.00033                   3.00
   LOST THRU OPEN BOUNDARY   0 LOST PARTICLES                    0.00003                   0.00
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Figure VIII.-7. Output from Main

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              SPILL_CONTROL_PARAMETERS__15.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL_

  ENVIRONMENTAL DATA READ THIS STEP:                          NONE

  ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  1 SPILLETS:    0 CLEANUP EFFORTS:    0 TREATMENT EFFORTS.,

*************************************************************************************************************

       PHYSICAL_CLEANUP_EFFORTS_IN_PROGRESS___15.00000_HOURS_AFTER_THE_BEGINNING_OF_THIS_RUN

                        CONTINUING SPILL CLEANUP EFFORTS THIS STEP

  THE   1 CLEANUP EFFORT CURRENTLY UNDERWAY IS CENTERED AT LONGITUDE  66.770000 AND LATITUDE  61.619990
  THE RADIUS OF COVERAGE OF THIS EFFORT IS  10000.000 METERS
  THE MAXIMUM RATE OF RECOVERY IS 100.000000 TONS/HOUR WITH AN EFFICIENCY OF  50.000000%
  THIS CLEANUP STARTS  12.000000 HOURS AFTER THE BEGINNING OF THE SPILL AND LASTS  5.000000 HOURS

                  EXISTING_SPILLETS___15.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                        SPILLETS CREATED PRIOR TO THIS STEP

  THE   1 SPILLET APPEARED      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
  IT IS CENTERED AT LONGITUDE  66.776320 AND LATITUDE  61.620220,
  IS OF RADIUS     1866.21 METERS AND IS OF WEIGHT  7029.1010 METRIC TONS.
  SOME PROPERTIES OF THE SPILLED OIL ARE:
                  DENSITY                1.011690 GRAMS/CC
                  INTERFACIAL TENSION   30.000000 DYNES/CM
                  KINEMATIC VISCOSITY    1.000000 CENTISTOKES
  BY WEIGHT THE OIL FRACTIONS ARE:
                                                     PARAFFIN (C6-C12)               0.333722
                                                     PARAFFIN (C13-C22)              0.099970
                                                     CYCLOPARAFFIN (C6-C12)          0.002757
                                                     CYCLOPARAFFIN (C13-C22)         0.089995
                                                     AROMATIC (C6-C11)               0.033119
                                                     AROMATIC (C12-C18)              0.079977
                                                     NAPTHENO-AROMATIC (C9-C25)      0.209517
                                                     RESIDUAL                        0.103339
  THE   2 SPILLET APPEARED      3.00  HOURS  AFTER THE BEGINNING OF THE SPILL
  IT IS CENTERED AT LONGITUDE  66.770010 AND LATITUDE  61.580330,
  IS OF RADIUS     1685.63 METERS AND IS OF WEIGHT  7180.0130 METRIC TONS.
  SOME PROPERTIES OF THE SPILLED OIL ARE:
                  DENSITY                1.006033 GRAMS/CC
                  INTERFACIAL TENSION   30.000000 DYNES/CM
                  KINEMATIC VISCOSITY    1.000000 CENTISTOKES
  BY WEIGHT THE OIL FRACTIONS ARE:
                                                     PARAFFIN (C6-C12)               0.330000
                                                     PARAFFIN (C13-C22)              0.099990
                                                     CYCLOPARAFFIN (C6-C12)          0.011030
                                                     CYCLOPARAFFIN (C13-C22)         0.089337
                                                     AROMATIC (C6-C11)               0.032111
                                                     AROMATIC (C12-C18)              0.019339
                                                     NAPTHENO-AROMATIC (C9-C25)      0.203715
                                                     RESIDUAL                        0.193133

-------------------------------------------------------------------------------------------------------------


            HORIZONTAL X-Y SCALE DEPENDENT DIFFUSION COEFF.=     0.3280E-05     0.2667E-06
      XAVG= 0.6222E-01     YAVG= 0.7037E-01     ZAVG= 0.755        SIGX= 0.607E-02SIGY= 0.125E-01


  DURING THE TIME STEP WHICH BEGAN AT  15.000000 HOURS 100.000000 TONS OF OIL WERE PHYSICALLY REMOVED FROM THE  1 SPILLET
  DURING THE TIME STEP WHICH BEGAN AT  15.000000 HOURS 100.000000 TONS OF OIL WERE PHYSICALLY REMOVED FROM THE  2 SPILLET

                  FLOATING_GRID_DEFINITION_AND_PARTICLE_LOCATION_STATISTICS

ORIGIN OF FLOATING GRID IS AT (     0.1555,      0.25921 IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS       0.0322359 DEGREES  IN X AND       0.0219312 DEGREES  IN Y
THE GRID SEPARATION IN THE FIXED SYSTEM IS      0.036 DEGREES  IN X AND     0.015 DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE         0.067806          0.071921          0.735017
THE STANDARD DEVIATIONS ARE            0.015517         0.011607         0.022083
        HORIZONTAL X-Y SCALE DEPENDENT DIFFUSION COEFF.=     0.5810E-06     0.1783E-05
    XAVG= 0.6580E-01     YAVG= 0.7260E-01     ZAVG= 0.750        SIGX= 0.117E-01SIGY= 0.113E-01
```

Figure VIII.-7. Output from Main

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ALL HORIZONTAL VELOCITIES ARE MULTIPLIED BY 10**6

          U VELOCITY FIELD      STEP NUMBER   5     TIME      54000.00  LEVEL   1
           0.27     0.29     0.32     0.34     0.37
   0.2     -0.161  -0.092  -0.092   0.027  -0.027
   0.2     -0.122  -0.168  -0.127  -0.157  -0.070
   0.2      0.157   0.198   0.211   0.282   0.290
   0.3      0.195   0.211   0.246   0.291   0.315
   0.3      0.145   0.177   0.406   0.428   0.450

          U VELOCITY FIELD      STEP NUMBER   5     TIME      54000.00  LEVEL   2
           0.27     0.29     0.32     0.34     0.37
   0.2     -0.161  -0.092  -0.092   0.027  -0.027
   0.2     -0.122  -0.168  -0.127  -0.157  -0.070
   0.2      0.157   0.198   0.211   0.282   0.290
   0.3      0.195   0.211   0.246   0.291   0.315
   0.3      0.145   0.177   0.406   0.428   0.450

          U VELOCITY FIELD      STEP NUMBER   5     TIME      54000.00  LEVEL   1
           0.27     0.29     0.32     0.34     0.37
   0.2     -0.153  -0.092  -0.092   0.027  -0.027
   0.2     -0.122  -0.168  -0.127  -0.157  -0.070
   0.2      0.157   0.198   0.211   0.282   0.290
   0.3      0.195   0.211   0.246   0.291   0.315
   0.3      0.145   0.177   0.406   0.428   0.450

          V VELOCITY FIELD      STEP NUMBER   5     TIME      54000.00  LEVEL   1
           0.27     0.29     0.32     0.34     0.37
   0.2     -0.466  -0.482  -0.495  -0.510  -0.520
   0.2     -0.471  -0.520  -0.510  -0.411  -0.391
   0.2     -0.290  -0.145  -0.172  -0.167  -0.120
   0.3     -0.104  -0.252  -0.261  -0.235  -0.217
   0.3     -0.112  -0.112  -0.272  -0.170  -0.129

          V VELOCITY FIELD      STEP NUMBER   5     TIME      54000.00  LEVEL   2
           0.27     0.29     0.32     0.34     0.37
   0.2     -0.456  -0.492  -0.495  -0.510  -0.520
   0.2     -0.471  -0.520  -0.510  -0.411  -0.391
   0.2     -0.290  -0.145  -0.172  -0.167  -0.120
   0.3     -0.104  -0.252  -0.261  -0.235  -0.217
   0.3     -0.112  -0.112  -0.272  -0.170  -0.129

          V VELOCITY FIELD      STEP NUMBER   5     TIME      54000.00  LEVEL   1
           0.27     0.29     0.32     0.34     0.37
   0.2     -0.466  -0.482  -0.495  -0.510  -0.520
   0.2     -0.471  -0.520  -0.510  -0.411  -0.391
   0.2     -0.290  -0.145  -0.172  -0.167  -0.120
   0.3     -0.104  -0.252  -0.261  -0.235  -0.217
   0.3     -0.112  -0.112  -0.272  -0.170  -0.129

          W VELOCITY FIELD      STEP NUMBER   5     TIME     54000.00  LEVEL   1
           0.27     0.29     0.32     0.34     0.37
   0.2      0.000   0.000   0.000   0.000   0.000
   0.2      0.000   0.000   0.000   0.000   0.000
   0.2      0.000   0.000   0.000   0.000   0.000
   0.3      0.000   0.000   0.000   0.000   0.000
   0.3      0.000   0.000   0.000   0.000   0.000

          W VELOCITY FIELD      STEP NUMBER   5     TIME     54000.00  LEVEL   2
```

```
           0.27     0.29     0.32     0.34     0.37
   0.2      0.000   0.000   0.000   0.000   0.000
   0.2      0.000   0.000   0.000   0.000   0.000
   0.2      0.000   0.000   0.000   0.000   0.000
   0.3      0.000   0.000   0.000   0.000   0.000
   0.3      0.000   0.000   0.000   0.000   0.000

          W VELOCITY FIELD      STEP NUMBER   5     TIME     54000.00  LEVEL   1
           0.27     0.29     0.32     0.34     0.37
   0.2      0.000   0.000   0.000   0.000   0.000
   0.2      0.000   0.000   0.000   0.000   0.000
   0.2      0.000   0.000   0.000   0.000   0.000
   0.3      0.000   0.000   0.000   0.000   0.000
   0.3      0.000   0.000   0.000   0.000   0.000

                         FLOATING_GRID_DEFINITION_AND_PARTICLE_LOCATION_STATISTICS

ORIGIN OF FLOATING GRID IS AT (      0.1516,       0.2738) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS       0.0341665 DEGREES  IN X AND       0.0234428 DEGREES  IN Y
THE GRID SEPARATION IN THE FIXED SYSTEM IS       0.036 DEGREES  IN X AND      0.036 DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE           0.068932           0.072529           0.754316
THE STANDARD DEVIATIONS ARE              0.014911           0.011102           0.141858



        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   5     TIME    54000.00  LEVEL   1

         0.27     0.29     0.32     0.34     0.37
  0.17   0.00000 0.00000 0.00000 0.00000 0.00000
  0.20   0.00000 0.00000 0.00019 0.00067 0.00000
  0.24   0.00000 0.00000 0.00029 0.00044 0.00000
  0.27   0.00000 0.00000 0.00005 0.00006 0.00000
  0.30   0.00000 0.00000 0.00000 0.00000 0.00000

        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   5     TIME    54000.00  LEVEL   2

         0.27     0.29     0.32     0.34     0.37
  0.17   0.00000 0.00000 0.00000 0.00000 0.00000
  0.20   0.00000 0.00009 0.00039 0.00255 0.00000
  0.24   0.00000 0.00012 0.00112 0.00164 0.00000
  0.27   0.00000 0.00004 0.00029 0.00024 0.00000
  0.30   0.00000 0.00000 0.00000 0.00000 0.00000

        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   5     TIME    54300.00  LEVEL   1

         0.27     0.29     0.32     0.34     0.37
  0.17   0.00000 0.00000 0.00000 0.00000 0.00000
  0.20   0.00000 0.00120 0.00552 0.01486 0.00000
  0.24   0.00000 0.00131 0.00529 0.00715 0.00000
  0.27   0.00000 0.00055 0.00160 0.00051 0.00000
  0.30   0.00000 0.00000 0.00000 0.00000 0.00000
```

Figure VIII.-7. Output from Main

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PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
                 PARTICLE PARAMETERS AT TIME    50000.00

                PARTICLE POSITION                     PARTICLE POSITION                              PARTICLE PARAMETERS
                 FLOATING SYSTEM                         FIXED SYSTEM
 #          X           Y           Z          X           Y                    DIAMETER      DENSITY   SET.,VEL.         MASS

 1       0.0618      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.999
 2       0.0619      0.0826      0.8150      0.218       0.336      0.8150      0.0010      0.8770      0.0000         0.999
 3       0.0619      0.0826      0.6037      0.213       0.336      0.6037      0.0010      0.8770      0.0000         0.998
 4       0.0619      0.0827      0.8150      0.218       0.336      0.8150      0.0010      0.8770      0.0000         0.993
 5       0.0518      0.0825      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.999
 6       0.0618      0.0825      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.999
 7       0.0519      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.998
 8       0.0619      0.0826      0.3022      0.218       0.336      0.3022      0.0013      0.8770      0.0000         0.999
 9       0.0520      0.0825      0.8150      0.218       0.336      0.8150      0.0010      0.8770      0.0000         0.998
10       0.0619      0.0826      0.8150      0.218       0.336      0.8150      0.0010      0.8770      0.0000         0.999
11       0.0519      0.0825      0.3865      0.218       0.336      0.3865      0.0013      0.8770      0.0000         0.999
12       0.0619      0.0825      0.5872      0.218       0.336      0.5872      0.0013      0.8770      0.0000         0.999
13       0.0619      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.999
14       0.0519      0.0825      0.8150      0.213       0.336      0.8150      0.0013      0.8770      0.0000         0.998
15       0.0619      0.0826      0.3558      0.213       0.336      0.3558      0.0010      0.8770      0.0000         0.993
16       0.0519      0.0826      0.8150      0.213       0.336      0.8150      0.0013      0.8770      0.0000         0.999
17       0.0618      0.0826      0.8167      0.213       0.336      0.8167      0.0010      0.8770      0.0000         0.999
18       0.0618      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.998
19       0.0618      0.0826      0.8150      0.213       0.336      0.8150      0.0013      0.8770      0.0000         0.993
20       0.0519      0.0826      0.8150      0.213       0.336      0.8150      0.0013      0.8770      0.0000         0.999
21       0.0618      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.999
22       0.0518      0.0826      0.8150      0.213       0.336      0.8150      0.0013      0.8770      0.0000         0.998
23       0.0619      0.0826      0.3938      0.218       0.336      0.3938      0.0010      0.8770      0.0000         0.993
24       0.0519      0.0826      0.8150      0.218       0.336      0.8150      0.0013      0.8770      0.0000         0.999
25       0.0619      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.999
26       0.0519      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.998
27       0.0620      0.0826      0.8150      0.218       0.336      0.8150      0.0013      0.8770      0.0000         0.993
28       0.0519      0.0827      0.8150      0.218       0.336      0.8150      0.0013      0.8770      0.0000         0.999
29       0.0618      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.999
30       0.0519      0.0825      0.8150      0.218       0.336      0.8150      0.0010      0.8770      0.0000         0.998
31       0.0618      0.0826      0.8150      0.213       0.336      0.8150      0.0013      0.8770      0.0000         0.993
32       0.0519      0.0825      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.998
33       0.0620      0.0825      0.8150      0.218       0.336      0.8150      0.0010      0.8770      0.0000         0.999
34       0.0518      0.0825      0.3608      0.213       0.336      0.3608      0.0010      0.8770      0.0000         0.998
35       0.0618      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.993
36       0.0519      0.0826      0.8150      0.213       0.336      0.8150      0.0010      0.8770      0.0000         0.999
37       0.0619      0.0826      0.5830      0.218       0.336      0.5830      0.0013      0.8770      0.0000         0.999
38       0.0518      0.0826      0.8150      0.213       0.336      0.8150      0.0013      0.8770      0.0000         0.999
39       0.0609      0.0818      0.8150      0.212       0.337      0.8150      0.0013      0.8770      0.0000         0.993
40       0.0510      0.0818      0.8150      0.213       0.337      0.8150      0.0013      0.8770      0.0000         0.978
41       0.0610      0.0818      0.8150      0.213       0.337      0.8150      0.0013      0.8770      0.0000         0.999
42       0.0510      0.0818      0.8150      0.213       0.337      0.8150      0.0013      0.8770      0.0000         0.999
43       0.0668      0.0527      0.8150      0.216       0.306      0.8150      0.0010      1.0032      0.0000         1.001
44       0.0739      0.0690      0.8150      0.225       0.322      0.8150      0.0013      1.0032      0.0000         1.001
45       0.0610      0.0818      0.8150      0.213       0.337      0.8150      0.0010      0.8770      0.0000         0.993
46       0.0533      0.0690      0.8150      0.205       0.323      0.8150      0.0013      1.0032      0.0000         1.001
47       0.0610      0.0818      0.8150      0.213       0.337      0.8150      0.0013      0.8770      0.0000         0.993
48       0.0513      0.0818      0.8150      0.213       0.337      0.8150      0.0013      0.8770      0.0000         0.999
49       0.0513      0.0513      0.8150      0.203       0.307      0.8150      0.0013      1.0032      0.0000         1.001
50       0.0507      0.0603      0.8150      0.210       0.318      0.8150      0.0013      1.0032      0.0000         1.001
```

Figure VIII.-7. Output from Main

```
 51     0.0617   0.0781   0.8150   0.215   0.128   0.8150   0.0013   1.0012   0.0000     1.001
 52     0.0615   0.0617   0.8150   0.216   0.115   0.8150   0.0010   1.0012   0.0000     1.001
 53     0.0567   0.0678   0.8150   0.218   0.116   0.8150   0.0010   1.0012   0.0000     1.001
 54     0.0688   0.0618   0.8150   0.216   0.116   0.8150   0.0013   1.0012   0.0000     1.001
 55     0.0510   0.0818   0.8150   0.211   0.117   0.8150   0.0010   0.8770   0.0000     0.999
 56     0.0510   0.0811   0.8150   0.211   0.117   0.8150   0.0010   0.8770   0.0000     0.998
 57     0.0619   0.0688   0.8150   0.211   0.122   0.8150   0.0010   1.0012   0.0000     1.031
 58     0.0509   0.0818   0.5717   0.211   0.117   0.5717   0.0010   0.9770   0.0000     0.999
 59     0.0998   0.0701   0.8150   0.251   0.128   0.8150   0.0010   1.0012   0.0000     1.001
 60     0.0658   0.0618   0.8150   0.217   0.115   0.8150   0.0010   1.0012   0.0000     1.001
 61     0.0516   0.0608   0.8150   0.201   0.118   0.8150   0.0013   1.0012   0.0000     1.001
 62     0.0589   0.0818   0.8150   0.211   0.117   0.8150   0.0013   0.8770   0.0000     0.999
 63     0.0628   0.0580   0.8150   0.218   0.112   0.8150   0.0010   1.0012   0.0000     1.001
 64     0.0810   0.0612   0.8150   0.215   0.117   0.8150   0.0013   1.0012   0.0000     1.001
 65     0.0682   0.0609   0.8150   0.216   0.115   0.8150   0.0013   1.0012   0.0000     1.031
 66     0.0557   0.0589   0.8150   0.218   0.111   0.8150   0.0013   1.0312   0.0000     1.001
 67     0.0610   0.0811   0.8786   0.211   0.117   0.8786   0.0010   0.8770   0.0000     0.999
 68     0.0516   0.0609   0.7611   0.215   0.115   0.7611   0.0013   1.0012   0.0000     1.001
 69     0.0658   0.0615   0.8150   0.217   0.117   0.8150   0.0010   1.0012   0.0000     1.031
 70     0.0617   0.0595   0.8150   0.215   0.112   0.8150   0.0010   1.0012   0.0000     1.001
 71     0.0668   0.0611   0.8150   0.218   0.117   0.8150   0.0010   1.0012   0.0000     1.001
 72     0.0609   0.0818   0.8150   0.212   0.117   0.8150   0.0010   0.8770   0.0000     0.998
 73     0.0609   0.0818   0.7679   0.212   0.117   0.7679   0.0010   0.8770   0.0000     0.999
 74     0.0510   0.0818   0.8150   0.211   0.117   0.8150   0.0010   0.8770   0.0000     0.999
 75     0.0610   0.0818   0.7887   0.211   0.117   0.7887   0.0013   0.8770   0.0000     0.999
 76     0.0610   0.0818   0.8150   0.213   0.117   0.8150   0.0010   0.8770   0.0000     0.998
 77     0.0609   0.0818   0.8150   0.212   0.117   0.8150   0.0010   0.8770   0.0000     0.999
 78     0.0510   0.0818   0.8150   0.211   0.117   0.8150   0.0013   0.8770   0.0000     0.998
 79     0.0609   0.0811   0.7275   0.211   0.117   0.7275   0.0013   0.8770   0.0000     0.999
 80     0.0509   0.0811   0.8150   0.212   0.117   0.8150   0.0010   0.8770   0.0000     0.998
 81     0.0610   0.0818   0.8150   0.211   0.117   0.8150   0.0010   0.8770   0.0000     0.993
 82     0.0510   0.0818   0.8150   0.211   0.117   0.8150   0.0013   0.9770   0.0000     0.999
 83     0.0610   0.0818   0.7111   0.211   0.117   0.7111   0.0013   0.8770   0.0000     0.999
 84     0.0512   0.0686   0.8150   0.215   0.118   0.8150   0.0013   0.9952   0.0000     0.958
 85     0.0619   0.0158   0.8150   0.215   0.290   0.8150   0.0013   1.0095   0.0000     1.069
 86     0.0596   0.0858   0.8150   0.220   0.100   0.8150   0.0010   1.0095   0.0000     1.069
 87     0.0662   0.0868   0.8150   0.218   0.109   0.8150   0.0010   1.0015   0.0000     1.069
 88     0.0530   0.0811   0.7199   0.215   0.295   0.7199   0.0013   1.0035   0.0000     1.069
 89     0.0788   0.0670   0.8150   0.226   0.321   0.8150   0.0013   0.9952   0.0000     0.958
 90     0.0511   0.0386   0.8150   0.215   0.292   0.8150   0.0013   1.0115   0.0000     1.069
 91     0.0607   0.0650   0.8150   0.212   0.119   0.8150   0.0010   0.9952   0.0000     0.958
 92     0.0619   0.0659   0.2011   0.215   0.121   0.2011   0.0010   0.9952   0.0000     0.958
 93     0.0571   0.0797   0.8150   0.219   0.125   0.8150   0.0013   0.9952   0.0000     0.958
 94     0.0958   0.0698   0.8150   0.218   0.121   0.8150   0.0010   0.9952   0.0000     0.958
 95     0.0688   0.0510   0.8150   0.216   0.105   0.8150   0.0013   1.0105   0.0000     0.993
 96     0.0811   0.0690   0.3215   0.211   0.121   0.3215   0.0010   1.0012   0.0000     0.991
 97     0.0998   0.0588   0.8150   0.251   0.108   0.8150   0.0013   1.0135   0.0000     0.999
 98     0.0328   0.0858   0.8150   0.288   0.100   0.8150   0.0010   1.0105   0.0000     0.998
 99     0.0920   0.0677   0.5017   0.218   0.121   0.5017   0.0013   1.0012   0.0000     0.991
100     0.0690   0.0709   0.8150   0.221   0.115   0.8150   0.0013   1.0002   0.0000     0.991
101     0.0920   0.0677   0.8118   0.218   0.121   0.8118   0.0013   1.0012   0.0000     0.991
102     0.0810   0.0677   0.5097   0.211   0.121   0.5097   0.0010   1.0002   0.0000     0.991
103     0.1035   0.0652   0.8150   0.261   0.119   0.8150   0.0013   1.0018   0.0000     0.991
104     0.1077   0.0772   0.8150   0.259   0.111   0.8150   0.0013   1.0018   0.0000     0.991
105     0.0959   0.0891   0.6951   0.287   0.101   0.6951   0.0013   1.0012   0.0000     1.086
106     0.1027   0.0611   0.8150   0.258   0.115   0.8150   0.0013   1.0112   0.0000     1.086
107     0.0777   0.0678   0.8150   0.279   0.117   0.8150   0.0013   1.0018   0.0000     0.991
108     0.1019   0.0785   0.8151   [illegible]   0.118   0.8151   0.0013   1.0018   0.0000     0.991
109     0.1159   0.0611   0.8150   0.268   0.115   0.8150   0.0013   [illegible]   0.0000     1.011
110     0.1099   [illegible]   0.8100   [illegible]   0.118   0.8100   0.0013   [illegible]   0.0000     1.011

111     0.1006   0.0805   0.8150   0.252   0.298   0.8150   0.0013   1.0117   0.0000     0.939
112     0.1192   0.0818   0.8150   0.271   0.296   0.8150   0.0013   1.0117   0.0000     0.918
113     0.1080   0.0686   0.8150   0.260   0.122   0.8150   0.0013   1.0068   0.0000     1.011
114     0.0986   0.0891   0.8150   0.282   0.101   0.8150   0.0013   1.0117   0.0000     0.938
115     0.0995   0.0616   0.8150   0.251   0.117   0.8150   0.0010   1.0068   0.0000     1.011
***********************************************************************************************************


                                  MASS_BALANCE

              TOTAL MASS OF OIL SPILLED       20000.00000  METRIC TONS


     LOCATION OF OIL                                          AMOUNT (METRIC TONS)         PERCENT OF TOTAL
        IN ATMOSPHERE                                               5003.20300                    25.02
        ON SURFACE                                                 13595.82000                    67.98
        IN WATER COLUMN         115 WATER PARTICLES                  114.96800                     0.57
        ON BOTTOM                86 DEPOSITED PARTICLES               85.95775                     0.43
        ON SHORE                                                       0.00000                     0.00
     REMOVAL MECHANISMS
        BIOLOGICALLY CONSUMED                                          0.03033                     0.00
        PHYSICALLY CLEANED UP                                       1200.00000                     6.00
        LOST THRU OPEN BOUNDARY     0 LOST PARTICLES                   0.00000                     0.00

***********************************************************************************************************
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Figure VIII.-7. Output from Main

```
INPUT CONTROL PARAMETERS        INPUT STREAM FOR THE SUBSURFACE PORTION OF THE MODEL        * * THIS IS A RESTARTED RUN ***
                                                                                            # AD   CVELOCITY     7 CONCENTRATION    7 PARTICLE    7 SPILLET AND    7 MAS: DATA SETS FOR    7 STEPS
         1   NSTRT                                                                               0.00000   1SPILLETS
         1   NSTEP                           1.33300   POWX                                  10800.00000   2SPILLETS
         1   NSUMS                           1.33300   POWY                                  21600.00000   2SPILLETS
         0   NRUN                            0.05000   EXX                                   32400.00000   2SPILLETS
       350   IDAT                            0.05000   EYY                                   43200.00000   2SPILLETS
         1   NENV                                  0   NTRANS                                54000.00000   2SPILLETS
   3.00000   DT                             10.00000   DXX                                   64800.00000   2SPILLETS
  33.00000   TIMMAX                         10.00000   DYY                          CONCENTRATION AT TIME                0.000 READ IN
         2   ISCAL                           0.00001   DZZ                          CONCENTRATION AT TIME            10800.000 READ IN
         1   NPRTA                           0.00001   DX                           CONCENTRATION AT TIME            21600.000 READ IN
         1   NPRTC                           0.00001   DY                           CONCENTRATION AT TIME            32400.000 READ IN
         5   NR                              0.33000   DZ                           CONCENTRATION AT TIME            43200.000 READ IN
         5   NCD                                   5   IMSUB                        CONCENTRATION AT TIME            54000.000 READ IN
         4   NCU                                   5   JMSUB                        CONCENTRATION AT TIME            64800.000 READ IN
         5   NDD                                   3   KMSUB                        PARTICLE POSITIONS AT TIME                0.000 READ IN
         3   NDU                                   0   NSUB                         PARTICLE POSITIONS AT TIME            10800.000 READ IN
         5   NED                                   1   NDIFF                        PARTICLE POSITIONS AT TIME            21600.000 READ IN
         3   NEU                                 200   NCRIT                        PARTICLE POSITIONS AT TIME            32400.000 READ IN
         5   NFD                                   1   NLITR                        PARTICLE POSITIONS AT TIME            43200.000 READ IN
         3   NFU                             0.50000   DEPC                         PARTICLE POSITIONS AT TIME            54000.000 READ IN
         5   NSD                             4.00000   POSIN                        PARTICLE POSITIONS AT TIME            64800.000 READ IN
         3   NSU                             0.50000   AFRAC                        MASS AT TIME                0.000 READ IN
        13   NTDU                            2.00000   BIFRAC                       MASS AT TIME            10800.000 READ IN
        14   NTDV                            2.00000   BOFRAC                       MASS AT TIME            21600.000 READ IN
         1   NTUU                           50.00000   NFST                         MASS AT TIME            32400.000 READ IN
         1   NTUV                            0.00100   DDIANT                       MASS AT TIME            43200.000 READ IN
        12   NWD                             0.00000   DVELXY                       MASS AT TIME            54000.000 READ IN
         3   NWU                                   1   NPTSUB                       MASS AT TIME            64800.000 READ IN
         5   NCRD                                  1   NPPTMS
         5   NCLD                                  1   KPRTX
         5   NSRD                                  1   KPRTC
         5   NSPD                                  1   KPRTP
       500   NMAX                                  1   NPRD
       200   NTCLAS                                0   NPRP
       200   NURCL                                 1   NPRC
   1.00000   XMSPAR                                1   NPPP
        10   MAXSPL
 100.00000   CONR
         8   NSPIL
         1   NSPPRD
         1   NSPPRP
         1   NOSP
         3   NUBS
        10   NOCR                                BATHYMETRY   INPUT DATA      21.0   HOURS  AFTER THE BEGINNING OF THE SPILL
        11   NOPT
        14   NOVL                 THE BATHYMETRY   GRID HAS    14 DIVISIONS IN X SPACED       0.0357 DEGREES  APART
        15   NOMS                                       AND    14 DIVISIONS IN Y SPACED       0.0357 DEGREES  APART.
         8   NODP
         9   NOLT                 THE (1,1) GRID LOCATION OF THE BATHYMETRY   COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.350000 DEGREES LATITUDE
         0   NSHOR

                                                                    DEPTH    VALUES IN UNITS OF METERS

                                Y                                                  X ELEMENTS
                              ELEMENTS    1       2       3       4       5       6       7       8       9      10      11      12      13      14

                                 14     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                 13     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                 12     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                 11     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                 10     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  9     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  8     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  7     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  6     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  5     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  4     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  3     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  2     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

                                  1     1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
```

Figure VIII.-8. Output from Main Simulation

```
                                      COMP CELL    INPUT DATA      21.00  HOURS  AFTER THE BEGINNING OF THE SPILL

THE COMP CELL    GRID HAS     14 DIVISIONS IN X SPACED        0.0357 DEGREES  APART
                      AND     14 DIVISIONS IN Y SPACED        0.0357 DEGREES  APART.

THE (1,1) GRID LOCATION OF THE COMP CELL    COORDINATE SYSTEM IS AT  67.000000 DEGREES LONGITUDE AND  41.350000 DEGREES LATITUDE


                                                  VALUES IN UNITS OF

    Y                                              X ELEMENTS
ELEMENTS    1       2       3       4       5       6       7       8       9      10      11      12      13      14
   14       2       2       2       2       2       2       2       2       2       2       2       2       2       2
   13       2     101     101     101     101     101     101     101     101     101     101     101     101       2
   12       2     101       1       1       1       1       1       1       1       1       1       1     101       2
   11       2     101       1       1       1       1       1       1       1       1       1       1     101       2
   10       2     101       1       1       1       1       1       1       1       1       1       1     101       2
    9       2     101       1       1       1       1       1       1       1       1       1       1     101       2
    8       2     101       1       1       1       1       1       1       1       1       1       1     101       2
    7       2     101       1       1       1       1       1       1       1       1       1       1     101       2
    6       2     101       1       1       1       1       1       1       1       1       1       1     101       2
    5       2     101       1       1       1       1       1       1       1       1       1       1     101       2
    4       2     101       1       1       1       1       1       1       1       1       1       1     101       2
    3       2     101       1       1       1       1       1       1       1       1       1       1     101       2
    2       2     101     101     101     101     101     101     101     101     101     101     101     101       2
    1       2       2       2       2       2       2       2       2       2       2       2       2       2       2
 AT STEP    1 OLD SPILLET INFORMATION READ IN
 AT STEP    2 OLD SPILLET INFORMATION READ IN
  AT STEP    5 OLD CLEANUP INFORMATION READ IN


                      SPILL_CONTROL_PARAMETERS__21.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL_

    ENVIRONMENTAL DATA READ THIS STEP:                              NONE

    ADDITION OF SPILLETS OR SPILL CONTROL EFFORTS THIS STEP:  0 SPILLETS;    0 CLEANUP EFFORTS;    1 TREATMENT EFFORTS.

 ***************************************************************************************************************

              CHEMICAL_TREATMENT_EFFORTS_IN_PROGRESS_21.000000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                           NEW TREATMENT EFFORTS BEGUN THIS STEP

    THE     1 CHEMICAL TREATMENT EFFORT IS CENTERED AT LONGITUDE  66.759990 AND LATITUDE  41.619990
      1000.000 LITRES OF DISPERSANT PER HOUR ARE USED ON AN AREA OF    1000.000 SQUARE METERS WITH AN EFFICIENCY OF  0.35 %
    THE RADIUS OVER WHICH SPILLETS TO BE TREATED ARE SOUGHT IS  10000.000 METERS
    THIS TREATMENT EFFORT STARTS  21.000000 HOURS AFTER THE BEGINNING OF THE SPILL AND LASTS   3.000000 HOURS.
    THIS TREATMENT EFFORT LOWERS THE INTERFACIAL TENSION TO  60.000000


                       EXISTING_SPILLETS___21.000_HOURS_AFTER_THE_BEGINNING_OF_THE_SPILL

                           SPILLETS CREATED PRIOR TO THIS STEP

    THE    1 SPILLET APPEARED      0.00  HOURS  AFTER THE BEGINNING OF THE SPILL
    IT IS CENTERED AT LONGITUDE  66.748450 AND LATITUDE  41.612710,
    IS OF RADIUS    2212.42 METERS AND IS OF WEIGHT  6701.2960 METRIC TONS.
    SOME PROPERTIES OF THE SPILLED OIL ARE:
                     DENSITY                  1.012299 GRAMS/CC
                     INTERFACIAL TENSION     30.000000 DYNES/CM
                     KINEMATIC VISCOSITY      1.000000 CENTISTOKES
    BY WEIGHT THE OIL FRACTIONS ARE:                         PARAFFIN (C6-C12)               0.000348
                                                             PARAFFIN (C13-C22)              0.099975
                                                             CYCLOPARAFFIN (C6-C12)          0.001462
                                                             CYCLOPARAFFIN (C13-C22)         0.049994
                                                             AROMATIC (C6-C11)               0.000045
                                                             AROMATIC (C12-C18)              0.079855
                                                             NAPTHENO-AROMATIC (C9-C25)      0.209457
                                                             RESIDUAL                        0.300000
    THE    2 SPILLET APPEARED      3.00  HOURS  AFTER THE BEGINNING OF THE SPILL
    IT IS CENTERED AT LONGITUDE  65.751700 AND LATITUDE  41.631620,
    IS OF RADIUS    2042.18 METERS AND IS OF WEIGHT  6837.9600 METRIC TONS.
    SOME PROPERTIES OF THE SPILLED OIL ARE:
                     DENSITY                  1.009588 GRAMS/CC
                     INTERFACIAL TENSION     30.000000 DYNES/CM
                     KINEMATIC VISCOSITY      1.000000 CENTISTOKES
    BY WEIGHT THE OIL FRACTIONS ARE:                         PARAFFIN (C6-C12)               0.002130
                                                             PARAFFIN (C13-C22)              0.099984
                                                             CYCLOPARAFFIN (C6-C12)          0.007066
                                                             CYCLOPARAFFIN (C13-C22)         0.049996
                                                             AROMATIC (C6-C11)               0.000787
                                                             AROMATIC (C12-C18)              0.079908
                                                             NAPTHENO-AROMATIC (C9-C25)      0.209455
                                                             RESIDUAL                        0.300000
```

Figure VIII.-8. Output from Main Simulation Restarted Run

```
ALL HORIZONTAL VELOCITIES ARE MULTIPLIED BY 10**6

        U VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   1
         0.26     0.28     0.31     0.33     0.36
  0.1     -0.117  -0.061   0.033    0.035  -0.008
  0.2     -0.061  -0.011  -0.036   -0.043  -0.025
  0.3      0.174   0.221   0.218    0.267   0.303
  0.3      0.285   0.329   0.332    0.360   0.378
  0.4      0.216   0.329   0.380    0.375   0.313

        U VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   2
         0.26     0.28     0.31     0.33     0.36
  0.1     -0.117  -0.061   0.033    0.035  -0.008
  0.2     -0.061  -0.011  -0.036   -0.043  -0.025
  0.3      0.174   0.221   0.219    0.267   0.303
  0.3      0.285   0.324   0.332    0.360   0.378
  0.4      0.216   0.324   0.380    0.375   0.313

        U VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   3
         0.26     0.28     0.31     0.33     0.36
  0.1     -0.117  -0.061   0.033    0.035  -0.008
  0.2     -0.061  -0.011  -0.036   -0.043  -0.025
  0.3      0.174   0.221   0.218    0.267   0.303
  0.3      0.285   0.329   0.332    0.360   0.378
  0.4      0.216   0.324   0.380    0.375   0.313

        V VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   1
         0.26     0.28     0.31     0.33     0.36
  0.1     -0.242  -0.248  -0.267   -0.258  -0.254
  0.2     -0.473  -0.506  -0.553   -0.464  -0.434
  0.3     -0.118  -0.241  -0.219   -0.251  -0.248
  0.3     -0.186  -0.337  -0.351   -0.215  -0.172
  0.4     -0.150  -0.401  -0.406   -0.227  -0.130

        V VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   2
         0.26     0.28     0.31     0.33     0.36
  0.1     -0.242  -0.248  -0.267   -0.258  -0.254
  0.2     -0.471  -0.506  -0.553   -0.464  -0.438
  0.3     -0.118  -0.241  -0.219   -0.251  -0.248
  0.3     -0.186  -0.337  -0.353   -0.235  -0.172
  0.4     -0.150  -0.401  -0.406   -0.227  -0.130

        V VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   3
         0.26     0.28     0.31     0.33     0.36
  0.1     -0.242  -0.248  -0.267   -0.258  -0.254
  0.2     -0.471  -0.506  -0.553   -0.464  -0.438
  0.3     -0.118  -0.241  -0.219   -0.251  -0.248
  0.3     -0.186  -0.337  -0.353   -0.235  -0.172
  0.4     -0.150  -0.401  -0.406   -0.227  -0.130

        W VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   1
         0.26     0.28     0.31     0.33     0.36
  0.1      0.000   0.000   0.000    0.000   0.000
  0.2      0.000   0.000   0.000    0.000   0.000
  0.3      0.000   0.000   0.000    0.000   0.000
  0.3      0.000   0.000   0.000    0.000   0.000
  0.4      0.000   0.000   0.000    0.000   0.000

        W VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   2
```

```
         0.26     0.28     0.31     0.33     0.36
  0.1      0.000   0.000   0.000    0.000   0.000
  0.2      0.000   0.000   0.000    0.000   0.000
  0.3      0.000   0.000   0.000    0.000   0.000
  0.3      0.000   0.000   0.000    0.000   0.000
  0.4      0.000   0.000   0.000    0.000   0.000

        W VELOCITY FIELD      STEP NUMBER   7     TIME      75600.00  LEVEL   3
         0.26     0.28     0.31     0.33     0.36
  0.1      0.000   0.000   0.000    0.000   0.000
  0.2      0.000   0.000   0.000    0.000   0.000
  0.3      0.000   0.000   0.000    0.000   0.000
  0.3      0.000   0.000   0.000    0.000   0.000
  0.4      0.000   0.000   0.000    0.000   0.000

                         FLOATING GRID DEFINITION AND PARTICLE LOCATION STATISTICS

ORIGIN OF FLOATING GRID IS AT (      0.1195,       0.2446) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS       0.0549006 DEGREES  IN X AND       0.0236763 DEGREES  IN Y
THE GRID SEPARATION IN THE FIXED SYSTEM IS       0.036 DEGREES  IN X AND     0.036 DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE          0.106405          0.071609          0.752923
THE STANDARD DEVIATIONS ARE              0.024053          0.012960          0.182052



        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   7     TIME    75600.00  LEVEL   1

         0.26     0.28     0.31     0.33     0.36
  0.15   0.00000 0.00000 0.00000 0.00000 0.00000
  0.20   0.00000 0.00000 0.00018 0.00052 0.00000
  0.26   0.00000 0.00002 0.00017 0.00028 0.00000
  0.31   0.00000 0.00002 0.00008 0.00001 0.00000
  0.36   0.00000 0.00000 0.00000 0.00000 0.00000

        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   7     TIME    75600.00  LEVEL   2

         0.26     0.28     0.31     0.33     0.36
  0.15   0.00000 0.00000 0.00000 0.00000 0.00000
  0.20   0.00000 0.00007 0.00088 0.00197 0.00000
  0.26   0.00000 0.00012 0.00070 0.00099 0.00000
  0.31   0.00000 0.00009 0.00016 0.00007 0.00000
  0.36   0.00000 0.00000 0.00000 0.00000 0.00000

        CONCENTRATION IN MG OF OIL PER ML OF WATER     STEP NUMBER   7     TIME    75600.00  LEVEL   3

         0.26     0.28     0.31     0.33     0.36
  0.15   0.00000 0.00000 0.00000 0.00000 0.00000
  0.20   0.00000 0.00101 0.00848 0.01098 0.00000
  0.26   0.00000 0.00081 0.00357 0.00409 0.00000
  0.31   0.00000 0.00032 0.00066 0.00037 0.00000
  0.36   0.00000 0.00000 0.00000 0.00000 0.00000
```

Figure VIII.-8. Output from Main Simulation
Restarted Run

```
PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
              PARTICLE PARAMETERS AT TIME    75600.00


           PARTICLE POSITION                   PARTICLE POSITION                                PARTICLE PARAMETERS
            FLOATING SYSTEM                      FIXED SYSTEM
 N        X          Y          Z          X          Y          Z          DIAMETER    DENSITY   SET. VEL.        MASS


 1      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
 2      0.0913     0.0821     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
 3      0.0912     0.0820     0.6037     0.213      0.327      0.6037      0.0010      0.8770     0.0000          0.998
 4      0.0912     0.0821     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
 5      0.0913     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
 6      0.0913     0.0819     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
 7      0.0912     0.0821     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
 8      0.0912     0.0820     0.3022     0.213      0.327      0.3022      0.0010      0.8770     0.0000          0.998
 9      0.0914     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
10      0.0912     0.0821     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
11      0.0913     0.0819     0.3465     0.213      0.327      0.3465      0.0010      0.8770     0.0000          0.998
12      0.0912     0.0819     0.5872     0.213      0.327      0.5872      0.0010      0.8770     0.0000          0.998
13      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
14      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
15      0.0912     0.0821     0.3554     0.213      0.327      0.3554      0.0010      0.8770     0.0000          0.998
16      0.0912     0.0821     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
17      0.0912     0.0820     0.8167     0.213      0.327      0.8167      0.0010      0.8770     0.0000          0.998
18      0.0913     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
19      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
20      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
21      0.0913     0.0821     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
22      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
23      0.0912     0.0821     0.3938     0.213      0.327      0.3938      0.0010      0.8770     0.0000          0.998
24      0.0912     0.0821     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
25      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
26      0.0912     0.0823     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
27      0.0913     0.0823     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
28      0.0912     0.0822     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
29      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
30      0.0913     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
31      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
32      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
33      0.0913     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
34      0.0913     0.0820     0.3608     0.213      0.327      0.3608      0.0010      0.8770     0.0000          0.998
35      0.0912     0.0824     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
36      0.0912     0.0820     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
37      0.0913     0.0821     0.5830     0.213      0.327      0.5830      0.0010      0.8770     0.0000          0.998
38      0.0912     0.0823     0.8150     0.213      0.327      0.8150      0.0010      0.8770     0.0000          0.998
39      0.0923     0.0829     0.8150     0.212      0.327      0.8150      0.0010      0.8770     0.0000          0.998
40      0.0924     0.0828     0.8150     0.212      0.327      0.8150      0.0010      0.8770     0.0000          0.998
41      0.0924     0.0828     0.8150     0.212      0.327      0.8150      0.0010      0.8770     0.0000          0.998
42      0.0924     0.0828     0.8150     0.212      0.327      0.8150      0.0010      0.8770     0.0000          0.998
43      0.0954     0.0522     0.8150     0.215      0.297      0.8150      0.0010      1.0032     0.0000          1.001
44      0.1047     0.0683     0.8150     0.224      0.333      0.8150      0.0010      1.0032     0.0000          1.001
45      0.0924     0.0828     0.8150     0.212      0.327      0.8150      0.0010      0.8770     0.0000          0.998
46      0.0498     0.0668     0.8150     0.209      0.333      0.8150      0.0010      1.0032     0.0000          1.001
47      0.0924     0.0828     0.8150     0.212      0.327      0.8150      0.0010      0.8770     0.0000          0.998
48      0.0925     0.0829     0.8150     0.212      0.327      0.8150      0.0010      0.8770     0.0000          0.998
49      0.0924     0.0533     0.8150     0.202      0.296      0.8150      0.0010      1.0032     0.0000          1.001
50      0.0900     0.0590     0.8150     0.209      0.338      0.8150      0.0010      1.0032     0.0000          1.001
```

Figure VIII.-8. Output from Main Simulation Restarted Run

```
 51      0.0950    0.0733    0.8150    0.214    0.318    0.8150    0.0010    1.0032    0.0000     1.001
 52      0.0956    0.0631    0.8150    0.235    0.106    0.8150    0.0010    1.0032    0.0000     1.001
 53      0.0978    0.0620    0.8150    0.217    0.307    0.8150    0.0010    1.0032    0.0000     1.001
 54      0.0956    0.0633    0.8150    0.215    0.306    0.8150    0.0010    1.0032    0.0000     1.001
 55      0.0928    0.0828    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 56      0.0928    0.0827    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 57      0.0933    0.0673    0.8150    0.213    0.312    0.8150    0.0010    1.0032    0.0000     1.001
 58      0.0923    0.0828    0.5717    0.212    0.327    0.5717    0.0010    0.8770    0.0000     0.998
 59      0.1182    0.0735    0.8150    0.258    0.118    0.8150    0.0010    1.0032    0.0000     1.001
 60      0.0965    0.0609    0.8150    0.216    0.305    0.8150    0.0010    1.0032    0.0000     1.001
 61      0.0830    0.0583    0.8150    0.202    0.303    0.8150    0.0010    1.0032    0.0000     1.001
 62      0.0923    0.0828    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 63      0.0939    0.0572    0.8150    0.211    0.302    0.8150    0.0010    1.0032    0.0000     1.001
 64      0.1150    0.0688    0.8150    0.238    0.109    0.8150    0.0010    1.0032    0.0000     1.001
 65      0.0958    0.0602    0.8150    0.215    0.305    0.8150    0.0010    1.0032    0.0000     1.001
 66      0.0978    0.0585    0.8150    0.217    0.303    0.8150    0.0010    1.0032    0.0000     1.001
 67      0.0928    0.0827    0.4786    0.212    0.327    0.4786    0.0010    0.8770    0.0000     0.998
 68      0.0988    0.0600    0.7633    0.218    0.305    0.7633    0.0010    1.0032    0.0000     1.001
 69      0.0969    0.0610    0.8150    0.216    0.308    0.8150    0.0010    1.0032    0.0000     1.001
 70      0.0989    0.0578    0.8150    0.218    0.302    0.8150    0.0010    1.0032    0.0000     1.001
 71      0.0979    0.0627    0.8150    0.217    0.307    0.8150    0.0010    1.0032    0.0000     1.001
 72      0.0923    0.0829    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 73      0.0923    0.0828    0.7679    0.212    0.327    0.7679    0.0010    0.8770    0.0000     0.998
 74      0.0928    0.0828    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 75      0.0928    0.0828    0.7887    0.212    0.327    0.7887    0.0010    0.8770    0.0000     0.998
 76      0.0928    0.0828    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 77      0.0923    0.0828    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 78      0.0928    0.0828    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 79      0.0923    0.0827    0.7275    0.212    0.327    0.7275    0.0010    0.8770    0.0000     0.998
 80      0.0923    0.0827    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 81      0.0928    0.0828    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 82      0.0928    0.0828    0.8150    0.212    0.327    0.8150    0.0010    0.8770    0.0000     0.998
 83      0.0928    0.0828    0.7333    0.212    0.327    0.7333    0.0010    0.8770    0.0000     0.998
 84      0.0988    0.0637    0.8150    0.218    0.308    0.8150    0.0010    0.9952    0.0000     0.958
 85      0.0986    0.0355    0.8150    0.218    0.280    0.8150    0.0010    1.0095    0.0000     1.069
 86      0.0995    0.0865    0.8150    0.219    0.293    0.8150    0.0010    1.0095    0.0000     1.069
 87      0.0973    0.0863    0.8150    0.217    0.293    0.8150    0.0010    1.0095    0.0000     1.069
 88      0.0938    0.0807    0.7399    0.213    0.285    0.7399    0.0010    1.0095    0.0000     1.069
 89      0.1058    0.0679    0.8150    0.225    0.312    0.8150    0.0010    0.9952    0.0000     0.958
 90      0.0983    0.0383    0.8150    0.218    0.283    0.8150    0.0010    1.0095    0.0000     1.069
 91      0.0939    0.0639    0.8150    0.211    0.308    0.8150    0.0010    0.9952    0.0000     0.958
 92      0.0951    0.0661    0.2013    0.215    0.313    0.2013    0.0010    0.9952    0.0000     0.958
 93      0.0982    0.0702    0.8150    0.218    0.315    0.8150    0.0010    0.9952    0.0000     0.958
 94      0.1193    0.0738    0.8150    0.219    0.316    0.8150    0.0010    0.9952    0.0000     0.958
 95      0.0958    0.0505    0.8150    0.215    0.295    0.8150    0.0010    1.0105    0.0000     0.999
 96      0.1128    0.0703    0.3235    0.232    0.315    0.3235    0.0010    1.0002    0.0000     0.983
 97      0.1116    0.0577    0.8150    0.253    0.302    0.8150    0.0010    1.0105    0.0000     0.999
 98      0.1255    0.0492    0.8150    0.285    0.298    0.8150    0.0010    1.0105    0.0000     0.999
 99      0.1138    0.0693    0.5017    0.233    0.318    0.5017    0.0010    1.0002    0.0000     0.983
100      0.1000    0.0706    0.8150    0.219    0.315    0.8150    0.0010    1.0002    0.0000     0.983
101      0.1138    0.0693    0.8338    0.233    0.318    0.8338    0.0010    1.0002    0.0000     0.983
102      0.1127    0.0689    0.5097    0.232    0.318    0.5097    0.0010    1.0002    0.0000     0.983
103      0.1452    0.0686    0.8150    0.265    0.313    0.8150    0.0010    1.0038    0.0000     0.993
104      0.1438    0.0807    0.8150    0.263    0.325    0.8150    0.0010    1.0038    0.0000     0.993
105      0.1295    0.0522    0.6953    0.249    0.297    0.6953    0.0010    1.0112    0.0000     1.086
106      0.1174    0.0646    0.8150    0.257    0.309    0.8150    0.0010    1.0112    0.0000     1.086
107      0.1090    0.0638    0.8150    0.228    0.308    0.8150    0.0010    1.0038    0.0000     0.993
108      0.1425    0.0780    0.8153    0.262    0.323    0.8153    0.0010    1.0038    0.0000     0.993
109      0.1525    0.0646    0.8150    0.272    0.309    0.8150    0.0010    1.0068    0.0000     1.030
110      0.1485    0.0738    0.8188    0.268    0.318    0.8188    0.0010    1.0068    0.0000     1.030

111      0.1388    0.0837    0.8150    0.258    0.288    0.8150    0.0010    1.0117    0.0000     0.938
112      0.1558    0.0886    0.8150    0.275    0.289    0.8150    0.0010    1.0117    0.0000     0.938
113      0.1836    0.0723    0.8150    0.263    0.337    0.8150    0.0010    1.0068    0.0000     1.030
114      0.1235    0.0539    0.8150    0.243    0.297    0.8150    0.0010    1.0117    0.0000     0.938
115      0.1339    0.0669    0.8150    0.253    0.332    0.8150    0.0010    1.0068    0.0000     1.030
116      0.1738    0.0820    0.8150    0.293    0.287    0.8150    0.0010    1.0120    0.0000     1.055
117      0.1763    0.0878    0.5988    0.296    0.292    0.5988    0.0010    1.0120    0.0000     1.055
118      0.1598    0.0515    0.3876    0.279    0.296    0.3876    0.0010    1.0120    0.0000     1.055
119      0.1587    0.0709    0.8150    0.278    0.335    0.8150    0.0010    1.0083    0.0000     0.959
120      0.1522    0.0727    0.5980    0.272    0.337    0.5980    0.0010    1.0083    0.0000     0.959
121      0.1338    0.0736    0.8150    0.253    0.322    0.8150    0.0010    1.0083    0.0000     0.959
122      0.1668    0.0733    0.8150    0.286    0.336    0.8150    0.0010    1.0096    0.0000     1.078
123      0.1537    0.0515    0.8150    0.273    0.296    0.8150    0.0010    1.0123    0.0000     0.989
124      0.1486    0.0722    0.8150    0.268    0.337    0.8150    0.0010    1.0096    0.0000     1.078
125      0.1922    0.0889    0.8150    0.312    0.298    0.8150    0.0010    1.0123    0.0000     0.989
126      0.1673    0.0735    0.8150    0.287    0.316    0.8150    0.0010    1.0096    0.0000     1.078
127      0.1673    0.0736    0.8150    0.287    0.316    0.8150    0.0010    1.0096    0.0000     1.078

************************************************************************************************************

                                         MASS BALANCE

                     TOTAL MASS OF OIL SPILLED         20000.00000   METRIC TONS

   LOCATION OF OIL                                                AMOUNT (METRIC TONS)            PERCENT OF TOTAL
      IN ATMOSPHERE                                                       5080.60100                     25.40
      ON SURFACE                                                         13494.18000                     67.47
      IN WATER COLUMN             127 MARKER PARTICLES                     130.14960                      0.65
      ON BOTTOM                    95 DEPOSITED PARTICLES                   94.98141                      0.47
      ON SHORE                                                               0.00000                      0.00
   REMOVAL MECHANISMS
      BIOLOGICALLY CONSUMED                                                  0.00000                      0.00
      PHYSICALLY CLEANED UP                                               1200.00000                      6.00
      LOST THRU OPEN BOUNDARY       0 LOST PARTICLES                         0.00000                      0.00
```

Figure VIII.-8. Output from Main Simulation
Restarted Run

```
INPUT PARAMETERS
          10     NST
           1     NPLOT
                                    MASS IN METRIC TONS

   TIME   ATMOSPHERE  BIO CONSUM  DEPOSITED  CLEANED UP  DUMPED        LOST       ON SHORE ON SURFACE  IN WATER
   0.0     2271.017      0.0        28.011      0.0      10000.000     0.0          0.0     7660.902    18.044
   3.000   4419.047      0.0        61.997      0.0      20000.000     0.0          0.0    15315.957    92.999
   6.000   4678.718      0.0        66.986      0.0      20000.000     0.0          0.0    15160.188    94.067
   9.000   4936.221      0.0        71.921      0.0      20000.000     0.0          0.0    14997.855   131.967
  12.000   4917.305      0.0        81.085    600.000    20000.000     0.0          0.0    14271.519   108.011
  15.000   5001.201      0.0        85.958   1200.000    20000.000     0.0          0.0    11595.873   114.960
  18.000   5048.727      0.0        90.944   1200.000    20000.000     0.0          0.0    11519.262   121.004
  21.000   5083.602      0.0        91.091   1200.000    20000.000     0.0          0.0    11494.189   112.042
  24.000   5101.215      0.0        96.959   1200.000    20000.000     0.0          0.0    11461.906   117.816
  27.000   5119.857      0.0       101.009   1200.000    20000.000     0.0          0.0    11416.602   102.811

FOR PLOT NUMBER     1

MASS IN WATER COLUMN PLOTTED
MASS PHYSICALLY CLEANED UP PLOTTED
MASS ON THE SURFACE PLOTTED
MASS IN ATMOSPHERE PLOTTED
```

Figure VIII.-9. Output from Program PLOTMASS

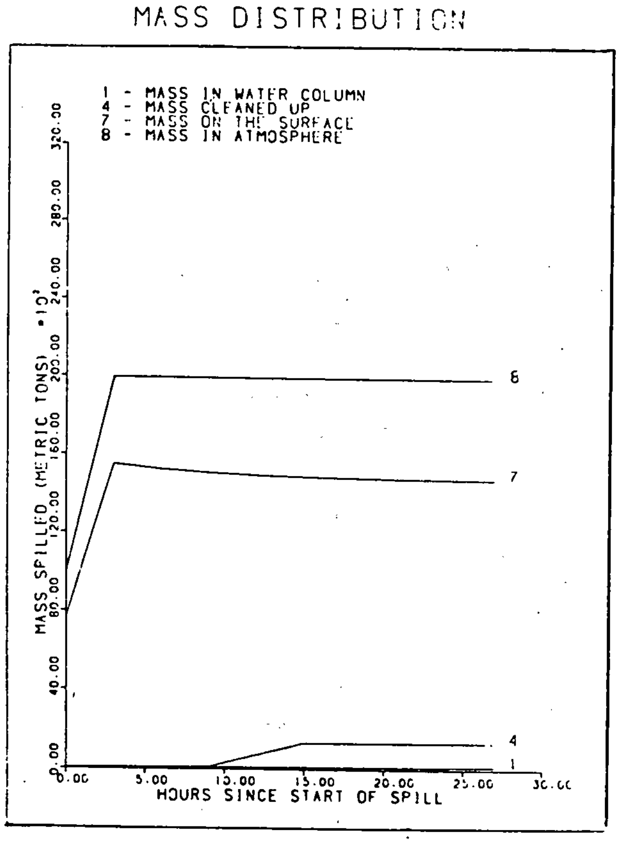

Figure VIII.-10. Plot from Program PLOTMASS

```
INPUT PARAMETERS
       1      NPRT
       1      ISCAL
       1      NPOSP
      10      NPDCH
       0      NPOPT
 0.05000      CCUT
```

```
JULIAN DATE  HOURS SINCE SPILL  #OF SPILLETS MIN LONG   MAX LONG   MIN LAT    MAX LAT ELEMENTS  ANGLE
     0.0    1
 1     0.0        66.820     41.670     25.000 10000.000      0.877     30.000      1.000
     0.05     0.10     0.11     0.05     0.10     0.08     0.21     0.30

   5   5   3  38    1  10    0    0  28
        0.0        6.055      9.935      0.0        0.000      0.000      0.330 67.000000 41.349991  0.0        0.035700  0.035700

0.215 0.216 0.216 0.216 0.216

0.356 0.356 0.356 0.356 0.356
     0.0      0.0      0.0      0.0      0.0      0.0      4.61    14.25     3.05     0.0      0.0      6.13    36.41     0.27     0.0
     0.0      0.66     5.25     0.01     0.0      0.0      0.0      0.0      0.0      0.0
     0.0      0.0      0.0      0.0      0.0      0.0      8.06    42.94     7.07     0.00     0.0     17.52    89.28     5.01     0.00
     0.0      2.36    20.60     2.82     0.0      0.0      0.0      0.00     0.00     0.0
     0.0      0.0      0.0      0.0      0.0      0.0     29.96    63.81    32.88     0.01     0.0    187.99   435.60    51.40     0.02
     0.0     46.49   120.17     7.14     0.0      0.0      0.0      0.04     0.00     0.0
    3.0     2
 1     0.0        66.817     41.650   1093.980  7660.906      1.003     30.000      1.000
     0.01     0.10     0.02     0.05     0.00     0.08     0.21     0.30

 2     3.000      66.820     41.670     25.800 10000.000      0.877     30.000      1.000
     0.05     0.10     0.11     0.05     0.10     0.08     0.21     0.30

   5   5   3  83    2  10    1    0  62
     10800.000     5.118      8.494      0.0        0.017      0.015      0.330 67.000000 41.349991  0.0        0.035700  0.035700

0.109 0.205 0.221 0.238 0.254

0.311 0.326 0.341 0.356 0.371
     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.0      0.0
     0.0      0.00     0.00     0.0      0.0      0.0      0.0      0.0      0.0      0.0
     0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.00     0.0      0.00     0.00     0.00     0.00
     0.0      0.00     0.01     0.0      0.0      0.0      0.00     0.00     0.0      0.0
     0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.01     0.00     0.00     0.0      0.01     0.01     0.00     0.00
     0.0      0.02     0.04     0.0      0.0      0.0      0.00     0.00     0.0      0.0
    6.0     2
 1     0.0        66.811     41.632   1300.711  7417.359      1.009     30.000      1.000
     0.00     0.10     0.01     0.05     0.00     0.08     0.21     0.30

 2     3.000      66.815     41.653   1094.729  7999.602      0.995     30.000      1.000
     0.01     0.10     0.08     0.05     0.01     0.08     0.21     0.30

   5   5   3  94    8  10    2    0  67
     21600.000     4.999      7.496      0.0        0.019      0.024      0.330 67.000000 41.349991  0.0        0.035700  0.035700

0.191 0.209 0.226 0.244 0.261

0.284 0.308 0.332 0.356 0.379
     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.0      0.0
     0.0      0.00     0.00     0.0      0.0      0.0      0.0      0.0      0.0      0.0
     0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.0      0.0      0.0      0.00     0.00     0.00     0.0
     0.0      0.00     0.00     0.00     0.0      0.0      0.00     0.00     0.0      0.0
     0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.0      0.0      0.0      0.00     0.01     0.00     0.0
     0.0      0.02     0.02     0.00     0.0      0.0      0.00     0.00     0.0      0.0
    9.0     2
 1     0.0        66.800     41.627   1496.972  7370.484      1.010     30.000      1.000
     0.00     0.10     0.01     0.05     0.00     0.08     0.21     0.30

 2     3.000      66.803     41.648   1101.611  7701.707      1.100     30.000      1.000
```

Figure VIII.-11. Input to Program DATAOUT from Main Program

```
      0.01     0.10     0.01     0.05     0.01     0.08     0.21     0.10

  5   5   3 102   6  10   3   0  74
      32400.000    4.874      7.361      0.0       0.021     0.024      0.330 67.000000 41.149991  0.0        0.035700  0.035700

0.188 0.207 0.226 0.246 0.265

0.275 0.300 0.326 0.351 0.377
      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.0
      0.0      0.00     0.00     0.00     0.0      0.0      0.0      0.0      0.0      0.0
      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.00     0.0      0.00     0.00     0.00     0.00
      0.0      0.00     0.00     0.00     0.0      0.0      0.0      0.0      0.0      0.0
      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.00     0.0      0.01     0.01     0.00     0.00
      0.0      0.02     0.02     0.00     0.0      0.0      0.0      0.0      0.0      0.0
    12.0    2
 1     0.0       66.787    41.624  1684.980  7349.875     1.011    30.000     1.000
      0.00     0.10     0.00     0.05     0.00     0.08     0.21     0.30

 2     3.000     66.791    41.644  1497.641  7637.984     1.004    30.000     1.000
      0.01     0.10     0.02     0.05     0.00     0.08     0.21     0.30

  5   5   3 108   8  10   4   0  81
      43200.000    4.565      7.213      0.0       0.027     0.024      0.330 67.000000 41.349991  0.0        0.035700  0.035700

0.179 0.205 0.232 0.258 0.284

0.275 0.299 0.323 0.347 0.371
      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.0
      0.0      0.00     0.00     0.00     0.0      0.0      0.0      0.0      0.0      0.0
      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.0      0.0      0.00     0.00     0.00     0.00
      0.0      0.00     0.00     0.00     0.00     0.0      0.00     0.00     0.0      0.0
      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.0      0.0      0.01     0.01     0.00     0.00
      0.0      0.02     0.01     0.00     0.00     0.0      0.00     0.00     0.0      0.0
    15.0    2
 1     0.0       66.774    41.620  1866.227  7029.102     1.012    30.000     1.000
      0.00     0.10     0.00     0.05     0.00     0.08     0.21     0.30

 2     3.000     66.778    41.641  1685.621  7244.434     1.006    30.000     1.000
      0.00     0.10     0.01     0.05     0.00     0.08     0.21     0.30

  5   5   3 115  10  10   5   0  86
      54000.000    4.247      7.109      0.0       0.034     0.024      0.330 67.000000 41.349991  0.0        0.035700  0.035700

0.172 0.204 0.236 0.269 0.301

0.270 0.294 0.318 0.342 0.366
      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.0
      0.0      0.00     0.00     0.00     0.0      0.0      0.0      0.0      0.0      0.0
      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.0      0.0      0.00     0.00     0.00     0.0
      0.0      0.00     0.00     0.00     0.0      0.0      0.0      0.0      0.0      0.0
      0.0      0.0      0.0      0.0      0.0      0.0      0.00     0.00     0.00     0.0      0.0      0.01     0.01     0.00     0.0
      0.0      0.01     0.01     0.00     0.0      0.0      0.0      0.0      0.0      0.0
    18.0    2
 1     0.0       66.762    41.617  2041.777  6713.637     1.012    10.000     1.000
      0.00     0.10     0.00     0.05     0.00     0.08     0.21     0.30

 2     3.000     66.765    41.617  1866.847  6882.160     1.008    10.000     1.000
      0.00     0.10     0.01     0.05     0.00     0.08     0.21     0.30

  5   5   3 121  12  10   6   0  91
```

Figure VIII.-11. Input to Program DATAOUT from Main Program

```
      64800.000      3.743      6.982      0.0       0.046      0.024      0.330 67.000000 41.349991  0.0        0.035700  0.035700
0.159 0.203 0.246 0.290 0.334
0.266 0.290 0.313 0.337 0.361
      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.00    0.00    0.00    0.0     0.0     0.0     0.0     0.0     0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.00    0.0     0.00    0.00    0.00    0.00
      0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.0     0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.00    0.0     0.00    0.00    0.00    0.00
      0.0     0.01    0.00    0.00    0.0     0.0     0.00    0.00    0.0     0.0
    21.0    2
 1      0.0      66.748    41.613  2212.425  6701.297    1.012    30.000     1.000
      0.00    0.10    0.00    0.05    0.00    0.08    0.21    0.30
 2      3.000    66.752    41.634  2082.376  6837.961    1.010    30.000     1.000
      0.00    0.10    0.01    0.05    0.00    0.08    0.21    0.30
   5   5   3 129   14   10   7   0  93
      75600.000      3.448      6.806      0.0       0.052      0.024      0.330 67.000000 41.349991  0.0        0.035700  0.035700
0.151 0.202 0.253 0.303 0.354
0.258 0.283 0.308 0.332 0.357
      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.00    0.00    0.00    0.0     0.0     0.0     0.0     0.0     0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.0     0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.01    0.00    0.00    0.0     0.0     0.00    0.00    0.0     0.0
    24.0    2
 1      0.0      66.734    41.609  2378.807  6689.898    1.012    30.000     1.000
      0.00    0.10    0.00    0.05    0.00    0.08    0.21    0.30
 2      3.000    66.737    41.631  2213.033  6804.285    1.011    30.000     1.000
      0.00    0.10    0.01    0.05    0.00    0.08    0.21    0.30
   5   5   3 135   16   10   8   0  97
      86400.000      3.223      6.720      0.0       0.058      0.024      0.330 67.000000 41.349991  0.0        0.035700  0.035700
0.146 0.202 0.258 0.314 0.370
0.252 0.279 0.306 0.333 0.360
      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.00    0.00    0.00    0.0     0.0     0.0     0.0     0.0     0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.00
      0.0     0.00    0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.00
      0.0     0.01    0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.0
    27.0    2
 1      0.0      66.720    41.606  2541.371  6681.457    1.013    30.000     1.000
      0.00    0.10    0.00    0.05    0.00    0.08    0.21    0.30
 2      3.000    66.722    41.627  2374.377  6780.445    1.011    30.000     1.000
      0.00    0.10    0.00    0.05    0.00    0.08    0.21    0.30
   5   5   3 140   18   10   9   0 101
      97200.000      2.662      6.543      0.0       0.072      0.025      0.330 67.000000 41.349991  0.0        0.035700  0.035700
0.132 0.202 0.271 0.341 0.411
0.248 0.275 0.303 0.330 0.357
      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.00    0.00    0.00    0.0     0.0     0.0     0.00    0.00    0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.00    0.00    0.00    0.0     0.0     0.0     0.00    0.00    0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.01    0.00    0.00    0.0     0.0     0.0     0.0     0.0     0.0
    30.0    2
 1      0.0      66.705    41.602  2700.542  6674.250    1.013    30.000     1.000
      0.00    0.10    0.00    0.05    0.00    0.08    0.21    0.30
 2      3.000    66.707    41.624  2541.933  6762.148    1.012    30.000     1.000
      0.00    0.10    0.00    0.05    0.00    0.08    0.21    0.30
   5   5   3 145   20   10  10   0 104
     108000.000      2.331      6.366      0.0       0.079      0.026      0.330 67.000000 41.349991  0.0        0.035700  0.035700
0.124 0.202 0.279 0.356 0.433
0.246 0.271 0.295 0.320 0.345
      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.00    0.00    0.00    0.0     0.0     0.0     0.00    0.00    0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.00    0.00    0.00    0.0     0.0     0.0     0.00    0.00    0.0
      0.0     0.0     0.0     0.0     0.0     0.0     0.00    0.00    0.00    0.0     0.0     0.00    0.00    0.00    0.0
      0.0     0.01    0.00    0.00    0.0     0.0     0.0     0.0     0.0     0.0
******************************************************* EOF ENCOUNTERED ON UNIT 1
```

Figure VIII.-11. Input to Program DATAOUT from Main Program

```
INPUT PARAMETERS
      -1      NPRT
       2      ISCAL
       1      NBDSP
      10      NBDCN
       0      NNOPT
 0.05000      CCUT
```

```
 JULIAN DATE  HOURS SINCE SPILL  #OF SPILLETS MIN LONG   MAX LONG    MIN LAT     MAX LAT ELEMENTS  ANGLE
     350           0.0                  1      66.8193    66.8190    41.6691     41.6694   13       0.0
     350           3.00000              2      66.8269    66.7921    41.6400     41.6700    8       0.0
     350           6.00000              2      66.8286    66.7903    41.6177     41.6655    8       0.0
     350           9.00000              2      66.8303    66.7884    41.6131     41.6609    9       0.0
     350          12.00000              2      66.8317    66.7771    41.6084     41.6563    9       0.0
     350          15.00000              2      66.8330    66.7648    41.6038     41.6515    9       0.0
     350          18.00000              2      66.8337    66.7426    41.5992     41.6467    9       0.0
     350          21.00000              2      66.8340    66.7291    41.5935     41.6418    9       0.0
     351          24.00000              2      66.8342    66.7188    41.5897     41.6371    9       0.0
     351          27.00000              2      66.8341    66.6911    41.5848     41.6342    9       0.0
     351          30.00000              2      66.8339    66.6759    41.5800     41.6313    9       0.0

******************************************************* EOF ENCOUNTERED ON UNIT 1
```

Figure VIII.-12. Output of Program DATAOUT

```
INPUT PARAMETERS
        1      NUNIT
        1      NPOCH

                  SPILLET PARAMETERS FOR JULIAN DAY  350 WHICH IS        0.0      HOURS FROM THE START OF THE SPILL

                                        SPILLET LOCATIONS AND RADII

     SPILLET #              LONGITUDE             LATITUDE              RADIUS               THICKNESS
         1                   66.81999             41.67000              25.00000              5.80726
 THE GRID SEPARATION IN THE X DIRECTION IS      9.60 METERSAND IN THE Y DIRECTION IS      9.71 METERS
        THERE ARE   13 GRIDS OVER THE MINIMUM CONCENTRATION

     THE DEPTH GRID HAS BEEN ROTATED 0.0     IN THE COUNTER CLOCKWISE DIRECTION
     AND HAS AN ORIGIN AT  67.000 N 41.350 W

     LONGITUDE LATITUDE PARTS/BILLION
      66.8193   41.6691 14209410.00
      66.8191   41.6692 70546560.00
      66.8191   41.6691 16502773.00
      66.8192   41.6691 40119136.00
      66.8192   41.6692 ************
      66.8192   41.6691 48674640.00
      66.8192   41.6694    11112.86
      66.8191   41.6691 18311201.00
      66.8191   41.6692 18895128.00
      66.8191   41.6693  3321670.00
      66.8191   41.6690      137.98
      66.8190   41.6691     4604.81
      66.8190   41.6692     6818.01

  MAXIMUM LONGITUDE         66.81900
  MINIMUM LONGITUDE         66.81934
  MAXIMUM LATITUDE          41.66936
  MINIMUM LATITUDE          41.66910

                  SPILLET PARAMETERS FOR JULIAN DAY  350 WHICH IS        3.00000 HOURS FROM THE START OF THE SPILL

                                        SPILLET LOCATIONS AND RADII

     SPILLET #              LONGITUDE             LATITUDE              RADIUS               THICKNESS
         1                   66.81670             41.66969            1093.98804              0.00201
         2                   66.81999             41.67000              25.00000              5.80726
 THE GRID SEPARATION IN THE X DIRECTION IS   1485.83 METERSAND IN THE Y DIRECTION IS   1666.16 METERS
        THERE ARE    6 GRIDS OVER THE MINIMUM CONCENTRATION

     THE DEPTH GRID HAS BEEN ROTATED 0.0     IN THE COUNTER CLOCKWISE DIRECTION
     AND HAS AN ORIGIN AT  67.000 N 41.150 W

     LONGITUDE LATITUDE PARTS/BILLION
      66.8269   41.6400     1067.11
      66.8269   41.6550     1442.47
      66.8269   41.6700     9151.47
      66.8095   41.6400     2197.70
      66.8095   41.6550     1788.29
      66.8095   41.6700    15469.80
```

Figure VIII.-13. Output of Program CHECDATA

```
  66.7921    41.6400       176.39
  66.7921    41.6550       460.29

MAXIMUM LONGITUDE       66.79207
MINIMUM LONGITUDE       66.82687
MAXIMUM LATITUDE        41.64998
MINIMUM LATITUDE        41.64001


      SPILLET PARAMETERS FOR JULIAN DAY  350 WHICH IS        6.00000 HOURS FROM THE START OF THE SPILL


                            SPILLET LOCATIONS AND RADII

   SPILLET #               LONGITUDE             LATITUDE             RADIUS               THICKNESS
       1                    66.81185             41.63202           1300.71118              0.00138
       2                    66.81868             41.65306           1094.72925              0.00213
 THE GRID SEPARATION IN THE X DIRECTION IS   1589.05 METERSAND IN THE Y DIRECTION IS   2656.45 METERS
       THERE ARE    8 GRIDS OVER THE MINIMUM CONCENTRATION

   THE DEPTH GRID HAS BEEN ROTATED 0.0    IN THE COUNTER CLOCKWISE DIRECTION
   AND HAS AN ORIGIN AT  67.000 N 41.350 W

   LONGITUDE LATITUDE PARTS/BILLION
    66.8286    41.6177       311.59
    66.8286    41.6416      1796.87
    66.8286    41.6655      6491.90
    66.8094    41.6177       764.16
    66.8094    41.6416      3557.80
    66.8094    41.6655      9072.64
    66.7903    41.6416       361.55
    66.7903    41.6655       125.12

MAXIMUM LONGITUDE       66.79031
MINIMUM LONGITUDE       66.82855
MAXIMUM LATITUDE        41.66553
MINIMUM LATITUDE        41.61774


      SPILLET PARAMETERS FOR JULIAN DAY  350 WHICH IS        9.00000 HOURS FROM THE START OF THE SPILL


                            SPILLET LOCATIONS AND RADII

   SPILLET #               LONGITUDE             LATITUDE             RADIUS               THICKNESS
       1                    66.79970             41.62717           1496.97241              0.00108
       2                    66.80272             41.64812           1301.41113              0.00146
 THE GRID SEPARATION IN THE X DIRECTION IS   1740.94 METERSAND IN THE Y DIRECTION IS   2662.18 METERS
       THERE ARE    9 GRIDS OVER THE MINIMUM CONCENTRATION

   THE DEPTH GRID HAS BEEN ROTATED 0.0    IN THE COUNTER CLOCKWISE DIRECTION
   AND HAS AN ORIGIN AT  67.000 N 41.350 W

   LONGITUDE LATITUDE PARTS/BILLION
    66.8303    41.6131       171.76
    66.8303    41.6370      1943.89
    66.8303    41.6609      6729.39
    66.8093    41.6131       716.51
```

```
    66.8093    41.6370      3658.51
    66.8093    41.6609      7702.15
    66.7884    41.6131       175.82
    66.7884    41.6370       676.87
    66.7884    41.6609       205.42

MAXIMUM LONGITUDE       66.78839
MINIMUM LONGITUDE       66.83039
MAXIMUM LATITUDE        41.66095
MINIMUM LATITUDE        41.61307


      SPILLET PARAMETERS FOR JULIAN DAY  350 WHICH IS       12.00000 HOURS FROM THE START OF THE SPILL


                            SPILLET LOCATIONS AND RADII

   SPILLET #               LONGITUDE             LATITUDE             RADIUS               THICKNESS
       1                    66.78700             41.62379           1684.98087              0.00081
       2                    66.79070             41.64479           1497.64111              0.00108
 THE GRID SEPARATION IN THE X DIRECTION IS   2270.50 METERSAND IN THE Y DIRECTION IS   2661.08 METERS
       THERE ARE    9 GRIDS OVER THE MINIMUM CONCENTRATION

   THE DEPTH GRID HAS BEEN ROTATED 0.0    IN THE COUNTER CLOCKWISE DIRECTION
   AND HAS AN ORIGIN AT  67.000 N 41.350 W

   LONGITUDE LATITUDE PARTS/BILLION
    66.8317    41.6084       412.38
    66.8317    41.6323      2081.39
    66.8317    41.6563      6594.70
    66.8044    41.6084       515.87
    66.8044    41.6323      2723.92
    66.8044    41.6563      4609.82
    66.7771    41.6084       118.73
    66.7771    41.6323       675.27
    66.7771    41.6563       289.74

MAXIMUM LONGITUDE       66.77708
MINIMUM LONGITUDE       66.83173
MAXIMUM LATITUDE        41.65627
MINIMUM LATITUDE        41.60841


      SPILLET PARAMETERS FOR JULIAN DAY  350 WHICH IS       15.00000 HOURS FROM THE START OF THE SPILL


                            SPILLET LOCATIONS AND RADII

   SPILLET #               LONGITUDE             LATITUDE             RADIUS               THICKNESS
       1                    66.77811             41.62022           1866.22729              0.00063
       2                    66.77800             41.64072           1685.62105              0.00081
 THE GRID SEPARATION IN THE X DIRECTION IS   2011.44 METERSAND IN THE Y DIRECTION IS   2651.20 METERS
       THERE ARE    9 GRIDS OVER THE MINIMUM CONCENTRATION

   THE DEPTH GRID HAS BEEN ROTATED 0.0    IN THE COUNTER CLOCKWISE DIRECTION
   AND HAS AN ORIGIN AT  67.000 N 41.350 W

   LONGITUDE LATITUDE PARTS/BILLION
```

Figure VIII.-13. Output of Program CHECDATA

```
  66.8310   41.6018      479.29
  66.8310   41.6277     2012.48
  66.8310   41.6515     6021.82
  66.7989   41.6018      475.29
  66.7989   41.6277     2239.31
  66.7989   41.6515     3145.29
  66.7668   41.6018      196.89
  66.7668   41.6277      649.75
  66.7668   41.6515      269.50

MAXIMUM LONGITUDE        66.76683
MINIMUM LONGITUDE        66.83296
MAXIMUM LATITUDE         41.65152
MINIMUM LATITUDE         41.60184


        SPILLET PARAMETERS FOR JULIAN DAY  350 WHICH IS       18.00000 HOURS FROM THE START OF THE SPILL


                          SPILLET LOCATIONS AND RADII

    SPILLET #              LONGITUDE          LATITUDE          RADIUS            THICKNESS
       1                    66.76161          41.61665        2041.77696           0.00051
       2                    66.76530          41.63715        1866.84741           0.00062
 THE GRID SEPARATION IN THE X DIRECTION IS   3787.19 METERSAND IN THE Y DIRECTION IS   2642.64 METERS
        THERE ARE    9 GRIDS OVER THE MINIMUM CONCENTRATION

    THE DEPTH GRID HAS BEEN ROTATED 0.0     IN THE COUNTER CLOCKWISE DIRECTION
    AND HAS AN ORIGIN AT  67.000 W 41.350 N

    LONGITUDE LATITUDE PARTS/BILLION
     66.8137   41.5992      386.60
     66.8137   41.6230     1847.91
     66.8137   41.6467     5052.05
     66.7882   41.5992      383.06
     66.7882   41.6210     1722.21
     66.7882   41.6467     2100.03
     66.7426   41.5992      208.22
     66.7426   41.6210      345.63
     66.7426   41.6467      154.74

MAXIMUM LONGITUDE        66.74260
MINIMUM LONGITUDE        66.83172
MAXIMUM LATITUDE         41.64671
MINIMUM LATITUDE         41.59918


        SPILLET PARAMETERS FOR JULIAN DAY  350 WHICH IS       21.00000 HOURS FROM THE START OF THE SPILL


                          SPILLET LOCATIONS AND RADII

    SPILLET #              LONGITUDE          LATITUDE          RADIUS            THICKNESS
       1                    66.79896          41.61273        2212.42980           0.00041
       2                    66.75171          41.63362        2042.37622           0.00052
 THE GRID SEPARATION IN THE X DIRECTION IS   4357.10 METERSAND IN THE Y DIRECTION IS   2687.18 METERS
        THERE ARE    9 GRIDS OVER THE MINIMUM CONCENTRATION
```

```
    THE DEPTH GRID HAS BEEN ROTATED 0.0     IN THE COUNTER CLOCKWISE DIRECTION
    AND HAS AN ORIGIN AT  67.000 W 41.350 N

    LONGITUDE LATITUDE PARTS/BILLION
     66.8340   41.5935      335.54
     66.8340   41.6177     1699.78
     66.8340   41.6418     8560.07
     66.7815   41.5935      326.60
     66.7815   41.6177     1512.44
     66.7815   41.6418     1811.28
     66.7291   41.5935      247.28
     66.7291   41.6177      369.77
     66.7291   41.6418      248.99

MAXIMUM LONGITUDE        66.72913
MINIMUM LONGITUDE        66.83195
MAXIMUM LATITUDE         41.64183
MINIMUM LATITUDE         41.59349


        SPILLET PARAMETERS FOR JULIAN DAY  351 WHICH IS       24.00000 HOURS FROM THE START OF THE SPILL


                          SPILLET LOCATIONS AND RADII

    SPILLET #              LONGITUDE          LATITUDE          RADIUS            THICKNESS
       1                    66.73395          41.60922        2378.80660           0.00037
       2                    66.73669          41.63060        2211.03296           0.00044
 THE GRID SEPARATION IN THE X DIRECTION IS   4793.41 METERSAND IN THE Y DIRECTION IS   2633.03 METERS
        THERE ARE    9 GRIDS OVER THE MINIMUM CONCENTRATION

    THE DEPTH GRID HAS BEEN ROTATED 0.0     IN THE COUNTER CLOCKWISE DIRECTION
    AND HAS AN ORIGIN AT  67.000 W 41.350 N

    LONGITUDE LATITUDE PARTS/BILLION
     66.8342   41.5897      355.99
     66.8342   41.6134     1700.01
     66.8342   41.6371     4260.80
     66.7765   41.5897      112.06
     66.7765   41.6134     1405.29
     66.7765   41.6371     1759.88
     66.7188   41.5897      200.75
     66.7188   41.6134      417.99
     66.7188   41.6371      173.07

MAXIMUM LONGITUDE        66.71883
MINIMUM LONGITUDE        66.83435
MAXIMUM LATITUDE         41.63705
MINIMUM LATITUDE         41.58971


        SPILLET PARAMETERS FOR JULIAN DAY  351 WHICH IS       27.00000 HOURS FROM THE START OF THE SPILL


                          SPILLET LOCATIONS AND RADII

    SPILLET #              LONGITUDE          LATITUDE          RADIUS            THICKNESS
       1                    66.71962          41.60559        2541.17061           0.00013
```

Figure VIII.-13. Output of Program CHECDATA

```
          2                    66.72198            41.62786           2179.17744               0.00038
 THE GRID SEPARATION IN THE X DIRECTION IS   5906.09 METERSAND IN THE Y DIRECTION IS   2742.33 METERS
        THERE ARE     9 GRIDS OVER THE MINIMUM CONCENTRATION

    THE DEPTH GRID HAS BEEN ROTATED 0.0     IN THE COUNTER CLOCKWISE DIRECTION
    AND HAS AN ORIGIN AT  67.000 W 41.350 N

    LONGITUDE LATITUDE PARTS/BILLION
     66.8341    41.5848       122.67
     66.8341    41.6095      1792.17
     66.8341    41.6342      3109.69
     66.7626    41.5848       276.44
     66.7626    41.6095      1248.40
     66.7626    41.6342      1237.10
     66.6911    41.5848       125.85
     66.6911    41.6095       303.21
     66.6911    41.6342       187.11

 MAXIMUM LONGITUDE        66.69106
 MINIMUM LONGITUDE        66.83411
 MAXIMUM LATITUDE         41.63417
 MINIMUM LATITUDE         41.58480


        SPILLET PARAMETERS FOR JULIAN DAY  151 WHICH IS        10.00000 HOURS FROM THE START OF THE SPILL

                                SPILLET LOCATIONS AND RADII

    SPILLET #             LONGITUDE             LATITUDE            RADIUS              THICKNESS
       1                   66.70529             41.60396          2700.59248             0.00029
       2                   66.70706             41.62931          2541.93111             0.00033
 THE GRID SEPARATION IN THE X DIRECTION IS   6570.73 METERSAND IN THE Y DIRECTION IS   2850.95 METERS
        THERE ARE     9 GRIDS OVER THE MINIMUM CONCENTRATION

    THE DEPTH GRID HAS BEEN ROTATED 0.0     IN THE COUNTER CLOCKWISE DIRECTION
    AND HAS AN ORIGIN AT  67.000 W 41.350 N

    LONGITUDE LATITUDE PARTS/BILLION
     66.8119    41.5800       112.04
     66.8119    41.6056      1861.85
     66.8119    41.6313      2452.70
     66.7549    41.5800       246.30
     66.7549    41.6056      1192.99
     66.7549    41.6313      1098.49
     66.6759    41.5800       102.00
     66.6759    41.6056       187.74
     66.6759    41.6313       167.20

 MAXIMUM LONGITUDE        66.67587
 MINIMUM LONGITUDE        66.81190
 MAXIMUM LATITUDE         41.63127
 MINIMUM LATITUDE         41.57999

 ************************************************** EOF ENCOUNTERED ON UNIT 1
```

Figure VIII.-13. Output of Program CHECDATA

```
                      1      NPLOT
                     10      NSTEP
                3.00000      RR
                0.0          THICK
               10.00000      XLNG
                5.00000      YLTD
                      1      NRD10
                      2      ISCAL
                      0      NSHOW
       SITE     66.820    41.670
        ANGLE IS      0.0
        ANGLE IS      0.0
        ANGLE IS      0.0
        ANGLE IS      0.0
        ANGLE IS      0.0
        ANGLE IS      0.0
        ANGLE IS      0.0
        ANGLE IS      0.0
        ANGLE IS      0.0

       MINIMUM LONGITUDE IS 66.03 MAXIMUM LONGITUDE IS 66.69
       MINIMUM LATITUDE IS  41.50 MAXIMUM LATITUDE IS  41.67
        SCAL FACTORS ARE      0.03383     0.02060     0.03382
       THE ORIGIN OF THIS PLOT IS 66.76 W 41.57 N


THIS RUN STARTED ON DAY 350AND IT IS    0.0 HOURS AFTER THE START OF THE SPILL


******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.820    41.670      35.000  5.807257

 THERE ARE     13  CONCENTRATION VALUES OUT THERE.
   LONGITUDE     LATITUDE PARTS/BILLION
     66.819      41.66914209410.000
     66.819      41.66970566560.000
     66.819      41.66916502771.000
     66.819      41.66940338316.000
     66.819      41.669**************
     66.819      41.66948674640.000
     66.819      41.669    13112.863
     66.819      41.66914333203.000
     66.819      41.66910895328.000
     66.819      41.669 3321670.000
     66.819      41.669      337.985
     66.819      41.669     4604.809
     66.819      41.669     6818.027
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Figure VIII.-14. Output of Program PLOTMAP

```
THIS RUN STARTED ON DAY 350AND IT IS    3.00HOURS AFTER THE START OF THE SPILL

******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.817    41.650   1093.988  0.002031
   66.820    41.670     25.000  5.807257

 THERE ARE      8  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
      66.827     41.640    1067.109
      66.827     41.655    1842.473
      66.827     41.670    9351.469
      66.809     41.640    2197.784
      66.809     41.655    3788.287
      66.809     41.670   15864.805
      66.792     41.640     176.391
      66.792     41.655     460.291
1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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```

```
THIS RUN STARTED ON DAY 350AND IT IS    6.00HOURS AFTER THE START OF THE SPILL

******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.811    41.632   1300.711  0.001382
   66.815    41.653   1094.729  0.002135

 THERE ARE      8  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
      66.829     41.618     311.593
      66.829     41.642    1796.867
      66.829     41.666    6491.902
      66.809     41.618     764.358
      66.809     41.642    3557.799
      66.809     41.666    9072.645
      66.790     41.642     361.554
      66.790     41.666     125.121
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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Figure VIII.-14. Output of Program PLOTMAP

```
THIS RUN STARTED ON DAY 350AND IT IS    9.00HOURS AFTER THE START OF THE SPILL

******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.800    41.627    1496.972  0.001017
   66.803    41.648    1301.411  0.001462

 THERE ARE     9  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
     66.830       41.613     373.764
     66.830       41.637    1943.876
     66.830       41.661    6729.395
     66.809       41.613     736.515
     66.809       41.637    3654.527
     66.809       41.661    7702.152
     66.788       41.613     175.820
     66.788       41.637     676.866
     66.788       41.661     205.420
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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```
THIS RUN STARTED ON DAY 350AND IT IS   12.00HOURS AFTER THE START OF THE SPILL

******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.787    41.624    1684.980  0.000815
   66.791    41.644    1497.641  0.001080

 THERE ARE     9  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
     66.832       41.608     432.339
     66.832       41.632    2081.394
     66.832       41.656    6594.695
     66.804       41.608     515.872
     66.804       41.632    2723.919
     66.804       41.656    4609.824
     66.777       41.608     118.767
     66.777       41.632     675.268
     66.777       41.656     289.794
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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Figure VIII.-14. Output of Program PLOTMAP

```
THIS RUN STARTED ON DAY 350AND IT IS   15.00HOURS AFTER THE START OF THE SPILL


******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.774    41.620    1866.227  0.000635
   66.778    41.641    1685.623  0.000806


 THERE ARE     9  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
     66.833      41.604     429.285
     66.833      41.628    2032.483
     66.833      41.652    6023.820
     66.799      41.604     475.237
     66.799      41.628    2238.312
     66.799      41.652    3145.239
     66.765      41.604     196.476
     66.765      41.628     644.750
     66.765      41.652     268.499
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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```
THIS RUN STARTED ON DAY 350AND IT IS   18.00HOURS AFTER THE START OF THE SPILL


******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.762    41.617    2041.777  0.000507
   66.765    41.637    1866.847  0.000623


 THERE ARE     9  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
     66.834      41.599     386.597
     66.834      41.623    1847.913
     66.834      41.647    5052.055
     66.788      41.599     383.061
     66.788      41.623    1722.232
     66.788      41.647    2100.029
     66.743      41.599     208.224
     66.743      41.623     345.626
     66.743      41.647     154.744
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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```

Figure VIII.-14. Output of Program PLOTMAP

```
THIS RUN STARTED ON DAY 350AND IT IS   21.00HOURS AFTER THE START OF THE SPILL


******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.748    41.613    2212.425  0.000430
   66.752    41.634    2042.376  0.000517


 THERE ARE      9  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
      66.834      41.593      335.544
      66.834      41.618     1699.736
      66.834      41.642     4560.070
      66.782      41.593      326.599
      66.782      41.618     1512.440
      66.782      41.642     1833.283
      66.729      41.593      247.277
      66.729      41.618      369.774
      66.729      41.642      248.993
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

```
THIS RUN STARTED ON DAY 351AND IT IS   24.00HOURS AFTER THE START OF THE SPILL


******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.734    41.609    2378.807  0.000372
   66.737    41.631    2213.033  0.000438


 THERE ARE      9  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
      66.834      41.590      355.991
      66.834      41.613     1704.030
      66.834      41.637     4264.797
      66.776      41.590      312.063
      66.776      41.613     1405.289
      66.776      41.637     1758.882
      66.719      41.590      200.749
      66.719      41.613      417.495
      66.719      41.637      373.074
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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Figure VIII.-14. Output of Program PLOTMAP

```
THIS RUN STARTED ON DAY 351AND IT IS   27.00HOURS AFTER THE START OF THE SPILL

******* CASE    1 *******

  LONGITUDE LATITUDE    RADIUS   THICKNESS
   66.720    41.606    2541.371  0.000125
   66.722    41.627    2379.377  0.000377

 THERE ARE     9  CONCENTRATION VALUES OUT THERE.
   LONGITUDE    LATITUDE PARTS/BILLION
     66.834      41.585     322.667
     66.834      41.610    1792.372
     66.834      41.634    3109.690
     66.763      41.585     276.485
     66.763      41.610    1248.397
     66.763      41.634    1297.100
     66.691      41.585     125.053
     66.691      41.610     301.231
     66.691      41.634     187.109
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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Figure VIII.-14. Output of Program PLOTMAP

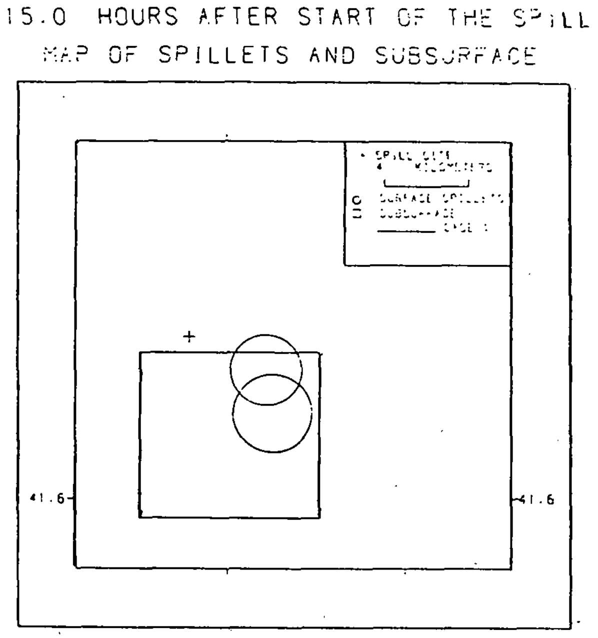

Figure VIII.-15. Plot from PLOTMAP

```
INPUT  PARAMETERS
          1       NAR
          1       NPLOT
  0.0             THICK
         10       NSTEP
```

```
NON PLOTTING CASE

 THERE ARE    13  CONCENTRATION VALUES AND   1 SPILLETS OUT THERE AT TIME           0.0  HOURS
            0.0020 SQUARE KILOMETERS ON SURFACE
            0.0012 SQUARE KILOMETERS IN SUBSURFACE
            0.0032  TOTAL AREA EXTENT


 THERE ARE     8  CONCENTRATION VALUES AND   2 SPILLETS OUT THERE AT TIME           3.00 HOURS
            3.7618 SQUARE KILOMETERS ON SURFACE
           19.2723 SQUARE KILOMETERS IN SUBSURFACE
           23.0341  TOTAL AREA EXTENT


 THERE ARE     8  CONCENTRATION VALUES AND   2 SPILLETS OUT THERE AT TIME           6.00 HOURS
            9.0801 SQUARE KILOMETERS ON SURFACE
           33.7698 SQUARE KILOMETERS IN SUBSURFACE
           42.8499  TOTAL AREA EXTENT


 THERE ARE     9  CONCENTRATION VALUES AND   2 SPILLETS OUT THERE AT TIME           9.00 HOURS
           12.3609 SQUARE KILOMETERS ON SURFACE
           41.7117 SQUARE KILOMETERS IN SUBSURFACE
           54.0726  TOTAL AREA EXTENT


 THERE ARE     9  CONCENTRATION VALUES AND   2 SPILLETS OUT THERE AT TIME          12.00 HOURS
           15.9658 SQUARE KILOMETERS ON SURFACE
           54.3769 SQUARE KILOMETERS IN SUBSURFACE
           70.3427  TOTAL AREA EXTENT


 THERE ARE     9  CONCENTRATION VALUES AND   2 SPILLETS OUT THERE AT TIME          15.00 HOURS
           19.8678 SQUARE KILOMETERS ON SURFACE
           67.5603 SQUARE KILOMETERS IN SUBSURFACE
           87.4281  TOTAL AREA EXTENT


 THERE ARE     9  CONCENTRATION VALUES AND   2 SPILLETS OUT THERE AT TIME          18.00 HOURS
           24.0456 SQUARE KILOMETERS ON SURFACE
           90.0782 SQUARE KILOMETERS IN SUBSURFACE
          114.1238  TOTAL AREA EXTENT


 THERE ARE     9  CONCENTRATION VALUES AND   2 SPILLETS OUT THERE AT TIME          21.00 HOURS
           28.4820 SQUARE KILOMETERS ON SURFACE
          105.3769 SQUARE KILOMETERS IN SUBSURFACE
          133.8589  TOTAL AREA EXTENT


 THERE ARE     9  CONCENTRATION VALUES AND   2 SPILLE S OUT THERE AT TIME          24.00 HOURS
            33.1633 SQUARE KILOMETERS ON SURFACE
           113.5909 SQUARE KILOMETERS IN SUBSURFACE
           146.7542  TOTAL AREA EXTENT


 THERE ARE     9  CONCENTRATION VALUES AND   2 SPILLETS OUT THERE AT TIME          27.00 HOURS
            38.0760 SQUARE KILOMETERS ON SURFACE
           146.7538 SQUARE KILOMETERS IN SUBSURFACE
           184.8298  TOTAL AREA EXTENT
```

Figure VIII.-16. Output of Program PLOTAREA

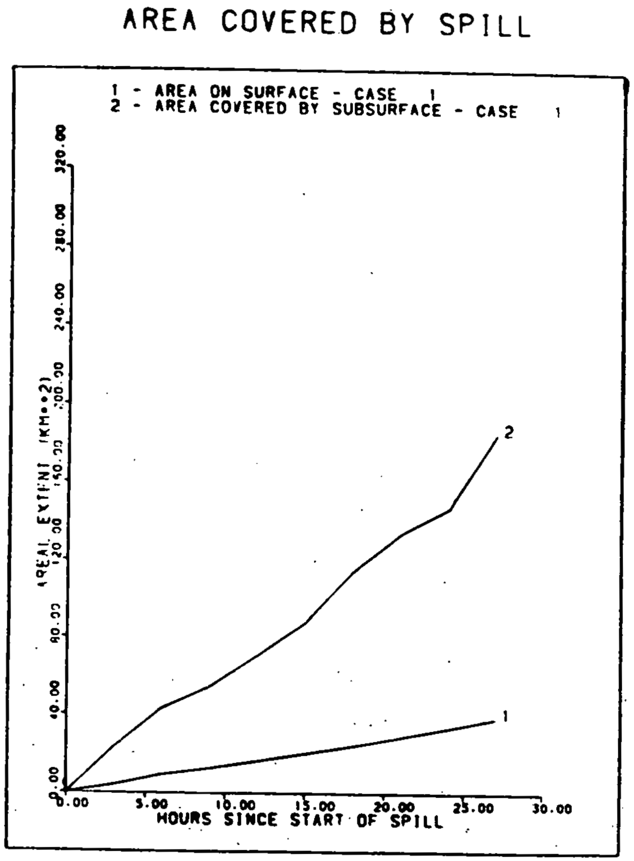

Figure VIII.-17. Plot from PLOTAREA

```
                                                        CONCENTRATIONS AT TIME       0.0  HOURS
                                                 WITH NEW MAX NUMBER OF GRIDS OF  10   10 AND    3 FOR X, Y, AND Z.
      5000      NMAX
         5      NSTEP                                                          FLOATING GRID DEFINITION AND PARTICLE LOCATION STATISTICS
         2      ISCAL
         1      NPTPLT          ORIGIN OF FLOATING GRID IS AT (    0.2163,     0.3548) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
         0      NTRANS          THE NEW GRID SEPERATION IN THE FLOATING SYSTEM IS       0.0000330DEGREES  IN X AND       0.0000249DEGREES  IN Y
        10      IMSUB           THE GRID SEPERATION IN THE FIXED SYSTEM IS       0.016DEGREES  IN X AND     0.016DEGREES  IN Y
        10      JMSUB
         3      KMSUB           THE AVERAGE VALUES OF X, Y AND Z ARE           0.000147          0.000125          0.736425
         1      NPRTC           THE STANDARD DEVIATIONS ARE                0.000046         0.000040         0.163854
         1      NPRTP
         1      NPPD                  CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   0      TIME         0.0   LEVEL
         1      NPRC                     0.35     0.35     0.35     0.35     0.35     0.35     0.35     0.35     0.35     0.35
         1      NPRP              0 22   0 0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   DEGREES      UNITS3            0.22   0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
        10      NUNCU             0 22   0 0      0.0      49.8664766.05672 0.0      0.0      0.0      0.0      0.0      0.0
        11      NUNPT             0.22   0.0      0.0      19.8881826.34531 0.0      31.5691110.65081 0.0      0.0      0.0
IDAY =   350                      0 22   0 0      0.0      0.0      0.0      41.40201********54.01831 0.0      0.0      0.0
                                  0.22   0 0      ******** 0.60175 0.0      50.24649********18.82642 0.0      0.0      0.0
                                  0 22   0 0      40.94527 0.20276 0.0      0.0      0.0      0.0      0.0      0.0      0.0
                                  0.22   0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
                                  0.22   0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
                                  0.22   0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0

                                      CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   0      TIME         0.0   LEVEL
                                         0.35     0.35     0.35     0.35     0.35     0.35     0.35     0.35     0.35     0.35
                                  0.22   0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
                                  0 22   0 0      0.0      1.61188 0.99449 0.20147 1.21705 0.0      3.27494 8.78600 0.0
                                  0.22   0.0      0.0      78.65147******** 3.8071016.12191 0.07510 0.00702 0.01883 0.0
                                  0.22   0 0      0.0      32.3487242.2035735.05057********18.22842 0.0      0.0      0.0
                                  0.22   0.0      42.83209 5.2276410.47947************************ 0.3650312.40440 0.02876
                                  0 22   0.0      ******** 4.61578 7.1773435.75613****************12.3669211.11303 0.04075
                                  0.22   0.0      50.55525 3.71980 8.08884 0.0      6.71057******** 6.77594 0.0      0.0
                                  0 22   0 0      1.05590 7.04627 0.0      0.0      5.95178 0.60400 0.0      0.0      0.0
                                  0 22   0 0      0 0      0.0      10.99161 1.07098 0.0      0.0      0.0      0.0      0.0
                                  0.22   0.0      0.0      0.0      0.02205 0.00215 0.0      0.0      0.0      0.0      0.0

                                      CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   0      TIME         0.0   LEVEL
                                         0 35     0.35     0.35     0.35     0.35     0.35     0.35     0.35     0.35     0.35
                                  0.22   0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
                                  0.22   0 0      0.0      51.5784931.82277 6.4469838.94428 0.0      **************** 0.0
                                  0.22   0.0      0.0      ******************************** 2.40302 0.22465 0.60268 0.0
                                  0 22   0 0      0.0      **************************************** 0.0      0.0      0.0
                                  0.22   0.0      16.61256****************************************11.68052******** 0.92034
                                  0.22   0.0      93.2649811.27748******** 0.0      ****************10.85428******** 1.30382
                                  0.22   0 0      16 61665**************** 0.0      **************** 2.46579 0.0      0.0
                                  0.22   0.0      31.78784******** 0.0      0.0      ********19.32744 0.0      0.0      0.0
                                  0 22   0 0      0.0      0.0      ********34.27025 0.0      0.0      0.0      0.0      0.0
                                  0.22   0.0      0.0      0.0      0.70547 0.06874 0.0      0.0      0.0      0.0      0.0
```

Figure VIII.-18. Output of Program Particle

```
          PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
                    PARTICLE PARAMETERS AT TIME         0.0


                  PARTICLE POSITION                    PARTICLE POSITION                               PARTICLE PARAMETERS
                   FLOATING SYSTEM                        FIXED SYSTEM
  N          X          Y          Z          X          Y          Z        DIAMETER     DENSITY   SET. VEL.         MASS

  1       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
  2       0.0002     0.0002     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
  3       0.0001     0.0001     0.6037     0.216      0.355      0.6017      0.0010      0.8770      0.0              1.001
  4       0.0002     0.0002     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
  5       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
  6       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
  7       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
  8       0.0002     0.0001     0.3022     0.216      0.355      0.3022      0.0010      0.8770      0.0              1.001
  9       0.0003     0.0001     0.8150     0.217      0.355      0.8150      0.0010      0.8770      0.0              1.001
 10       0.0002     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 11       0.0002     0.0000     0.3865     0.216      0.355      0.3465      0.0010      0.8770      0.0              1.001
 12       0.0002     0.0000     0.5872     0.216      0.355      0.5872      0.0010      0.8770      0.0              1.001
 13       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 14       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 15       0.0001     0.0001     0.3554     0.216      0.355      0.3554      0.0010      0.8770      0.0              1.001
 16       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 17       0.0001     0.0001     0.8167     0.216      0.355      0.8167      0.0010      0.8770      0.0              1.001
 18       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 19       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 20       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 21       0.0000     0.0002     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 22       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 23       0.0002     0.0001     0.3938     0.216      0.355      0.3918      0.0010      0.8770      0.0              1.001
 24       0.0002     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 25       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 26       0.0002     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 27       0.0002     0.0001     0.8150     0.217      0.355      0.8150      0.0010      0.8770      0.0              1.001
 28       0.0002     0.0002     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 29       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 30       0.0002     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 31       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 32       0.0002     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 33       0.0002     0.0001     0.8150     0.217      0.355      0.8150      0.0010      0.8770      0.0              1.001
 34       0.0001     0.0001     0.3608     0.216      0.355      0.3608      0.0010      0.8770      0.0              1.001
 35       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 36       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001
 37       0.0002     0.0002     0.5830     0.216      0.355      0.5810      0.0010      0.8770      0.0              1.001
 38       0.0001     0.0001     0.8150     0.216      0.355      0.8150      0.0010      0.8770      0.0              1.001


                      CONCENTRATIONS AT TIME         3.00 HOURS
              WITH NEW MAX NUMBER OF GRIDS OF  10    10 AND     3 FOR X, Y, AND Z.


                            FLOATING GRID DEFINITION AND PARTICLE LOCATION STATISTICS

ORIGIN OF FLOATING GRID IS AT (      0.2013,      0.3193) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
THE NEW GRID SEPERATION IN THE FLOATING SYSTEM IS       0.0049718DEGREES  IN X AND       0.0042812DEGREES  IN Y
THE GRID SEPERATION IN THE FIXED SYSTEM IS       0.036DEGREES  IN X AND      0.016DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE              0.019036             0.030806             0.768247
THE STANDARD DEVIATIONS ARE                  0.003903             0.008971             0.123089


        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   1       TIME          0.0   LEVEL
           0.32     0.33     0.33     0.33     0.34     0.34     0.35     0.35     0.36     0.36
   0.20    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.21    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.21    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.22    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.00510  0.01970  0.0
   0.22    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.00197  0.00716  0.0
   0.23    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.23    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.24    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.24    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.25    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0


        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   1       TIME          0.0   LEVEL
           0.32     0.33     0.33     0.33     0.34     0.34     0.35     0.35     0.36     0.36
   0.20    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.21    0.0      0.00011  0.00036  0.00030  0.00015  0.00027  0.00005  0.0      0.0      0.0
   0.21    0.0      0.00000  0.00000  0.00010  0.00001  0.00012  0.00002  0.0      0.0      0.0
   0.22    0.0      0.00013  0.00015  0.00192  0.00013  0.00025  0.00014  0.01509  0.09814  0.00000
   0.22    0.0      0.00014  0.00078  0.00418  0.00065  0.00015  0.00027  0.00580  0.02435  0.00000
   0.23    0.0      0.0      0.00002  0.00005  0.00028  0.00013  0.0      0.0      0.0      0.0
   0.23    0.0      0.0      0.00009  0.00035  0.0      0.0      0.0      0.0      0.0      0.0
   0.24    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.24    0.0      0.0      0.0      0.00011  0.00035  0.0      0.0      0.0      0.0      0.0
   0.25    0.0      0.0      0.0      0.00000  0.00000  0.0      0.0      0.0      0.0      0.0


        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   1       TIME          0.0   LEVEL
           0.32     0.33     0.33     0.33     0.34     0.34     0.35     0.35     0.36     0.36
   0.20    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.21    0.0      0.00359  0.01136  0.00968  0.00495  0.00868  0.00160  0.0      0.0      0.0
   0.21    0.0      0.00000  0.00000  0.00135  0.00017  0.00196  0.00071  0.0      0.0      0.0
   0.22    0.0      0.00401  0.00895  0.01401  0.00419  0.00814  0.00564  0.07536  0.54635  0.00000
   0.22    0.0      0.01094  0.02130  0.08782  0.02086  0.00479  0.00470  0.02675  0.13173  0.00000
   0.23    0.0      0.0      0.00055  0.00166  0.00904  0.00415  0.0      0.0      0.0      0.0
   0.23    0.0      0.0      0.00301  0.01126  0.0      0.0      0.0      0.0      0.0      0.0
   0.24    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   0.24    0.0      0.0      0.0      0.00163  0.01132  0.0      0.0      0.0      0.0      0.0
   0.25    0.0      0.0      0.0      0.00000  0.00000  0.0      0.0      0.0      0.0      0.0
```

Figure VIII.-18. Output of Program Particle

```
PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
              PARTICLE PARAMETERS AT TIME         3.00

                 PARTICLE POSITION               PARTICLE POSITION                           PARTICLE PARAMETERS
                  FLOATING SYSTEM                  FIXED SYSTEM
  N        X          Y          Z          X          Y          Z       DIAMETER     DENSITY    SET. VEL.

  1      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
  2      0.0188     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
  3      0.0187     0.0355     0.6017     0.220      0.355     0.6017     0.0010      0.8770      0.0             0.998
  4      0 0188     0.0356     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
  5      0.0187     0.0354     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
  6      0.0187     0.0354     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
  7      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
  8      0.0188     0.0355     0.3022     0.220      0.355     0.3022     0.0010      0.8770      0.0             0.998
  9      0.0189     0.0354     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 10      0 0188     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 11      0.0188     0.0354     0.3465     0.220      0.355     0.3465     0.0010      0.8770      0.0             0.998
 12      0 0188     0.0354     0.5872     0.220      0.355     0.5872     0.0010      0.8770      0.0             0.998
 13      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 14      0.0187     0.0354     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 15      0.0187     0.0355     0.3554     0.220      0.355     0.3554     0.0010      0.8770      0.0             0.998
 16      0 0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 17      0.0187     0.0355     0.8167     0.220      0.355     0.8167     0.0010      0.8770      0.0             0.998
 18      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 19      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 20      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 21      0.0186     0.0356     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 22      0 0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 23      0.0188     0.0355     0.3938     0.220      0.355     0.3938     0.0010      0.8770      0.0             0.998
 24      0.0188     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 25      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 26      0 0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 27      0.0188     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 28      0.0188     0.0356     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 29      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 30      0.0188     0.0354     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 31      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 32      0.0189     0.0354     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 33      0.0188     0.0354     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 34      0.0187     0.0354     0.3608     0.220      0.355     0.3608     0.0010      0.8770      0.0             0.998
 35      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 36      0 0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 37      0.0188     0.0355     0.5810     0.220      0.355     0.5810     0.0010      0.8770      0.0             0.998
 38      0.0187     0.0355     0.8150     0.220      0.355     0.8150     0.0010      0.8770      0.0             0.998
 39      0.0178     0.0364     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 40      0.0180     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 41      0.0180     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 42      0 0180     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 43      0.0210     0.0064     0.8150     0.222      0.326     0.8150     0.0010      1.0032      0.0             1.001
 44      0 0266     0.0207     0.8150     0.228      0.340     0.8150     0.0010      1.0032      0.0             1.001
 45      0.0180     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 46      0 0090     0.0242     0.8150     0.210      0.344     0.8150     0.0010      1.0032      0.0             1.001
 47      0.0179     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 48      0.0180     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 49      0.0075     0.0097     0.8150     0.209      0.329     0.8150     0.0010      1.0032      0.0             1.001
 50      0.0164     0.0150     0.8150     0.218      0.334     0.8150     0.0010      1.0032      0.0             1.001

 51      0.0204     0.0277     0.8150     0.222      0.347     0.8150     0.0010      1.0032      0.0             1.001
 52      0.0211     0.0155     0.8150     0.222      0.335     0.8150     0.0010      1.0032      0.0             1.001
 53      0 0226     0.0158     0.8150     0.224      0.335     0.8150     0.0010      1.0032      0.0             1.001
 54      0.0211     0.0156     0.8150     0.222      0.335     0.8150     0.0010      1.0032      0.0             1.001
 55      0.0180     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 56      0.0180     0.0362     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 57      0.0190     0.0226     0.8150     0.220      0.342     0.8150     0.0010      1.0032      0.0             1.001
 58      0.0179     0.0363     0.5717     0.219      0.356     0.5717     0.0010      0.8770      0.0             0.998
 59      0.0423     0.0182     0.8150     0.244      0.318     0.8150     0.0010      1.0032      0.0             1.001
 60      0.0217     0.0151     0.8150     0.223      0.316     0.8150     0.0010      1.0032      0.0             1.001
 61      0 0076     0.0164     0.8150     0.209      0.336     0.8150     0.0010      1.0032      0.0             1.001
 62      0.0179     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 63      0 0199     0.0120     0.8150     0.221      0.331     0.8150     0.0010      1.0032      0.0             1.001
 64      0.0321     0.0141     0.8150     0.233      0.313     0.8150     0.0010      1.0032      0.0             1.001
 65      0.0209     0.0147     0.8150     0.222      0.334     0.8150     0.0010      1.0032      0.0             1.001
 66      0.0226     0.0123     0.8150     0.224      0.332     0.8150     0.0010      1.0032      0.0             1.001
 67      0.0180     0.0362     0.4786     0.219      0.356     0.4786     0.0010      0.8770      0.0             0.998
 68      0.0205     0.0147     0.7633     0.222      0.334     0.7633     0.0010      1.0032      0.0             1.001
 69      0.0219     0.0171     0.8150     0.221      0.316     0.8150     0.0010      1.0032      0.0             1.001
 70      0.0206     0.0124     0.8150     0.222      0.312     0.8150     0.0010      1.0032      0.0             1.001
 71      0.0226     0.0166     0.8150     0.224      0.336     0.8150     0.0010      1.0032      0.0             1.001
 72      0.0179     0.0364     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 73      0.0179     0.0363     0.7679     0.219      0.356     0.7679     0.0010      0.8770      0.0             0.998
 74      0.0180     0.0361     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 75      0 0180     0.0363     0.7887     0.219      0.356     0.7887     0.0010      0.8770      0.0             0.998
 76      0.0179     0.0364     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 77      0.0179     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 78      0.0180     0.0361     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 79      0 0179     0.0363     0.7275     0.219      0.356     0.7275     0.0010      0.8770      0.0             0.998
 80      0.0179     0.0361     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 81      0.0180     0.0363     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 82      0.0180     0.0361     0.8150     0.219      0.356     0.8150     0.0010      0.8770      0.0             0.998
 83      0.0180     0.0361     0.7111     0.219      0.356     0.7111     0.0010      0.8770      0.0             0.998
```

Figure VIII.-18. Output of Particle

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                    CONCENTRATIONS AT TIME       6.00 HOURS
        WITH THE MAX NUMBER OF GRIDS OF  10    10 AND     1 FOR X, Y, AND Z.

                        FLOATING GRID DEFINITION AND PARTICLE LOCATION STATISTICS

ORIGIN OF FLOATING GRID IS AT (      0.1989,      0.2932) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
THE NEW GRID SEPERATION IN THE FLOATING SYSTEM IS        0.00546300DEGREES  IN X AND       0.00682560DEGREES  IN Y
THE GRID SEPERATION IN THE FIXED SYSTEM IS       0.036DEGREES  IN X AND     0.036DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE          0.020816           0.049760           0.766389
THE STANDARD DEVIATIONS ARE              0.008572           0.012019           0.130512

        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   2      TIME         0.0   LEVEL
          0 30    0.30    0.31    0.32    0.32    0.33    0.34    0.34    0.35    0.36
  0.20    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0 21    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.21    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.00000 0.00003 0.0
  0 22    0 0     0.0     0.0     0.0     0.0     0.00136 0.00272 0.00242 0.01544 0.0
  0.22    0.0     0.0     0.0     0.0     0.0     0.00111 0.00226 0.00022 0.00137 0.0
  0 23    0 0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.23    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.24    0 0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.25    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0 25    0 0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   2      TIME         0.0   LEVEL
          0.30    0.30    0.31    0.32    0.32    0.33    0.34    0.34    0.35    0.36
  0 20    0 0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.21    0.0     0.0     0.0     0.00002 0.00026 0.00025 0.00016 0.00003 0.0     0.0
  0 21    0 0     0.0     0.0     0.00000 0.00002 0.00012 0.00008 0.00004 0.00240 0.00000
  0.22    0.0     0.00048 0.00144 0.00029 0.00061 0.00191 0.00079 0.00692 0.06572 0.00000
  0 22    0 0     0.00013 0.00098 0.00033 0.00060 0.00208 0.00068 0.00072 0.00176 0.0
  0.23    0.0     0.0     0.00002 0.00002 0.00001 0.00018 0.00025 0.0     0.0     0.0
  0 23    0 0     0.0     0.0     0.0     0.00005 0.00024 0.00011 0.0     0.0     0.0
  0.24    0.0     0.0     0.0     0.0     0.0     0.00003 0.00005 0.0     0.0     0.0
  0 25    0.0     0.0     0.0     0.0     0.0     0.00014 0.00011 0.0     0.0     0.0
  0.25    0.0     0.0     0.0     0.0     0.0     0.00000 0.00000 0.0     0.0     0.0

        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   2      TIME         0.0   LEVEL
          0.30    0.30    0.31    0.32    0.32    0.33    0.34    0.34    0.35    0.36
  0.20    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.21    0 0     0.0     0.0     0.00055 0.00830 0.00789 0.00504 0.00085 0.0     0.0
  0.21    0.0     0.0     0.0     0.00000 0.00079 0.00178 0.00258 0.00051 0.01571 0.00000
  0 22    0 0     0.00810 0.00703 0.00272 0.01154 0.01659 0.01456 0.01753 0.37189 0.00000
  0.22    0.0     0.00683 0.01051 0.01069 0.01453 0.04728 0.01290 0.00670 0.01865 0.0
  0 23    0 0     0.0     0.00051 0.00059 0.00025 0.00563 0.00797 0.0     0.0     0.0
  0.23    0.0     0.0     0.0     0.0     0.00164 0.00778 0.00358 0.0     0.0     0.0
  0 24    0.0     0.0     0.0     0.0     0.0     0.00092 0.00164 0.0     0.0     0.0
  0.25    0.0     0.0     0.0     0.0     0.0     0.00415 0.00419 0.0     0.0     0.0
  0 25    0 0     0.0     0.0     0.0     0.0     0.00000 0.00000 0.0     0.0     0.0
```

Figure VIII.-18. Output of Particle

```
PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
              PARTICLE PARAMETERS AT TIME         6.00


             PARTICLE POSITION              PARTICLE POSITION                          PARTICLE PARAMETERS
              FLOATING SYSTEM                 FIXED SYSTEM
 N        X         Y         Z          X         Y         Z        DIAMETER    DENSITY   SET. VEL.         MASS


 1     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
 2     0.0196    0.0571    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
 3     0.0194    0.0571    0.6037     0.218     0.350     0.6037     0.0010      0.8770     0.0             0.998
 4     0.0196    0.0572    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
 5     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
 6     0.0195    0.0570    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
 7     0.0196    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
 8     0.0196    0.0571    0.3022     0.219     0.350     0.3022     0.0010      0.8770     0.0             0.998
 9     0.0197    0.0571    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
10     0.0196    0.0571    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
11     0.0194    0.0570    0.3465     0.219     0.350     0.3465     0.0010      0.8770     0.0             0.998
12     0.0196    0.0570    0.5872     0.219     0.350     0.5872     0.0010      0.8770     0.0             0.998
13     0.0194    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
14     0.0196    0.0570    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
15     0.0196    0.0571    0.3554     0.218     0.350     0.3554     0.0010      0.8770     0.0             0.998
16     0.0196    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
17     0.0195    0.0571    0.8167     0.218     0.350     0.8167     0.0010      0.8770     0.0             0.998
18     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
19     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
20     0.0196    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
21     0.0195    0.0572    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
22     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
23     0.0194    0.0571    0.3918     0.219     0.350     0.3918     0.0010      0.8770     0.0             0.998
24     0.0196    0.0571    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
25     0.0196    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
26     0.0196    0.0571    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
27     0.0197    0.0571    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
28     0.0196    0.0572    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
29     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
30     0.0196    0.0571    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
31     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
32     0.0196    0.0571    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
33     0.0197    0.0570    0.8150     0.219     0.350     0.8150     0.0010      0.8770     0.0             0.998
34     0.0195    0.0570    0.3608     0.218     0.350     0.3608     0.0010      0.8770     0.0             0.998
35     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
36     0.0196    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
37     0.0196    0.0571    0.5830     0.219     0.350     0.5830     0.0010      0.8770     0.0             0.998
38     0.0195    0.0571    0.8150     0.218     0.350     0.8150     0.0010      0.8770     0.0             0.998
39     0.0185    0.0580    0.8150     0.217     0.351     0.8150     0.0010      0.8770     0.0             0.998
40     0.0187    0.0580    0.8150     0.218     0.351     0.8150     0.0010      0.8770     0.0             0.998
41     0.0187    0.0579    0.8150     0.218     0.351     0.8150     0.0010      0.8770     0.0             0.998
42     0.0187    0.0579    0.8150     0.218     0.351     0.8150     0.0010      0.8770     0.0             0.998
43     0.0221    0.0277    0.8150     0.221     0.321     0.8150     0.0010      1.0012     0.0             1.001
44     0.0286    0.0422    0.8150     0.227     0.335     0.8150     0.0010      1.0012     0.0             1.001
45     0.0187    0.0579    0.8150     0.218     0.351     0.8150     0.0010      0.8770     0.0             0.998
46     0.0099    0.0451    0.8150     0.209     0.339     0.8150     0.0010      1.0012     0.0             1.001
47     0.0187    0.0580    0.8150     0.218     0.351     0.8150     0.0010      0.8770     0.0             0.998
48     0.0187    0.0580    0.8150     0.218     0.351     0.8150     0.0010      0.8770     0.0             0.998
49     0.0082    0.0101    0.8150     0.207     0.321     0.8150     0.0010      1.0012     0.0             1.001
50     0.0166    0.0162    0.8150     0.216     0.329     0.8150     0.0010      1.0012     0.0             1.001
```

Figure VIII.-18. Output of Particle

```
51    0.0214   0.0490   0.8150   0.220   0.342   0.8150   0.0010   1.0032   0.0        1.001
52    0.0221   0.0168   0.8150   0.221   0.330   0.8150   0.0010   1.0032   0.0        1.001
53    0.0218   0.0172   0.8150   0.221   0.330   0.8150   0.0010   1.0032   0.0        1.001
54    0.0221   0.0169   0.8150   0.221   0.330   0.8150   0.0010   1.0032   0.0        1.001
55    0.0187   0.0580   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
56    0.0187   0.0579   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
57    0.0198   0.0438   0.8150   0.219   0.337   0.8150   0.0010   1.0032   0.0        1.001
58    0.0186   0.0580   0.5737   0.218   0.351   0.5737   0.0010   0.8770   0.0        0.998
59    0.0468   0.0409   0.8150   0.245   0.334   0.8150   0.0010   1.0032   0.0        1.001
60    0.0228   0.0364   0.8150   0.222   0.330   0.8150   0.0010   1.0032   0.0        1.001
61    0.0084   0.0173   0.8150   0.207   0.330   0.8150   0.0010   1.0032   0.0        1.001
62    0.0186   0.0580   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
63    0.0207   0.0332   0.8150   0.220   0.326   0.8150   0.0010   1.0032   0.0        1.001
64    0.0348   0.0360   0.8150   0.234   0.329   0.8150   0.0010   1.0032   0.0        1.001
65    0.0219   0.0360   0.8150   0.221   0.329   0.8150   0.0010   1.0032   0.0        1.001
66    0.0238   0.0336   0.8150   0.223   0.327   0.8150   0.0010   1.0032   0.0        1.001
67    0.0187   0.0579   0.4786   0.218   0.351   0.4786   0.0010   0.8770   0.0        0.998
68    0.0215   0.0359   0.7633   0.220   0.329   0.7633   0.0010   1.0032   0.0        1.001
69    0.0233   0.0388   0.8150   0.222   0.332   0.8150   0.0010   1.0032   0.0        1.001
70    0.0215   0.0337   0.8150   0.220   0.327   0.8150   0.0010   1.0032   0.0        1.001
71    0.0239   0.0380   0.8150   0.221   0.331   0.8150   0.0010   1.0032   0.0        1.001
72    0.0186   0.0580   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
73    0.0186   0.0579   0.7679   0.217   0.351   0.7679   0.0010   0.8770   0.0        0.998
74    0.0187   0.0580   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
75    0.0187   0.0580   0.7887   0.218   0.351   0.7887   0.0010   0.8770   0.0        0.998
76    0.0187   0.0580   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
77    0.0186   0.0580   0.8150   0.217   0.351   0.8150   0.0010   0.8770   0.0        0.998
78    0.0187   0.0579   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
79    0.0186   0.0579   0.7275   0.218   0.351   0.7275   0.0010   0.8770   0.0        0.998
80    0.0186   0.0579   0.8150   0.217   0.351   0.8150   0.0010   0.8770   0.0        0.998
81    0.0187   0.0580   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
82    0 0187   0.0580   0.8150   0.218   0.351   0.8150   0.0010   0.8770   0.0        0.998
83    0.0187   0.0579   0.7111   0.218   0.351   0.7111   0.0010   0.8770   0.0        0.998
84    0.0211   0.0398   0.8150   0.220   0.333   0.8150   0.0010   0.9952   0.0        0.954
85    0.0218   0.0302   0.8150   0.221   0.303   0.8150   0.0010   1.0095   0.0        1.069
86    0.0252   0.0207   0.8150   0.224   0.314   0.8150   0.0010   1.0095   0.0        1.069
87    0.0236   0.0233   0.8150   0.222   0.314   0.8150   0.0010   1.0095   0.0        1.069
88    0.0210   0.0360   0.7399   0.220   0.309   0.7399   0.0010   1.0095   0.0        1.069
89    0.0290   0.0415   0.8150   0.228   0.335   0.8150   0.0010   0.9952   0.0        0.954
90    0.0233   0.0133   0.8150   0.220   0.307   0.8150   0.0010   1.0095   0.0        1.069
91    0.0187   0.0406   0.8150   0.218   0.334   0.8150   0.0010   0.9952   0.0        0.954
92    0.0216   0.0421   0.2011   0.221   0.335   0.2011   0.0010   0.9952   0.0        0.954
93    0.0241   0.0456   0.8150   0.223   0.339   0.8150   0.0010   0.9952   0.0        0.954
94    0.0172   0.0419   0.8150   0.236   0.335   0.8150   0.0010   0.9952   0.0        0.954


                 CONCENTRATIONS AT TIME       9.00 HOURS
         WITH NEW MAX NUMBER OF GRIDS OF  10    10 AND    3 FOR X, Y, AND Z.


                 FLOATING_GRID_DEFINITION_AND_PARTICLE_LOCATION_STATISTICS

ORIGIN OF FLOATING GRID IS AT (      0.1964,      0.2885) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
THE NEW GRID SEPERATION IN THE FLOATING SYSTEM IS        0.0059852DEGREES  IN X AND       0.0068403DEGREES  IN Y
THE GRID SEPERATION IN THE FIXED SYSTEM IS        0.036DEGREES  IN X AND      0.036DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE          0.022198          0.048696          0.755364
THE STANDARD DEVIATIONS ARE                0.006793         0.012580         0.142089


       CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   3      TIME          0.0   LEVEL
        0 29    0.30    0.31    0.31    0.32    0.33    0.33    0.34    0.35    0.35
 0.20   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0 21   0 0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.21   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.00029 0.00194 0.0
 0 22   0 0     0.0     0.0     0.0     0.0     0.00190 0.00321 0.00210 0.01341 0.0
 0.22   0.0     0.0     0.0     0.0     0.0     0.00061 0.00106 0.0     0.0     0.0
 0 23   0 0     0.0     0.0     0.0     0.0     0.00081 0.00180 0.0     0.0     0.0
 0.24   0.0     0.0     0.0     0.0     0.0     0.00115 0.00229 0.0     0.0     0.0
 0 24   0 0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.25   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0 25   0 0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0


       CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   3      TIME          0.0   LEVEL
        0.29    0.30    0.31    0.31    0.32    0.33    0.33    0.34    0.35    0.35
 0.20   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.21   0.0     0.0     0.0     0.00005 0.00023 0.00020 0.00016 0.00001 0.0     0.0
 0 21   0.0     0.0     0.0     0.00000 0.00004 0.00018 0.00012 0.00088 0.01242 0.00000
 0.22   0.0     0.00063 0.00172 0.00025 0.00090 0.00216 0.00085 0.00602 0.05307 0.00000
 0 22   0 0     0.00016 0.00045 0.00032 0.00017 0.00120 0.00063 0.00010 0.0     0.0
 0.23   0.0     0.0     0.0     0.0     0.00001 0.00448 0.00603 0.0     0.0     0.0
 0.24   0 0     0.0     0.0     0.0     0.00003 0.00658 0.00845 0.0     0.0     0.0
 0.24   0.0     0.0     0.00018 0.00005 0.0     0.00002 0.00005 0.0     0.0     0.0
 0 25   0.0     0.0     0.00001 0.00016 0.00008 0.00007 0.00016 0.0     0.0     0.0
 0.25   0.0     0.0     0.0     0.00000 0.00000 0.0     0.0     0.0     0.0     0.0


       CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   3      TIME          0.0   LEVEL
        0.29    0.30    0.31    0.31    0.32    0.33    0.33    0.34    0.35    0.35
 0.20   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.21   0.0     0.0     0.0     0.00146 0.00736 0.00631 0.00504 0.00036 0.0     0.0
 0.21   0.0     0.0     0.0     0.00000 0.00143 0.00571 0.00388 0.00459 0.07501 0.00000
 0.22   0 0     0.01054 0.00903 0.00815 0.02010 0.04422 0.01440 0.01352 0.29690 0.00000
 0.22   0.0     0.00346 0.00716 0.01034 0.00939 0.02959 0.01601 0.00308 0.0     0.0
 0 23   0 0     0.0     0.0     0.0     0.00025 0.00511 0.00607 0.0     0.0     0.0
 0.24   0.0     0.0     0.0     0.0     0.00089 0.00679 0.00419 0.0     0.0     0.0
 0 24   0.0     0.0     0.00568 0.00165 0.0     0.00058 0.00154 0.0     0.0     0.0
 0.25   0.0     0.0     0.00033 0.00527 0.00258 0.00219 0.00517 0.0     0.0     0.0
 0.25   0.0     0.0     0.0     0.00000 0.00000 0.0     0.0     0.0     0.0     0.0
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Figure VIII.-18. Output of Particle

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PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
               PARTICLE PARAMETERS AT TIME        9.00

            PARTICLE POSITION              PARTICLE POSITION                      PARTICLE PARAMETERS
             FLOATING SYSTEM                 FIXED SYSTEM
 N        X          Y          Z          X          Y          Z      DIAMETER   DENSITY  SET. VEL.,      MASS

  1    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
  2    0.0203     0.0573     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
  3    0.0202     0.0572     0.6037     0.217      0.346     0.6037     0.0010     0.8770     0.0         0.998
  4    0.0202     0.0573     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
  5    0.0201     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
  6    0.0201     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
  7    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
  8    0.0202     0.0572     0.3022     0.217      0.346     0.3022     0.0010     0.8770     0.0         0.998
  9    0.0204     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 10    0.0202     0.0573     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 11    0.0203     0.0571     0.3465     0.217      0.346     0.3465     0.0010     0.8770     0.0         0.998
 12    0.0203     0.0571     0.5872     0.217      0.346     0.5872     0.0010     0.8770     0.0         0.998
 13    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 14    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 15    0.0202     0.0572     0.3554     0.217      0.346     0.3554     0.0010     0.8770     0.0         0.998
 16    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 17    0.0202     0.0572     0.8167     0.217      0.346     0.8167     0.0010     0.8770     0.0         0.998
 18    0.0201     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 19    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 20    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 21    0.0201     0.0571     0.8150     0.216      0.346     0.8150     0.0010     0.8770     0.0         0.998
 22    0.0201     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 23    0.0202     0.0572     0.3918     0.217      0.346     0.3918     0.0010     0.8770     0.0         0.998
 24    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 25    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 26    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 27    0.0201     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 28    0.0202     0.0571     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 29    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 30    0.0201     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 31    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 32    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 33    0.0203     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 34    0.0201     0.0572     0.3608     0.217      0.346     0.3608     0.0010     0.8770     0.0         0.998
 35    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 36    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 37    0.0201     0.0573     0.5810     0.217      0.346     0.5810     0.0010     0.8770     0.0         0.998
 38    0.0202     0.0572     0.8150     0.217      0.346     0.8150     0.0010     0.8770     0.0         0.998
 39    0.0190     0.0581     0.8150     0.215      0.347     0.8150     0.0010     0.8770     0.0         0.998
 40    0.0192     0.0581     0.8150     0.216      0.347     0.8150     0.0010     0.8770     0.0         0.998
 41    0.0192     0.0581     0.8150     0.216      0.347     0.8150     0.0010     0.8770     0.0         0.998
 42    0.0192     0.0581     0.8150     0.216      0.347     0.8150     0.0010     0.8770     0.0         0.998
 43    0.0229     0.0276     0.8150     0.219      0.316     0.8150     0.0010     1.0032     0.0         1.001
 44    0.0104     0.0422     0.8150     0.227      0.331     0.8150     0.0010     1.0032     0.0         1.001
 45    0.0192     0.0581     0.8150     0.216      0.347     0.8150     0.0010     0.8770     0.0         0.998
 46    0.0108     0.0449     0.8150     0.207      0.333     0.8150     0.0010     1.0032     0.0         1.001
 47    0.0192     0.0581     0.8150     0.216      0.347     0.8150     0.0010     0.8770     0.0         0.998
 48    0.0191     0.0581     0.8150     0.216      0.347     0.8150     0.0010     0.8770     0.0         0.998
 49    0.0090     0.0295     0.8150     0.205      0.318     0.8150     0.0010     1.0032     0.0         1.001
 50    0.0169     0.0158     0.8150     0.213      0.324     0.8150     0.0010     1.0032     0.0         1.001
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Figure VIII.-18. Output of Particle

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 51     0.0223   0.0490   0.8150   0.219   0.337   0.8150   0.0010   1.0032   0.0    1.001
 52     0.0230   0.0367   0.8150   0.219   0.325   0.8150   0.0010   1.0032   0.0    1.001
 53     0.0250   0.0371   0.8150   0.221   0.326   0.8150   0.0010   1.0032   0.0    1.001
 54     0.0229   0.0367   0.8150   0.219   0.325   0.8150   0.0010   1.0032   0.0    1.001
 55     0.0192   0.0581   0.8150   0.216   0.347   0.8150   0.0010   0.8770   0.0    0.998
 56     0.0192   0.0580   0.8150   0.216   0.347   0.8150   0.0010   0.8770   0.0    0.998
 57     0.0201   0.0416   0.8150   0.217   0.332   0.8150   0.0010   1.0032   0.0    1.001
 58     0.0191   0.0581   0.5737   0.216   0.347   0.5737   0.0010   0.8770   0.0    0.998
 59     0.0507   0.0423   0.8150   0.247   0.311   0.8150   0.0010   1.0032   0.0    1.001
 60     0.0217   0.0363   0.8150   0.220   0.325   0.8150   0.0010   1.0032   0.0    1.001
 61     0.0093   0.0167   0.8150   0.206   0.325   0.8150   0.0010   1.0032   0.0    1.001
 62     0.0191   0.0581   0.8150   0.216   0.347   0.8150   0.0010   0.8770   0.0    0.998
 63     0.0218   0.0111   0.8150   0.218   0.322   0.8150   0.0010   1.0032   0.0    1.001
 64     0.0176   0.0166   0.8150   0.218   0.325   0.8150   0.0010   1.0032   0.0    1.001
 65     0.0227   0.0358   0.8150   0.219   0.328   0.8150   0.0010   1.0032   0.0    1.001
 66     0.0289   0.0336   0.8150   0.221   0.322   0.8150   0.0010   1.0032   0.0    1.001
 67     0.0192   0.0580   0.4786   0.216   0.346   0.4786   0.0010   0.8770   0.0    0.998
 68     0.0222   0.0358   0.7633   0.219   0.324   0.7633   0.0010   1.0032   0.0    1.001
 69     0.0281   0.0383   0.8150   0.221   0.327   0.8150   0.0010   1.0032   0.0    1.001
 70     0.0223   0.0335   0.8150   0.219   0.322   0.8150   0.0010   1.0032   0.0    1.001
 71     0.0250   0.0379   0.8150   0.221   0.326   0.8150   0.0010   1.0032   0.0    1.001
 72     0.0191   0.0581   0.8150   0.215   0.347   0.8150   0.0010   0.8770   0.0    0.998
 73     0.0190   0.0581   0.7679   0.215   0.347   0.7679   0.0010   0.8770   0.0    0.998
 74     0.0192   0.0581   0.8150   0.216   0.347   0.8150   0.0010   0.8770   0.0    0.998
 75     0.0192   0.0581   0.7887   0.216   0.347   0.7887   0.0010   0.8770   0.0    0.998
 76     0.0192   0.0581   0.8150   0.216   0.347   0.8150   0.0010   0.8770   0.0    0.998
 77     0.0191   0.0581   0.8150   0.215   0.347   0.8150   0.0010   0.8770   0.0    0.998
 78     0.0192   0.0581   0.8150   0.216   0.347   0.8150   0.0010   0.8770   0.0    0.998
 79     0.0191   0.0580   0.7275   0.215   0.347   0.7275   0.0010   0.8770   0.0    0.998
 80     0.0191   0.0580   0.8150   0.215   0.347   0.8150   0.0010   0.8770   0.0    0.998
 81     0.0192   0.0581   0.8150   0.216   0.347   0.8150   0.0010   0.8770   0.0    0.998
 82     0.0192   0.0581   0.8150   0.216   0.347   0.8150   0.0010   0.8770   0.0    0.998
 83     0.0192   0.0581   0.7111   0.216   0.347   0.7111   0.0010   0.8770   0.0    0.998
 84     0.0218   0.0396   0.8150   0.218   0.328   0.8150   0.0010   0.9952   0.0    0.958
 85     0.0227   0.0103   0.8150   0.219   0.299   0.8150   0.0010   1.0095   0.0    1.069
 86     0.0266   0.0208   0.8150   0.223   0.309   0.8150   0.0010   1.0095   0.0    1.069
 87     0.0287   0.0211   0.8150   0.221   0.310   0.8150   0.0010   1.0095   0.0    1.069
 88     0.0218   0.0159   0.7399   0.218   0.308   0.7399   0.0010   1.0095   0.0    1.069
 89     0.0109   0.0416   0.8150   0.227   0.330   0.8150   0.0010   0.9952   0.0    0.958
 90     0.0221   0.0133   0.8150   0.219   0.302   0.8150   0.0010   1.0095   0.0    1.069
 91     0.0190   0.0403   0.8150   0.215   0.329   0.8150   0.0010   0.9952   0.0    0.958
 92     0.0228   0.0419   0.2013   0.219   0.310   0.2013   0.0010   0.9952   0.0    0.958
 93     0.0253   0.0455   0.8150   0.222   0.318   0.8150   0.0010   0.9952   0.0    0.958
 94     0.0408   0.0428   0.8150   0.237   0.311   0.8150   0.0010   0.9952   0.0    0.958
 95     0.0230   0.0259   0.8150   0.219   0.318   0.8150   0.0010   1.0105   0.0    0.999
 96     0.0361   0.0427   0.3235   0.233   0.331   0.3235   0.0010   1.0002   0.0    0.981
 97     0.0509   0.0262   0.8150   0.287   0.315   0.8150   0.0010   1.0105   0.0    0.999
 98     0.0452   0.0186   0.8150   0.242   0.307   0.8150   0.0010   1.0105   0.0    0.999
 99     0.0368   0.0433   0.5017   0.233   0.310   0.5017   0.0010   1.0002   0.0    0.981
100     0.0287   0.0455   0.8150   0.223   0.318   0.8150   0.0010   1.0002   0.0    0.981
101     0.0368   0.0413   0.4118   0.233   0.330   0.4118   0.0010   1.0002   0.0    0.981
102     0.0361   0.0413   0.5097   0.232   0.330   0.5097   0.0010   1.0002   0.0    0.981

            CONCENTRATIONS AT TIME      12.00 HOURS
     WITH USE MAX NUMBER OF GRIDS OF  10   10 AND    1 FOR X, Y, AND Z.

                     FLOATING GRID DEFINITION AND PARTICLE LOCATION STATISTICS

ORIGIN OF FLOATING GRID IS AT (     0.1922,      0.2839) IN  DEGREES  WITH RESPECT TO THE ORIGIN OF THE FIXED DEPTH GRID
THE NEW GRID SEPARATION IN THE FLOATING SYSTEM IS      0.0078053DEGREES  IN X AND      0.0068375DEGREES  IN Y
THE GRID SEPARATION IN THE FIXED SYSTEM IS      0.036DEGREES  IN X AND     0.036DEGREES  IN Y

THE AVERAGE VALUES OF X, Y AND Z ARE          0.026867          0.048125          0.753867
THE STANDARD DEVIATIONS ARE                0.010684          0.012585          0.142487

        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   4      TIME        0.0   LEVEL
          0.29     0.29     0.30     0.31     0.31     0.32     0.33     0.34     0.34     0.35
  0.20    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  0.20    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  0.21    0.0      0.0      0.0      0.0      0.0      0.00071  0.00108  0.00108  0.00715  0.0
  0.22    0.0      0.0      0.0      0.0      0.0      0.00136  0.00207  0.00071  0.00467  0.0
  0.23    0.0      0.0      0.0      0.0      0.0      0.00014  0.00102  0.0      0.0      0.0
  0.24    0.0      0.0      0.0      0.0      0.0      0.00089  0.00240  0.0      0.0      0.0
  0.24    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  0.25    0.0      0.0      0.0      0.0      0.0      0.0      0.00028  0.00025  0.0      0.0
  0.26    0.0      0.0      0.0      0.0      0.0      0.0      0.00050  0.00044  0.0      0.0
  0.27    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0

        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   4      TIME        0.0   LEVEL
          0.29     0.29     0.30     0.31     0.31     0.32     0.33     0.34     0.34     0.35
  0.20    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  0.20    0.0      0.0      0.0      0.00006  0.00017  0.00014  0.00010  0.0      0.0      0.0
  0.21    0.0      0.00024  0.00062  0.00006  0.00038  0.00091  0.00037  0.00312  0.03272  0.00000
  0.22    0.0      0.00040  0.00098  0.00016  0.00069  0.00188  0.00070  0.00210  0.01764  0.00000
  0.23    0.0      0.0      0.00002  0.00003  0.00002  0.00211  0.00359  0.00001  0.0      0.0
  0.24    0.0      0.0      0.00000  0.00000  0.00002  0.00533  0.00087  0.0      0.0      0.0
  0.24    0.0      0.0      0.00045  0.00129  0.00002  0.00001  0.00008  0.0      0.0      0.0
  0.25    0.0      0.0      0.00021  0.00088  0.00016  0.00010  0.00102  0.00083  0.0      0.0
  0.26    0.0      0.0      0.0      0.0      0.00001  0.00018  0.00160  0.00151  0.0      0.0
  0.27    0.0      0.0      0.0      0.0      0.0      0.00000  0.00000  0.0      0.0      0.0

        CONCENTRATION IN MG OF OIL PER ML OF WATER      STEP NUMBER   4      TIME        0.0   LEVEL
          0.29     0.29     0.30     0.31     0.31     0.32     0.33     0.34     0.34     0.35
  0.20    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  0.20    0.0      0.0      0.0      0.00192  0.00555  0.00442  0.00437  0.0      0.0      0.0
  0.21    0.0      0.00367  0.00277  0.00200  0.00885  0.01769  0.00750  0.01668  0.18821  0.00000
  0.22    0.0      0.00725  0.00869  0.01154  0.01617  0.04101  0.01425  0.01366  0.09776  0.00000
  0.23    0.0      0.0      0.00075  0.00098  0.00048  0.00839  0.00860  0.00033  0.0      0.0
  0.24    0.0      0.0      0.00001  0.00002  0.00049  0.00710  0.00138  0.0      0.0      0.0
  0.24    0.0      0.0      0.00406  0.00477  0.00067  0.00087  0.00256  0.0      0.0      0.0
  0.25    0.0      0.0      0.00013  0.00132  0.00509  0.00114  0.00435  0.00139  0.0      0.0
  0.26    0.0      0.0      0.0      0.0      0.00088  0.00546  0.00116  0.00171  0.0      0.0
  0.27    0.0      0.0      0.0      0.0      0.0      0.00000  0.00000  0.0      0.0      0.0
```

Figure VIII.-18. Output of Particle

```
PARTICLE POSITIONS X AND Y IN THE FLOATING SYSTEM IN DEGREES  Z IN METERS
              PARTICLE PARAMETERS AT TIME  =   12.00

               PARTICLE POSITION               PARTICLE POSITION                     PARTICLE PARAMETERS
                FLOATING SYSTEM                  FIXED SYSTEM
 #        X          Y          Z          X          Y          Z       DIAMETER    DENSITY   SET. VEL.          MASS

 1     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
 2     0.0227     0.0573     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
 3     0.0226     0.0572     0.6037     0.215      0.341     0.6037     0.0010     0.8770     0.0              0.998
 4     0.0226     0.0573     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
 5     0.0225     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
 6     0.0225     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
 7     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
 8     0.0226     0.0572     0.3022     0.215      0.341     0.3022     0.0010     0.8770     0.0              0.998
 9     0.0228     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
10     0.0226     0.0573     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
11     0.0227     0.0571     0.3865     0.215      0.341     0.3865     0.0010     0.8770     0.0              0.998
12     0.0226     0.0571     0.5872     0.215      0.341     0.5872     0.0010     0.8770     0.0              0.998
13     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
14     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
15     0.0226     0.0572     0.3554     0.215      0.341     0.3554     0.0010     0.8770     0.0              0.998
16     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
17     0.0226     0.0572     0.8167     0.215      0.341     0.8167     0.0010     0.8770     0.0              0.998
18     0.0225     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
19     0.0224     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
20     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
21     0.0225     0.0573     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
22     0.0225     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
23     0.0226     0.0572     0.3938     0.215      0.341     0.3938     0.0010     0.8770     0.0              0.998
24     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
25     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
26     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
27     0.0227     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
28     0.0226     0.0573     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
29     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
30     0.0227     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
31     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
32     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
33     0.0227     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
34     0.0225     0.0572     0.3608     0.215      0.341     0.3608     0.0010     0.8770     0.0              0.998
35     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
36     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
37     0.0227     0.0573     0.5830     0.215      0.341     0.5830     0.0010     0.8770     0.0              0.998
38     0.0226     0.0572     0.8150     0.215      0.341     0.8150     0.0010     0.8770     0.0              0.998
39     0.0215     0.0581     0.8150     0.214      0.342     0.8150     0.0010     0.8770     0.0              0.998
40     0.0217     0.0581     0.8150     0.214      0.342     0.8150     0.0010     0.8770     0.0              0.998
41     0.0217     0.0581     0.8150     0.214      0.342     0.8150     0.0010     0.8770     0.0              0.998
42     0.0217     0.0581     0.8150     0.214      0.342     0.8150     0.0010     0.8770     0.0              0.998
43     0.0252     0.0278     0.8150     0.217      0.311     0.8150     0.0010     1.0032     0.0              1.001
44     0.0119     0.0428     0.8150     0.226      0.326     0.8150     0.0010     1.0032     0.0              1.001
45     0.0217     0.0581     0.8150     0.214      0.342     0.8150     0.0010     0.8770     0.0              0.998
46     0.0117     0.0481     0.8150     0.206      0.328     0.8150     0.0010     1.0032     0.0              1.001
47     0.0217     0.0581     0.8150     0.214      0.342     0.8150     0.0010     0.8770     0.0              0.998
48     0.0217     0.0581     0.8150     0.214      0.342     0.8150     0.0010     0.8770     0.0              0.998
49     0.0117     0.0286     0.8150     0.204      0.312     0.8150     0.0010     1.0032     0.0              1.001
50     0.0193     0.0154     0.8150     0.212      0.319     0.8150     0.0010     1.0032     0.0              1.001
```

Figure VIII.-18. Output of Particle

```
 51    0.0285  0.0089  0.8150  0.217  0.333  0.8150  0.0010  1.0032  0.0    1.001
 52    0.0252  0.0165  0.8150  0.217  0.320  0.8150  0.0010  1.0032  0.0    1.001
 53    0.0275  0.0170  0.8150  0.220  0.321  0.8150  0.0010  1.0032  0.0    1.001
 54    0.0252  0.0166  0.8150  0.217  0.320  0.8150  0.0010  1.0032  0.0    1.001
 55    0.0217  0.0581  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 56    0.0217  0.0580  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 57    0.0226  0.0438  0.8150  0.235  0.327  0.8150  0.0010  1.0032  0.0    1.001
 58    0.0216  0.0581  0.5737  0.218  0.342  0.5737  0.0010  0.8770  0.0    0.998
 59    0.0569  0.0436  0.8150  0.249  0.327  0.8150  0.0010  1.0032  0.0    1.001
 60    0.0261  0.0161  0.8150  0.218  0.320  0.8150  0.0010  1.0032  0.0    1.001
 61    0.0121  0.0159  0.8150  0.208  0.320  0.8150  0.0010  1.0032  0.0    1.001
 62    0.0216  0.0581  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 63    0.0235  0.0128  0.8150  0.216  0.317  0.8150  0.0010  1.0032  0.0    1.001
 64    0.0821  0.0172  0.8150  0.238  0.321  0.8150  0.0010  1.0032  0.0    1.001
 65    0.0249  0.0157  0.8150  0.217  0.320  0.8150  0.0010  1.0032  0.0    1.001
 66    0.0275  0.0335  0.8150  0.220  0.317  0.8150  0.0010  1.0032  0.0    1.001
 67    0.0217  0.0580  0.8786  0.218  0.342  0.8786  0.0010  0.8770  0.0    0.998
 68    0.0283  0.0156  0.7633  0.217  0.318  0.7633  0.0010  1.0032  0.0    1.001
 69    0.0266  0.0182  0.8150  0.219  0.322  0.8150  0.0010  1.0032  0.0    1.001
 70    0.0288  0.0133  0.8150  0.217  0.317  0.8150  0.0010  1.0032  0.0    1.001
 71    0.0276  0.0178  0.8150  0.220  0.322  0.8150  0.0010  1.0032  0.0    1.001
 72    0.0216  0.0581  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 73    0.0215  0.0580  0.7679  0.218  0.342  0.7679  0.0010  0.8770  0.0    0.998
 74    0.0217  0.0581  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 75    0.0217  0.0581  0.7887  0.218  0.342  0.7887  0.0010  0.8770  0.0    0.998
 76    0.0216  0.0581  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 77    0.0216  0.0581  0.8150  0.214  0.342  0.8150  0.0010  0.8770  0.0    0.998
 78    0.0217  0.0581  0.8150  0.214  0.342  0.8150  0.0010  0.8770  0.0    0.998
 79    0.0216  0.0580  0.7275  0.218  0.342  0.7275  0.0010  0.8770  0.0    0.998
 80    0.0215  0.0580  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 81    0.0217  0.0581  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 82    0.0217  0.0581  0.8150  0.218  0.342  0.8150  0.0010  0.8770  0.0    0.998
 83    0.0217  0.0580  0.7111  0.218  0.342  0.7111  0.0010  0.8770  0.0    0.998
 84    0.0280  0.0198  0.8150  0.216  0.323  0.8150  0.0010  0.9952  0.0    0.958
 85    0.0250  0.0103  0.8150  0.217  0.298  0.8150  0.0010  1.0095  0.0    1.069
 86    0.0298  0.0209  0.8150  0.222  0.305  0.8150  0.0010  1.0095  0.0    1.069
 87    0.0272  0.0210  0.8150  0.219  0.305  0.8150  0.0010  1.0095  0.0    1.069
 88    0.0280  0.0158  0.7399  0.216  0.300  0.7399  0.0010  1.0095  0.0    1.069
 89    0.0188  0.0818  0.8150  0.227  0.326  0.8150  0.0010  0.9952  0.0    0.958
 90    0.0288  0.0132  0.8150  0.217  0.297  0.8150  0.0010  1.0095  0.0    1.069
 91    0.0213  0.0800  0.8150  0.218  0.328  0.8150  0.0010  0.9952  0.0    0.958
 92    0.0286  0.0817  0.2013  0.217  0.326  0.2013  0.0010  0.9952  0.0    0.958
 93    0.0280  0.0858  0.8150  0.220  0.329  0.8150  0.0010  0.9952  0.0    0.958
 94    0.0858  0.0833  0.8150  0.238  0.327  0.8150  0.0010  0.9952  0.0    0.958
 95    0.0253  0.0257  0.8150  0.218  0.310  0.8150  0.0010  1.0105  0.0    0.999
 96    0.0808  0.0831  0.3235  0.233  0.327  0.3235  0.0010  1.0002  0.0    0.981
 97    0.0569  0.0277  0.8150  0.249  0.312  0.8150  0.0010  1.0105  0.0    0.999
 98    0.0507  0.0198  0.8150  0.243  0.308  0.8150  0.0010  1.0105  0.0    0.999
 99    0.0812  0.0817  0.5017  0.233  0.326  0.5017  0.0010  1.0002  0.0    0.981
100    0.0296  0.0855  0.8150  0.222  0.329  0.8150  0.0010  1.0002  0.0    0.981
101    0.0811  0.0817  0.8118  0.231  0.326  0.8118  0.0010  1.0002  0.0    0.981
102    0.0803  0.0817  0.5097  0.233  0.326  0.5097  0.0010  1.0002  0.0    0.981
103    0.0663  0.0181  0.8150  0.259  0.322  0.8150  0.0010  1.0018  0.0    0.993
104    0.0682  0.0508  0.8150  0.256  0.318  0.8150  0.0010  1.0018  0.0    0.993
105    0.0538  0.0228  0.6953  0.246  0.306  0.6953  0.0010  1.0112  0.0    1.048
106    0.0598  0.0183  0.8150  0.252  0.318  0.8150  0.0010  1.0112  0.0    1.048
107    0.0378  0.0170  0.8150  0.230  0.321  0.8150  0.0010  1.0018  0.0    0.993
108    0.0635  0.0877  0.8151  0.256  0.332  0.8151  0.0010  1.0018  0.0    0.993
```

Figure VIII.-18. Output of Particle

APPENDIX IX, OIL PROPERTIES

Estimated Percent Weight

Fraction	Description	Venezuelan Crude 1	Nigerian Crude 1	#2 Fuel 1	Bunker C 1	Kuwait Crude 2
1	Paraffin C_6-C_{12}	10	15	10	0	5
2	Paraffin	8	15	25	1	10
3	Cycloparaffin C_6-C_{12}	15	20	15	0	11
4	Cycloparaffin C_{13}-C_{23}	20	20	15	1	5
5	Aromatic Mono- and Di-Cyclic C_6-C_{11}	5	5	15	0	10
6	Aromatic Polycyclic C_{12}-C_{18}	2	3	5	1	08
7	Naphtheno-Aromatic C_9-C_{25}	15	7	15	1	21
8	Residual	25	15	0	96	30
	Specific Gravity	.8769	.8446	.8472	1.019	0.867

References for Oil Properties

1. Wang et al. (1976)
2. Persen (1979), approximated composition from this data.

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12.4 Section 6 Appendices

12.4.1 Appendix A Advective Currents for Computer Model
12.4.2 Appendix B Oil Spill Fisheries Computer Program

APPENDIX A

A theoretical relationship between the variance s^2 in one dimension of a diffusing cloud and the diffusivity D is

$$s = 2*D*t, \tag{1}$$

(Csanady, 1973) in which t is time. Let us assume a characteristic diffusion velocity for the cloud as a whole at the j^{th} timestep, u'_j. Then in a discrete particle and time model with timestep dt, the position of the k^{th} particle at the j^{th} timestep, r_{jk}, will be the sum of all previous displacements. Incorporating the intrinsically stochastic nature of turbulence through the use of a random variate, R_{jk}, chosen from the uniform probability distribution [-1,1], we have, for no bulk transport velocities,

$$r_{jk} = \sum_{\ell=1}^{k} R_{lk} * u'_{\ell} *dt. \tag{2}$$

Equating (1) with the statistical definition of the variance, and performing a translation of coordinates so that the origin coincides with the center of mass of the diffusing cloud composed of N particles gives

$$2*j*dt*D = (1/N) * \sum_{k=1}^{N} \left(\sum_{\ell=1}^{j} R_{\ell k} * u'_{\ell} * dt\right)^2 \tag{3}$$

Replacing u' with its expected value for the given problem, $E(u')^{\ell}$, and noting that

$$\left(\sum_{\ell=1}^{j} R_{\ell k}\right)^2 = \sum_{\ell=1}^{j} R_{\ell k}^2 + 2*\sum_{\substack{i=1 \\ (i\neq\ell)}}^{j} \sum_{\ell=1}^{j} R_{ik} * R_{\ell k} \tag{4}$$

in which the double sum on the right tends to zero for large j, and further that

$$\sum_{k=1}^{N} \sum_{\ell=1}^{j} R_{\ell k}^2 = N*j/3, \tag{5}$$

the probability density function being equal to 1/2 on the given interval, we have

$$E(u') = \sqrt{6*D/dt} \tag{6}$$

The value of D is then chosen from an oceanic diffusion diagram (Okubo, 1974, for example), the radius of the spawning area being used as the characteristic length. By superposition, the net transport of the k^{th} particle during the j^{th} timestep, dr_{dk}, is

$$dr_{jk} = (R_{jk} *E(u') + U_{jk})*dt, \tag{7}$$

in which U_{jk} is the net advective velocity contribution.

Section 12.4 Appendix 6B

CONTENTS

I. Program Purpose and Overview

This computer program was constructed as part of a larger effort at the University of Rhode Island to investigate environmental effects of oil spill treatment strategies. The specific problem addressed here is when and whether chemical oil spill treatment with dispersants might mitigate the impacts of an offshore commercial fishery. The primary effect is assumed to occur through egg and larval mortality. This implicitly assumes that both demersal juveniles and adults will avoid contaminated areas, that the feeding and spawning cycles will not be grossly interrupted, and that the stock will not suffer through subsequent bioaccumulation. The major program components are, therefore, a population model for a unit stock fishery, an ocean transport model, and a set of subroutines designed to interface these with output from the oil spill fates model also designed as part of this project. The program has been carefully and fully described internally through comment statements. After reading this manual, any actual applications of the program to an area and/or fishery other than the Georges Bank cod stock will require a working knowledge of the program itself, a listing of which is included here as Appendix I. It is advised that no internal program changes be made until one has read through and understands the program in its entirety, since changes in one section will have second and third order manifestations elsewhere.

The following description is designed to assist in the implementation of the program for new species and physical areas. For explicit sources of information regarding parameters used in the given data sets, the user is referred to the following publications:

Reed, M., Development and Application of a Fishery Population Dynamics Model for Environmental Impact Assessment, unpub. Ph.D. Thesis, Fall, 1979.

Reed, M., and M.L. Spaulding, "An Oilspill-Fishery Interaction Model," Part X in Environmental Assessment of Treated Versus Untreated Oil Spills: Second Interim Progress Report, U.S. Dept. of Energy Contract No. E(11-1) 4047, 1978.

Reed, M., and M.L. Spaulding, "An Oilspill-Fishery Interaction Model: Comparison of Treated and Untreated Spill Impacts," Proceedings of 1979 Oilspill Conference, pp. 63-73, March, 1979.

Reed, M., M.L. Spaulding and P. Cornillon, "A Fishery-Oilspill Interaction Model: Estimated Consequences of Oil Well Blowouts," Proceedings of the NATO Symposium on Operations Research in Fisheries, Trondheim, Norway, August 1979 (in press).

Cornillon, P., M.L. Spaulding and M. Reed, "Impact Assessment in Oil Spill Modeling," paper presented at the Workshop on the Physical Behavior of Oil in the Marine Environment, Princeton, May, 1979.

II. Program Component Explanation

1) Main

The main program contains the daily cycle elements for the population model. This is the master program from which all subroutines are called, and through which all program activities are coordinated. The program is initialized, all control variables are read in, and then the annual and daily cycles are entered. Operations continue until the specified end time is reached.

2) Subroutine COMPAR

This subroutine was designed to attempt to sort out reduction rates in numbers of larvae per unit volume due to mortality versus diffusion and transport. The day of the year for this comparison is specified as input variable IDATE. The comparison is performed in the elements read into array INTELM from data set 9.

3) Subroutine BYPASS

Program run time can be reduced by increasing variable DT2 up to 5 days. This subroutine uses this secondary timestep subsequent to the spill year in both analytical and numerical time integrations, and bypasses the daily cycle in the main program.

4) Subroutine MOROIL

If MULTI is greater than 1, and KYEAR is greated than SPILYR, this subroutine is called to assign a new spill year and oil source data set.

5) Subroutine WEIGHT

Here the statistical data for the stock at hand is used to calculate weight-at-age data. Weight is called only once from Main.

6) Subroutine AVGFEC

The average number of eggs per female is calculated here, as a check against both weight and fecundity assumptions. Output is annual.

7) Subroutine SPNTIM

The spawning distribution in time is specified here. This is the result of relatively subjective evaluations to date, since no statistical data is available.

8) Subroutine DEVELOP

This subroutine controls development of eggs and larvae according to whatever information is available.

9) Subroutine TEMP

At present a constant seasonal surface water temperature is supplied. This input can be altered in response to improved data availability.

10) Subroutine TOXIC

This subroutine interfaces the hydrocarbon concentration data, input either through SR HCCONC or HCCON2, with population model. First natural mortality effects are accounted for, followed by a check to see which, if any, organisms are within an area in which concentrations exceed that specified by THRSLD. This routine is called from MAIN directly after the input of the oil concentration data.

11) Subroutine HCCONC

For SPLTYP = 1 (an instantaneous spill), this subroutine reads in data output by the oil spill behavior model on a daily basis. Conversion from latitude and longitude to the distance units of the fish model is followed by output to data set 4 of the oil, egg, and larvae distributions at that time.

12 Subroutine OUTPUT

Here annual output is directed to the printer, and oil spill case identification data with the annual yield estimates are output to data set 8.

13 Subroutine EGGMRT

Natural mortality of both density dependent and density independent varieties is applied to the egg stages. The toxicity sections originally programmed here and in SR PLNMRT are not used.

14) Subroutine PLNMRT

Here background mortalities are applied to the three planktonic stages in the model. As with SR EGGMRT, the toxicity section is not used.

15) Subroutine BTMMRT

Here a second order Taylor expansion supplies means for a numerical solution of the juvenile mortalities, including cannibalism by adults.

16) Subroutine HATCH

This is actually only a function, which returns the number of days to hatch, given an input temperature. The call is from SR DEVELP.

17) Subroutine SPNPLC

Here eggs to be spawned on a particular day are divided into groups, and placed at random within the spawning area. On first entry, the center and radius of the spawning area are read in from data set 9. Then for each particle, or group, a call is made to SR RANDU, which returns a random variate used to locate the particle's initial positon.

18) Subroutine HCCON2

When SPLTYP = 2 (i.e., a blowout), this SR reads in the concentration data output by the oil model (data set 3). These are then written out to data set 4 along with the current egg and larval fish distributions.

19 Subroutine DSCWRT

The first time this subroutine is called, 12 days are read into array IDAYZ from data set 16. On subsequent calls, the present modeled day is compared with the members of KDAYZ. If a match is found, the day's ichthyoplankton distribution is output to disc. Otherwise, control is returned to SR ADVDIF.

20) Subroutine ADVDIF

This subroutine, which is called from MAIN, controls the advective - dispersive section of the model. Upon first entry, the physical sector of the model is initialized through subroutines FEREAD, VAREAD, VARSET, and CHECK. Calls are then made to subroutines MOVE, DEAD, COMPRS, and DSCNRT. After the first entry, only this latter group is activated.

21) Subroutine MOVE

Advection and diffusion of particles is accomplished here. First subroutine VELIN is called, to supply the advective currents for the day in question. If the logical variable DOSPWN has a value of true, SR SPNPLC is called. Then each particle is located within an element (grid) of the physical model, and planar interpolation among the three defining modes is applied to determine an advective contribution at the given particle location. A random walk diffusion velocity calculation follows, the result being superimposed on the advective velocity and multiplied by the model timestep to produce a physical displacement of the particle.

22) Subroutine INIT

This is a convenience subroutine, where in any arrays and variables can be initialized. In general, everything is set to zero to avoid undefined variables.

23) Subroutine FEREAD

Called once from subroutine ADVDIF, the program section reads element, node, and diffusive control parameters from data set 10. Then actual node numbers and locations (in latitude and longitude) are read in and converted. Thus, the physical reference grid is established.

24) Subroutine VELIN

Here the velocity data is read into the model from data sets 13 (long term net drifts) and 14 (wind-wave currents). The output values are the sum of these two.

25) Subroutine VAREAD

The initial particle data and random variate seed, along with output write and plot time steps are read in from data set 10. Thus, an initial particle distribution can be stipulated if desired. In addition, if a uniform drift velocity is to be applied over the entire physical field, that is input here from data set 10.

26) Subroutine DEAD

Mortality due to transport out of a favorable developmental area can be included here by setting variable IOFF = 1. Due to lack of any verification data for this process, this subroutine has not been used to date.

27) Subroutine COMPRS

In an effort to keep storage requirements to a minimum this subprogram was designed to compress arrays as particles are removed from the system. Particle attrition occurs as the result of the growth of larvae to juveniles, hydrocarbon mortality, or whenever particles are transported out of the physical domain of the model.

28) Subroutine CHECK

After input of the node and element data through SR FEREAD, this subroutine checks to confirm that the nodes associates with a given element are ordered counterclockwise. This is necessary so that, when associating a given particle with a given element, SR MOVE can simply proceed around the element counterclockwise and check to see that the particle is always to the left of the line between successive nodes.

29) Subroutine VARSET

The slope and direction of the lines connecting successive nodes are calculated here, along with adjacent elements. Storage of this information greatly decreases subsequent search time when attempting to locate particles in elements.

30) Subroutine SLPDIR

This does the actual mathematics for SR VARSET, which is primarily logical in nature.

31) Subroutine WRTOUT

This generates printed output at the desired intervals, and calls SR STATS.

32) Subroutine STATS

Here particle statistics (e.g. centroid and variance of the present distribution) are calculated. Although not employed for the full scale fishery runs, this subroutine is useful for verifying the physical system definitions, initial conditions for particle placement, and for comparing theoretical with modeled diffusion rates. Changes can be made freely in this subroutine, so long as no common arrays and variables are revalued.

III. Basic User Instructions

There are 21 primary options built into the program. The user can, therefore, run the program in a variety of modes without altering any internal code. The options are read in by the main program from data set 9. In this data set (see end of program listing in Appendix I) the variables are explicitly labeled so that no confusion will exist. A self-explanatory list of input control variables follows.

```
1150 C*********************************************************************
1160 C
1170 C LIST AND EXPLANATION OF INPUT CONTROL VARIABLES
1180 C
1190 C*********************************************************************
1200 C OILCOD = 1 THEN OIL IS TRUE
1210 C        = 0 THEN OIL IS FALSE AND NO ADVECTION IS PERFORMED EVER
1220 C IOFF   = 1 THEN DELETE EGGS AND LARVAE BLOWN OFF THE BANK (SEE SR DEAD
1230 C        = 0 THEN DON'T
1240 C YEARLY = THE FIRST YEAR USING THE LARGER TIMESTEP (DT2)
1250 C            (IF SPILDA=350 OR 90 AND MULTI > 1, YEARLY IS C ALCULATED
1260 C                                                  INTERNALLY.)
1270 C IRWND  = 1 THEN REWIND DATASET 3 AFTER EACH SPILL AND REREAD
1280 C        = 0 THEN READ FT03F002 THE SECOND SPILL, ETC.
1290 C INTPOP = 1 THEN READ THE INITIAL POPULATION FOR YEAR ISTART FROM
1300 C                              DATASET 15
1310 C        = 0 THE READ IT FROM FT09F001 (CARDS)
1320 C OUTPOP = 1 THEN WRITE THE POPULATION OUT TO 15 FOR LASTYR
1330 C        = 0 THEN DON'T
1340 C FRSTYR = THE FIRST YEAR OF RECORDED OUTPUT
1350 C LASTYR = THE LAST ONE
1360 C ISTART = THE STARTUP YEAR
1370 C MULTI  = 1 THEN THERE'S ONLY ONE SPILL
1380 C        = GT 1, THEN THAT'S THE NUMBER OF SPILLS THERE WILL BE
1390 C OILSTP = THE NUMBER (INTEGER) OF YEARS BETWEEN SPILLS
1400 C SPILYR = THE YEAR OF THE SPILL
1410 C          (OR PERHAPS SPILYR + 1 IF IADV=1 AND SPILDA IS IN AUTUMN)
1420 C SPILDA = THE JULIAN DAY OF THE SPILL
1430 C MRTDAY = JULIAN DAY FROM WHICH TO FOLLOW EGG AND LARVAL MORTALITY
1440 C MRTYR  = THE YEAR FOR SAME....RESULTS OUTPUT TO DATASET 17
1450 C IDALST = THE LAST DAY OF ADVECTION WHEN IADV = 1
1460 C IADV   = 1 THEN WE ADVECT WITHOUT OIL (SET OILCOD = 1)
1470 C        = 0 THEN NO EFFECT
1480 C SPLTYP = 1 THEN THE PROGRAM USES SR HCCONC, AND ONLY C HECKS THE
1490 C            EXTREMES OF THE SUBSURFACE DISTRIBUTION
1500 C        = 2 THEN USES HCCON2, AND C HECK C ELL BY C ELL....THIS IS THE
1510 C            INPUT VALUE FOR THE BLOWOUT SIMULATION, SINCE THE PATTERN
1520 C            IS NOT EXPECTED TO BE SO NICELY REGULAR....
1530 C THRSLD = THE THRESHOLD TOXICITY VALUE AT WHICH EGGS AND LARVAE ARE
1540 C            ASSUMED TO BE KILLED (IN PARTS PER BILLION)
1550C
 560 C ICROP  = 1 THEN ARTIFICIAL C ROPPING AT SPILYRS (INTERVAL OILSTP)
1570 C          WILL OCCUR; SET OILCOD TO 0 AND MULTI GT 1
1580 C CROPRT = THE REDUCTION RATE FOR RECRUITS WHEN ICROP=1 AND KYEAR=SPILY
```

It should be noted that every combination of control variable values will require a different amount of CPU time. The program as listed (and punched on cards) is set up to be run under WAT 5, to permit facile location of user errors. When a particular model run is seen to be operating correctly, future runs (with different threshold values, for example) can be made more rapidly by switching to the "G" or "H" compiler, or by creating a compiled load module. This latter option will also decrease core requirements from 512K to 320K, an important consideration in computer turn around time.

The data sets as included with the punched output, will simulate the population response to an oilwell blowout occurring at 66.75° W Long., 41.6° N Lat. on December 15th (Julian Day 350). The spill year is 1979, and the run will end in 2020. The secondary (rapid integration) timestep is set at 5, its maximum acceptable value. Fishing effort oscillates randomly about 25 thousand standard days per year. For verification purposes, the output of the card deck is available with the cards (2 boxes). This run should take approximately 35 minutes of CPU time at 512K.

IV. Program Listing

```
// EXEC MONITOR,REGION=512K
//SYSIN DD *
/FTC
C******************************************************
      COMMON /I2ARR/ ICON,IEN,INC,INCD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IOP,IPOND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVA,NVAC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTY,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL OIL,DOSPWN
      COMMON /SPILL/ SPILYR,SPILDA,MRTDAY,MRTYR,IADV,IDALST,SPLTYP,
     &              SPLMAG
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     &              FEC(18),PRED(18),PLARVA(365,10),
     &              SUMPR,EGGCHK(365)
      DIMENSION EXPNT(18)
      INTEGER LAYDAY/0/
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     &              YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     &              RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
      COMMON /LINK/ PLVCLD(365),PLVTOX(365),OILCON(148),
     &              XOILMN,XOILMX,YOILMN,YOILMX,
     &              XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
      INTEGER FRSTYR,SPILYR,SPILDA,NPTMAX/0/,SPLTYP,IDALST
      INTEGER YEARLY, OILCOD, INTELM(10),OILSTP,OUTPOP
      COMMON /BLWOUT/ CONC(350,3),RUNELP,THRSLD,DX,DY,IDAYZ(12)
C
C************************************************
C  EXPLANATION OF SOME OF THE VARIABLES, PARAMETERS, AND ARRAYS
C
C       PLVCLD(I) CONTAINS THE NUMBER OF LARVAE SPAWNED ON THE
C                 ITH DAY THAT REMAINED ALIVE THE DAY BEFORE, AND
C                 IS  USED TO APPLY MORTALITY TO ARRAY PART
C                 IN SR TOXIC.
C       PLVTOX(I) CONTAINS THENUMBER OF LARVAE SPAWNED ON THE ITH DAY
C                 KILLED BY OIL TO DATE.
C       SUMPR=SUM OF PRODUCTS OF CURRENT VALUES OF PRED(I)*POPNEW(I)


C       PLARVA(I,1)=NO. OF ORGANISMS REMAINING FROM EGGS
C                   SPAWNED THAT DAY
C       PLARVA(I,2)=STAGE OF DEVELOPMENT
C                   1=EGGS
C                    2=YOLKSAC
C                     3=PLANKTONI CSWITCHING TO FREE-FEEDING
C                      4=SUCESSFULLY ADAPTED FREE-FEEDERS
C                        5=DEMERSAL JUVENILES
C       PLARVA(I,3)=TIME SINCE SPAWNING
C       PLARVA(I,4)=TIME PRESENT STAGE BEGAN
C       PLARVA(I,5)=TIME TO HATCH FOR THIS GROUP, GIVEN INFO FROM
C                   SUBROUTINE TEMP
C       PLARVA(I,6)=YOLKTIME
C       PLARVA(I,7)=PLANKTONI CFREE-FEEDING ADAPTION TIME
C       PLARVA(I,8)=PLANKTONI CFREEFEEDING TIME
C       PLARVA(I,9)=# EGGS INITIALLY SPAWNED ON THE ITH DAY
C
C       NOTE THAT WHEN PLARVA(I,3)=365, THEY JOIN THE 1+ GROUP,
C       AND NEW EGGS ARE SPAWNED.
C************************************************
C
CINPUT AND OUTPUT DATA SETS:
C                  1  ELEMENT DATA FOR PHYSICAL MODEL
C                      (ELEMENT #, & 3 NODES, FORMAT(4(I5,1X))    )
C                  2  LARVAL DISTRIBUTION OURPUT TO DISC
C                     (UNFORMATED, DAY SPAWNED, DEVELOPMENTAL STAGE, LOCATION )
C                  3  OIL CONCENTRATION DATA
C                     (INPUT FROM OIL SPILL MODEL; SEE  THAT WRITEUP, OR
C                      SR MCCONC, OR MCON2 FOR THE INPUT FORMATS , VARIABLE ORD
C                  4  OUTPUT  EGG AND LARVAL AND OIL DISTRIBUTIONS
C                     FOR EVERY DAY OF THE SPILL
C                       (SAME AS 2)
C                  8  OUTPUT ANNUAL CATCH DATA FOR FINAL IMPACT ANALYSIS
C                    (YEAR, AND CATCH IN THOUS METRIC TONS: FORMAT(I7,F12.4)   )
C                  9  FISH PARAMETER DATA
C                     (FORMAT INPUTS AS BELOW, OR SEE THE DATA SET AT END)
C                 10  PLOT AND WRITE STEPS, NUMBER OF TIMESTEPS/DAY
C                     FOR THE PHYSICAL MODEL
C                 11  NODE LOCATION DATA
C                       (FORMAT(I5,2F8.3) : NODE # AND LOCATION IN LAT, LONG.)
C                 12  DAILY OUTPUT OF LARVAL MORTALITY FOR PLOTTING
C                     (NUMBER REMAINING, STAGE, DAY SPAWNED; E14.5,2I4 )
C                 13  THE MASSAGED VERSION OF BUMPUS DATA FOR LONG-
C                     TERM NET TRANSPORT ON GEORGE'S BANK.
C                     (SEE SR VELIN FOR THIS AND THE WIND DRIVEN INPUT FORMAT)
C                 14    THE HYDRODYNAMI CWIND-DRIVEN DATA
C                 15      THE INITIAL POPULATION ON DIS C(DIFFERENT FOR EACH
C                                   MODE)
C                 16      THE DAYS FOR LARVAL DISTRIBUTION OUTPUT TO DISC
C                           (DATA SETS 2 (SR DSCWRT) AND 4 (SR MCCON2))
C
C******************************************************
```

```
C
CLIST AND EXPLANATION OF INPUT CONTROL VARIABLES FOR FSHOILML, THE
C                MULTIPLE SPILL PROGRAM
C
C**********************************************************
C OILCOD = 1 THEN OIL IS TRUE
C        = 0 THEN OIL IS FALSE AND NO ADVECTION IS PERFORMED EVER
C IOFF   = 1 THEN DELETE EGGS AND LARVAE BLOWN OFF THE BANK (SEE SR DEAD)
C        = 0 THEN DON'T
C YEARLY = THE FIRST YEAR USING THE LARGER TIMESTEP (DT2)
C              (IF SPILDA=350 OR 90 AND MULTI > 1, YEARLY.IS C ALCULATED
C                                                 INTERNALLY.)
C IRWND  = 1 THEN REWIND DATASET 3 AFTER EACH SPILL AND REREAD
C        = 0 THEN READ FT03F002 THE SECOND SPILL, ETC.
C INTPOP = 1 THEN READ THE INITIAL POPULATION FOR YEAR ISTART FROM
C                        DATASET 15
C        = 0 THE READ IT FROM FT09F001 (CARDS)
C OUTPOP = 1 THEN WRITE THE POPULATION OUT TO 15 FOR LASTYR
C        = 0 THEN DON'T
C FRSTYR = THE FIRST YEAR OF RECORDED OUTPUT  -
C LASTYR = THE LAST ONE
C ISTART = THE STARTUP YEAR
C MULTI  = 1 THEN THERE'S ONLY ONE SPILL
C        = GT 1, THEN THAT'S THE NUMBER OF SPILLS THERE WILL BE
C OILSTP = THE NUMBER (INTEGER) OF YEARS BETWEEN SPILLS
C SPILYR = THE YEAR OF THE SPILL
C          (OR PERHAPS SPILYR + 1 IF IADV=1 AND SPILDA IS IN AUTUMN)
C SPILDA = THE JULIAN DAY OF THE SPILL
C MRTDAY = JULIAN DAY FROM WHICH TO FOLLOW EGG AND LARVAL MORTALITY
C MRTYR  = THE YEAR FOR SAME....RESULTS OUTPUT TO DATASET 17
C IDALST = THE LAST DAY OF ADVECTION WHEN IADV = 1
C IADV   = 1 THEN WE ADVECT WITHOUT OIL (SET OILCOD = 1)
C        = 0 THEN NO EFFECT
C SPLTYP = 1 THEN THE PROGRAM USES SR MCCONC, AND ONLY C HECKS THE
C            EXTREMES OF THE SUBSURFACE DISTRIBUTION
C        = 2 THEN USES MCCON2, AND C HECK C ELL BY C ELL....THIS IS THE
C            INPUT VALUE FOR THE BLOWOUT SIMULATION, SINCE THE PATTERN
C            IS NOT EXPECTED TO BE SO NICELY REGULAR...
C THRSLD = THE THRESHOLD TOXICITY VALUE AT WHICH EGGS AND LARVAE ARE
C            ASSUMED TO BE KILLED (IN PARTS PER BILLION)
C
C ICROP  = 1 THEN ARTIFICIAL C ROPPING AT SPILYRS (INTERVAL OILSTP)
C          WILL OCCUR; SET OILCOD TO 0 AND MULTI GT 1
C CROPRT = THE REDUCTION RATE FOR RECRUITS WHEN ICROP=1 AND KYEAR=SPILYR
C
C*********** START READING IN THE FISHERY PARAMETERS *****************
C
CINITIALIZATION:
C
      CALL INIT
C
      READ(9,801)OILCOD,IOFF,YEARLY,IRWND,INTPOP,OUTPUP


      WRITE(6,800)YEARLY
      OIL=.TRUE.
      IF(OILCOD.EQ.0)OIL=.FALSE.
      READ(9,801)FRSTYR,LASTYR,ISTART,MULTI,OILSTP,ICROP
      WRITE(6,802)FRSTYR,LASTYR,ISTART
C
      WRITE(6,831)MULTI,OILSTP
C
CREAD IN THE TIME AND LOCATION OF THE SPILL:
C
      READ(9,801)SPILYR,SPILDA,MRTDAY,MRTYR
      READ(9,818)IADV,IDALST,SPLTYP,THRSLD,CROPRT
C
      MORTD=MRTDAY
C
CREAD IN THE EGG AND LARVAL MORTALITY COEFFICIENTS:
C
      READ(9,805)EM10,EM11,EM12,EM13
      READ(9,805)EM14,EM15,EM16
      READ(9,821)RATIO,EM,FINITL,FEQLBM,Q
      WRITE(6,809)RATIO,EM,FINITL,FEQLBM,Q
 800  FORMAT('1',///,'     THE BYPASS TIMESTEP WILL BE USED AFTER YEAR',
     & I6)
 801  FORMAT(6(8X,I4))
 802  FORMAT(' ',' FRSTYR= ',I4,' LASTYR=',I4,' ISTART=',I4)
 803  FORMAT('1',/,T30,'******* THE CONTROL VARIABLES *******',//,
     &//,T10,'IS ADVECTION INCLUDED (OILCOD)?',T85,I4,
     &//,T10,'IS OFF-THE-BANK MORTALITY INCLUDED (IOFF)?',T85,I4,
     &//,T10,'USE THE BYPASS TIMESTEP AFTER YEAR (YEARLY)',T85,I4,
     &//,T10,'REWIND DATASET 3 OR USE A NEW ONE FOR MULTIPLE RUNS ',
     & '(IRWND)',
     &                                                  T85,I4,
     &//,T10,'READ INITIAL POPULATION FROM CARDS (0) OR FT15 (1) ',
     & '(INTPOP)',
     &                                                  T85,I4,
     &//,T10,'WRITE OUT THE LAST YEAR POPULATION TO FT15 (OUTPOP)?',
     &                                                  T85,I4,
     &//,T10,'FIRST YEAR OF THE RUN (FRSTYR)',T85,I4,
     &//,T10,'LAST YEAR OF THE RUN (LASTYR)',T85,I4,
     &//,T10,'STARTUP YEAR (ISTART)',T85,I4,
     &//,T10,'NUMBER OF OILSPILLS IN THE SERIES (MULTI)',T85,I4,
     &//,T10,'NUMBER OF YEARS BETWEEN SPILLS (OILSTP)',T85,I4,
     &//,T10,'YEAR OF THE FIRST SPILL (SPILYR)',T85,I4,
     &//,T10,'JULIAN DAY OF THE SPILL (SPILDA)',T85,I4)
 804  FORMAT(' ',
     &//,T10,'DAY TO BEGIN TRACING DAILY MORTALITY OF EGGS AND LARVAE',
     &' (MRTDAY)', T85,I4,
     &//,T10,'YEAR IN WHICH THE TRACING BEGINS (OUTPUT TO FT17',
     & '...MRTYR)',
     &                                                       T85,I4,
     &//,T10,'LAST DAY FOR ADVECTION (IDALST)',T85,I4,
     &//,T10,'ADVECTION WITHOUT OIL (IADV)?',T85,I4,
```

```
     $//,T10,'SPLTYP = 1 THEN ITS SHORT, =2 THEN A BLOWOUT',T65,I4,
     $//,T10,'THE THRESHOLD TOXICITY IN PARTS PER BILLION IS',T85,
     $ F7.2,
     $//,T10,'IS THIS AN ARTIFICIAL CROPPING RUN? (ICROP)',T85,I4,
     $//,T10,'CROPPING RATE FOR RECRUITS DURING SPILYR (CROPRT)',
     $ T65,E10.4)
  805 FORMAT(4(8X,E8.1))
  806 FORMAT(/,' EPLC = ',E12.4,'  EM11 = ',E12.4,'  EM12 = ',
     $    E12.4,'  EM13 = ',E12.4)
  808 FORMAT(/,' EM14 = ',E12.4,'  EM15 = ',E12.4,'  EM16 = ',E12.4)
  809 FORMAT(/,'  RATIO OF FEMALES IN THE POPULATION = ',F6.4,
     $ /,'  ADULT NATURAL MORTALITY = ',F6.4,
     $ /,'  STARTUP FISHING MORTALITY = ',F6.4,
     $ /,'  EQUILIBRIUM FISHING MORTALITY = ',F6.4,
     $ /,'   CATCHABILITY COEFFICIENT = ',F6.4)
  810 FORMAT(2(8X,F8.4))
  811 FORMAT(/,'  DELTAT FOR THE FISHERY MODEL IS ',F6.4,' DAYS.')
  813 FORMAT(/, '  HISTOGRAMS WILL BE PRODUCED FOR YEARS ',
     $ I4,' TO ',I4,'.')
  814 FORMAT(2X,E8.2)
  815 FORMAT(14X,I2,10X,E8.2)
  816 FORMAT('1',11X,'AGE GROUP',4X,'INITIAL NUMBERS')
  817 FORMAT(//,'  THE SHORTCUT TIMESTEP IS ',F8.4,'  DAYS.')
  818 FORMAT(3(8X,I4),8X,E7.1,8X,E10.4)
  821 FORMAT(5(8X,F6.4))
  831 FORMAT(//,'   THERE WILL BE',I4,' OILSPILLS SEPARATED BY',
     $ I4,' YEARS EACH.',//)
C
CREAD IN THE FISHERY MODEL TIMESTEP, AND THE SHORTCUT TIMESTEP:
C
      READ(9,810)DELTAT,DT2
      WRITE(6,811)DELTAT
      WRITE(6,817)DT2
C
CSET TOXICITY MORTALITY RATES TO ZERO:
C
      T1=0.0
      T2=0.0
      T3=0.0
      T4=0.0
C
C
      DO 20 I=1,75
   20 YRMASS(I)=0.0
C*********************************
C
C      MINYR AND MAXYR  ARE THE FIRST AND LAST YEARS FOR
C      WHICH HISTOGRAPHS WILL BE PRODUCED.  (THEY WILL ALWAYS
C     BE OUTPUT FOR YEAR FRSTYR AND YEAR LASTYR.)
C
      READ(9,801)MINYR,MAXYR
      WRITE(6,813)MINYR,MAXYR


C
CHERE  READ IN  THE DAY AND THE ELEMENT NUMBERS FOR DIFFUSION
CVERSUS MORTALITY RATE COMPARISONS
C
      READ(9,820)(INTELM(I),I=1,10)
      READ(5,820)IDATE
      WRITE(6,822)IDATE
      WRITE(6,820)(INTELM(I),I=1,10)
  820 FORMAT(10I4)
  822 FORMAT(//,10X,'  HERE ARE THE ELEMENTS IN WHICH',
     $ ' MORTALITY AND DIFFUSION RATES WILL BE COMPARED ON DAY',I4)
C
      WRITE(6,802) OILCGO,IOFF,YEARLY,IRWND,INTPOP,CUTPOP,FRSTYR,
     $                 LASTYR,ISTART,MULTI,OILSTP,SPILYR,SPILDA
      WRITE(6,804)MRIDAY,
     $                 MRTYP,IDALST,IACV,SPLTYP,THRSLD,ICROP,CROPRT
      WRITE(6,806)EM10,EM11,EM12,EM13
      WRITE(6,808)EM14,EM15,EM16
C
C     INITIALIZE THE MODEL POPULATION
C
      WRITE(6,816)
C
      KX1=9
      IF(INTPOP.EQ.1)KX1=15
      DO 30 I=1,18
      IMIN=I-1
      READ(KX1,814)POPN(I)
      IF(INTPOP.EQ.1)READ(5,814)DUMMY
      WRITE(6,815)IMIN,POPN(I)
      POPNEW(I)=POPN(I)
   30 POPOLD(I)=0.0
C*******************************************
C
CFECUNDITY AND SELECTIVITY FACTORS
C
C*******************************************
      READ(9,832)
      READ(9,832)(FEC(I),I=1,18)
      READ(9,834)(SEL(I),I=1,18)
      READ(9,832)
      READ(5,836)EGPRGM
  832 FORMAT(18F4.1)
  834 FORMAT(1X,18F4.2)
  836 FORMAT(1X,E8.3)
C
C
      CALL WEIGHT
C
C  WTCALC(I) IS IN KG
C
      DO 40 I=1,18
   40 FEC(I)=FEC(I)*EGPRGM*WTCALC(I)
C
C
      WRITE(6,50)
   50 FORMAT(//,20X,' AGE',10X,' FECUNDITY')
C
      DO 60 I=2,18
      JJ=I-1
   60 WRITE(6,70)JJ,FEC(I)
   70 FORMAT(20X,I2,13X,E10.4)
C
C********************************
C
C      READ IN THE CATCH AND EFFORT DATA
C     AND WRITE IT OUT THE FIRST TIME THRU
C
C*******************************
      WRITE(6,80)
      WRITE(6,90)
   80 FORMAT('1',3X,'YEAR',14X,'CATCH',20X,'EFFORT')
   90 FORMAT(18X,'(THOUS. METRIC TONS)',3X,'(THOUS. STANDARD DAYS)')
C
      DO 100 I=1,75
      READ(9,110,END= 130)KYR,RLCTCH(I),EFFORT(I)
      WRITE(6,120)KYR,RLCTCH(I),EFFORT(I)
      IF(KYR.GE.2050)GO TO 130
  100 CONTINUE
  120  FORMAT(4X,I4,10X,F10.2,15X,F10.2)
  110  FORMAT(I4,F5.1,F5.1)
C
  130 CONTINUE
C
C        THESE ARE THE RATES OF PREDATION OF THE
C        ITH AGE GROUP ON THE FIRST YEAR GROUP
C
      READ(9,840)
      READ(9,840)(PRED(I),I=1,18)
      WRITE(6,842)
      WRITE(6,840)(PRED(I),I=1,18)
  840 FORMAT(9F8.2)
  842 FORMAT(//,'  FOLLOWING ARE THE PREDATION RATES OF THE OLDER COD',
     $ 'ON THE JUVENUILES OF THE YEAR:')
C
CEMPTY OUT PLARVA, OR INITIALIZE LATER WHEN YOU KNOW HOW
C
C
C
      DO 150 I=1,365
      EGGCHK(I)=0.0
      DO 150 J=1,10
  150 PLARVA(I,J)=0.0


      LOT=IFIX(DELTAT)
C
C*********************************************
C
C       START IN ISTART TO ACHIEVE ECLBM
C
C
C       KYEAR IS THE ANNUAL COUNTER.
C
C
C********************************************
C
      KYEAR=ISTART
  170 KYEAR=KYEAR+1
      IF(MULTI.GT.1.AND.KYEAR.GT.SPILYR.AND..NOT.OIL)
     $         CALL MOROIL(SPILYR,MULTI,OILSTP,IRWND)
      IF(ICROP.EQ.1)OIL=.FALSE.
C
      IF(MULTI.GT.1.AND.SPILDA.EQ.350)YEARLY=SPILYR + 2
      IF(MULTI.GT.1.AND.SPILDA.EQ.90)YEARLY=SPILYR + 1
C
      KCOUNT=KYEAR-ISTART
      IF(KYEAR.LT.FRSTYR)KCOUNT=1
C
C COUNT THE RECRUITS FOR THE YEAR W/ RCTCNT
C
      RCTCNT=0.0
C
C
C
      DO 175 I=2,18
      IF(KYEAR.EQ.(ISTART + 1))POPNEW(I)=POPN(I)
  175 IF(KYEAR.GT.(ISTART+1))POPN(I)=POPNEW(I)
C
C
CWRITE THE POPULATION OUT TO DIS FOR SYMV3 PLOTS
C
C
C
C
C       CALCULATE THE ANNUAL F
C
      IF(KYEAR.LT.FRSTYR)F=FINITL
      IF(KYEAR.LT.FRSTYR)GO TO 182
      IF(KYEAR.GT.LASTYR)F=FECLBM
      IF(KYEAR.GT.LASTYR)GO TO 182
C
C
  180 F=Q*EFFORT(KCOUNT)
C
C
C       STORE THE PRESENT POPULATION SIZE
```

```
C
 182  POPSIZ(KCOUNT)=0.0
      DO 185 I=2,18
      POPSIZ(KCOUNT)=POPSIZ(KCOUNT)+POPN(I)
 185  CONTINUE
C
C
C      CYCLE THE ADULT POPULATION
C
 190  DO 200 I=2,18
      PCPN(I)=POPN(I)*EXP(-(EM+(F*SEL(I))))
      EXPNT(I)=EXP((-EM - (F*SEL(I)))*DELTAT/365.0)
 200   CONTINUE
C
C      CALCULATE ANNUAL YIELD
C
      YIELD=0.0
      DO 205 I=2,18
      DIFF(I)=POPNEW(I)-PCPN(I)
      WTDIST(I)=(DIFF(I))*WTCALC(I)*F*SEL(I)/
     X      (EM + (F*SEL(I)))
      YIELD = YIELD + WTDIST(I)
 205  CONTINUE
C
      CCATCH(KCOUNT)=YIELD
C
CWRITE THIS OUT FOR THE INITIALIZATION PERIOD
C
      IF(KYEAR.LT.FRSTYR)WRITE(6,208)KYEAR,YIELD
 208  FORMAT(4X,I5,4X,E10.2)
C
C*****************************************************
C
C
C
C      CALCULATE BIOMASS B
C
      B=0.0
      DO 210 I=2,18
      BTEMP=POPN(I)*WTCALC(I)
      B=B+BTEMP
 210  CONTINUE
C
      YRMASS(KCOUNT)=B
C
C
C      CALCULATE CONDITION FACTOR
C
      CCND=1.0
C
C      CALCULATE THE SPAWN FOR THE YEAR
C
      POPN(1)=0.0


      DO 215 I=4,18
      POPN(1)=POPN(1)+((POPN(I)+POPNEW(I))/2.0)*RATIO*FEC(I)*CUND
 215  CCNTINUE
      EGGS=PCPN(1)
C
C      THE ANNUAL OUTPUT SECTION
C
C  (SKIP IT FOR THE INITIALIZATION YEARS)
C
      IF(KYEAR.LT.FRSTYR)GC TO 216
C
C
      CALL OUTPUT(YIELD,B,F,EM,KYEAR)
C
C
C      CALCULATE THE AVERAGE FECUNDITY
C
      CALL AVGFEC(POPN(1))
C
C
 216  CONTINUE
C****************************************
C
C
C      NOW ENTER THE DAILY CYCLE
C
C
C****************************************
C
CAFTER ADVECTION  IS NO LONGER OF INTEREST, AND WE ONLY
CWANT THE CATCH PROJECTION INTO THE FUTURE, WE DO THIS LITTLE
CSECTION.  OTHERISE, BYPASS IT.
C
CYEARLY IS THE FIRST YEAR OF THIS TYPE OF REGIME
C****************************************************
C
      IF(KYEAR.LT.YEARLY)GC TO 230
C
      CALL BYPASS(RCTCNT,EM10,EM11,EM12,EM13,EM14,EM15,EM16,
     X                    IDAY,DT2,DELTAT,EM,F,KYEAR,ICROP,CROPRT)
C
      GO TO 400
C*************************************************
C
CHERE FOR THE REGULAR DAILY CYCLE
C
 230  IDAY=1
 225  CONTINUE
C
C      CALCULATE TODAYS'S ADULT POPULATION
C
      DO 300 I=2,18
      POPNEW(I)=PCPNEW(I)*EXPNT(I)
 300  CONTINUE
C
C
C      THEY ALSO AGE DAILY
C
      DO 305 I=3,18
      K=20-I
      J=21-I
      ADDS=POPNEW(K)*DELTAT/365.0
      POPNEW(J)=POPNEW(J) + ADDS
      PCPNEW(K)=POPNEW(K) - ADDS
 305   CCNTINJE
C
C      AND NEW RECRUITS ARE ADDED
C
C ARBITRARY FIRST YEAR RECRUITMENT
C
      IF(KYEAR.EC.(ISTART+1))RECRUT=15.0E6*DELTAT/365.0
      IF(ICROP.EC.1.ANC.KYEAR.EQ.SPILYR)RECRUT=RECRUT*CROPRT
      RCTCNT=RCTCNT + RECRUT
      POPNEW(2)=PCPNEW(2) + RECRUT
C
C
C
C
C  THE LARVAE AGE
C
      DO 310 I=1,365,LDT
      IF(PLARVA(I,1).EC.0.0)GC TO 310
      PLARVA(I,3)=PLARVA(I,3)+DELTAT
      PLARVA(I,4)=PLARVA(I,4)+DELTAT
 310  CONTINUE
C
C
C      SPAWN DISTRIBUTION IN TIME
C
C
      TIME=FLOAT(IDAY)
      CALL SPNTIM(TIME,DELTAT,DISTRB)
      PLARVA(IDAY,1)=PCPN(1)*DISTRB
      PLARVA(IDAY,2)=1.0
      PLARVA(IDAY,3)=0.0
      PLARVA(IDAY,4)=0.0
C
CHERE TC KEEP TRACK OF FIRST YEAR MORTALITY FOR FUTURE PLOTTING
C
      IF(KYEAR.NE.MRTYR)GC TO 32C
      IF(IDAY.NE.MRTDAY)GO TO 320
      MRTDAY=MRTDAY+1
      LRVDAY=LRVDAY+1
      IF(MRTDAY.EQ.364)MRTYR=MRTYR+1
      IF(MRTDAY.EQ.364)MRTDAY=1

      WRITE(12,833)PLARVA(MORTD,1), LRVDAY,IDAY
 833  FORMAT(E14.5,2I4)
      IF(LRVDAY.EQ.365)MRTYR=9995
 320  CONTINUE
C
CCIRCUMVENT THE SPATIAL SECTION IF THERE'S NC SPILL.
CFOR THE BASELINE CASE, GO TO 37C 30 DAYS AFTER THE SPILL.
CFOR THE ONE YEAR ADVECTION OF LARVAE, IADV = 1
C
C
      IF(.NOT.OIL)GO TC 37C
      IF(KYEAR.LT.(SPILYR-1))GC TC 370
C
C
      IF(IADV.EQ.0)GC TO 350
      IF(IADV.EQ.1.AND.KYEAR.GT.SPILYR)OIL=.FALSE.
      IF(IADV.EQ.1.AND.KYEAR.EQ.(SPILYR-1).AND.IDAY.GE.270)GO TO 355
      IF(IADV.EQ.1.AND.KYEAR.EQ.SPILYR.AND.IDAY.LE.IDALST)GO TO 355
      IF(IADV.EQ.1)GO TC 37C
C
C
 350  IF(SPILDA.EQ.350.AND.KYEAR.LT.SPILYR)GO TO 370
      IF(SPILDA.EQ.350.AND.KYEAR.EC.SPILYR.
     X            AND.IDAY.LE.270)GC TC 370
      IF(SPILDA.EC.90.AND.KYEAR.LT.(SPILYR-1))GO TO 370
      IF(SPILDA.EC.90.AND.KYEAR.EQ.(SPILYR-1).
     X            AND.IDAY.LT.270)GO TO 370
C
CTHAT SETS UP THE SPATIAL DISTRIBUTION FOR THE SPILL.
CCOME HERE IN SUBSEQUENT YEARS TC CHECK FOR OIL
C
C
      IF(SPLTYP.EC.1)CALL MCCONC(KYEAR,IDAY)
      IF(SPLTYP.EC.2)CALL MCCON2(KYEAR,IDAY)
C
CIF OIL COMES BACK .TRUE. THEN THERE'S OIL OUT THERE SOMEWHERE.
C              (OR WILL BE)
C
CADVECT AND DIFFUSE EGGS AND LARVAE ALREADY PRESENT.
C
C
 355  CONTINUE
      IF(IDAY.EQ.IDATE)CALL COMPAR(IDAY,KYEAR,INTELM)
  360 CALL ADVDIF(IDAY,NPTMAX,ICFF)
      IF(IDAY.EQ.IDATE)CALL COMPAR(IDAY,KYEAR,INTELM)
C
CSPAWN DISTRIBUTION IN SPACE IS ACCOMPLISHED BY SR SPNPLC,
CCALLED FROM SR MOVE.
C
C
      CALL TOXIC(STAGE,IDAY)
C
```

```
C******************************************************
C
C
C      EGG, LARVAL, AND JUVENILE MCRTALITY
C
 370  CALL EGGMRT(EM10,EM11,T1,T2,ICAY,DELTAT)
C
      SUMPN=0.0
      DO 380 I=2,18
      SUMPN=SUMPN + (PRED(I)*PGPNEW(I))
 380  CONTINUE
C
C
      CALL PLNMRT(EM12,EM13,T3,T4,IDAY,DELTAT)
C
      Z=EM+F
C
      CALL BTMMRT(Z,EM14,EM15,EM16,ICAY,DELTAT)
      IF(IDAY.EQ.IDATE)CALL COMPAR(ICAY,KYEAR,INTELM)
C
C
C
C
C       NOW THEY DEVELOPE
C
 390  CALL DEVELP(IDAY,RECRUT)
C
C
C
C
C       THIS IS THE END OF THE DAILY CYCLE
C
C
      IDAY=ICAY + LDT
C
      IF(IDAY.LT.365)GC TO 225
C
C
C*************************************
 400  CCNTINUE
C
      IF(KYEAR.LT.FRSTYR)GC TO 170
      IF(KYEAR.EC.FRSTYR)GO TO 998
       IF(KYEAR.EQ.LASTYR)GO TO 998
       IF(KYLAR.LT.MINYR)GC TO 997
       IF(KYEAR.GT.MAXYR)GO TC 997
 998  CONTINUE
C      CALL MSTFSH(POPNEW,KYEAR,LASTYR)
 997  CONTINUE
C     CALL STKRCT(FRSTYR,LASTYR)
C
CCALCULATE PERCENTAGE EGGS LOST BEFORE HATCHING
C
      SUM=C.0
      DO 990 I=1,365



 990  SUM = SUM + EGGCHK(I)
C
      PERCNT=SUM/EGGS
      WRITE(6,995)PERCNT
 995  FORMAT(' THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS ',E12.4)
C
 999  IF(KYEAR.LT.LASTYR)GO TO 17C
C     CALL CATCH(FRSTYR,LASTYR)
C     CALL POPPLT(FRSTYR,LASTYR)
C     CALL MASPLT(FRSTYR,LASTYR)
      WRITE(6,1800)NPTMAX
1800  FORMAT(//,5X,' THE MAXIMUM NUMBER OF PARTICLES ',
     &'IN THE SYSTEM AT ANY ONE TIME WAS ',I5,////)
C
      KDUM=3132
      CALL CCMPAR(ICAY,KDUM,INTELM)
C
      DO 1820 I=1,365
      IF(PLVTOX(I).EC.0.0)GC TO 1820
      WRITE(6,1810)I,PLVTOX(I)
1810  FORMAT(' ',2X,'DAY SPAWNED:',I6,
     &'      NUMBER OILED:',E16.4)
1820  CONTINUE
C
      IF(OUTPOP.EQ.0)GO TO 1826
      REWIND 15
      DO 1825 I=1,18
1825  WRITE(15,814)POPN(I)
1826  CONTINUE
C
      WRITE(6,1830)
 1830 FORMAT(40X,///,'   ****NORMAL TERMINATION*****')
      RETURN
      END
C*************************************
C*************************************
C*************************************
C*************************************
C
      SUBROUTINE CCMPAR(ICAY,KYEAR,INTELM)
C
C*************************************
C
CCOMPARES RATES OF REDUCXTICN IN NUMBERS PER UNIT VCLUME
CDUE TO MORTALITY AND DIFFUSION
C
      INTEGER ICAT/0/,INTELM(10)
      REAL SUM(10,3)
C
      CCMMCN /LINK/ PLVOLD(365), PLVTOX(365), OILCCN(148),
     &              XOILMN,XOILMX,YOILMN,YOILMX
     &               ,XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
```

```
      REAL LRVSUM(365)
      COMMON /LCGIC/ DCSPWN,OIL
      LOGICAL DOSPWN,OIL
      COMMCN /I2ARR/ ICCN,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      CCMMCN /R4ARR/ PART,CATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),CATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTCLD(2,2019),UVNET(2,153)
      CCMMCN /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMCN /I4VAR/ IN,IT,IP,IF,IF,IRA,IRB,IOP,IPOND,INTKA,INTKB,NPLT,
     *               NPRT,INTKT,KYR,NYRC,ISTRT,JPLT,NNCT,
     *               IFLT,ISTOP,ISTEC,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMCN /L1VAR/ TF
      CCMMCN /R4VAR/ UP,VP,UPA,VPA,UPO,VPO,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTY,COVL,UNET,VNET,
     *               ARA,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIMF,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
      COMMCN/ARRAYS/ POPNEW(18),POPN(18),SURV(18),PCPULD(18),
     & FEC(18),PREC(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      CCMMCN /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     &                YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     &                 RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
C
CCALLED CNCE JUST BEFORE ADVECTICN ON DAY IDATE, ONCE JUST AFTER,
CONCE AFTER MORTALITY, AND ONCE AT THE VERY END FOR RESULTS
C
      IF(NP.EC.0)RETURN
      ICNT=ICNT+1
      IF(ICNT.GT.3.AND.KYEAR.NE.3132)RETURN
      IF(ICNT.EQ.1)GO TO 10C
      IF(ICNT.EQ.2)GC TC 2CC
      IF(ICNT.EC.3)GO TO 300
      IF(ICNT.CE.4)GC TC 400
C
 100  DO 105 I=1,10
      DO 1C5 J=1,3
 105  SUM(I,J)=0.0
      IDAY1=IDAY
      KYEAR1=KYEAR
C
      CO 140 I=1,NP
C
CDON'T CCUNT TODAY'S
C
      IF(PART(7,I).EQ.ICAY)GO TO 140
C
      CO 110 J=1,10
      IF(IELP(I).EQ.INTELM(J))GC TO 120


 110  CONTINUE
      GO TC 140
 120  SUM(J,1)=SUM(J,1) + PART(3,I)
 140  CONTINUE
      RETURN
C
CNOW AFTER ADVECTION, DC IT AGAIN
C
 200  DO 240 I=1,NP
      IF(PART(7,I).EQ.IDAY)GO TO 240
      DO 210 J=1,1C
      IF(IELP(I).EC.INTELM(J))GO TO 220
 210  CONTINUF
      GO TO 240
 220  SUM(J,2)=SUM(J,2) + PART(3,I)
 240  CONTINUE
      RETURN
C
CAND HERE AFTER MORTALITIES
C
 300  CO 340 I=1,NP
      IF(PART(7,I).EQ.IDAY)GO TO 340
      DO 310 J=1,10
      IF(IELP(I).EQ.INTELM(J))GO TC 320
 310  CONTINUE
      GO TC 340
 320  SUM(J,3)=SUM(J,3) + PART(3,I)
 340  CONTINUE
      RETURN
C
CAND HERE AT THE END TO CACULATE AND OUTPUT
C
 400  WRITE(6,800)IDAY1,KYEAR1
 800  FORMAT('1',///,' THESE ARE THE LOSS RATES IN 10 ELEMENTS',
     &' DUE TO TRANSPORT AND MORTALITY CN DAY',I4,', YEAR',I5)
      WRITE(6,810)
 810  FORMAT(//,' ELEMENT',5X,'INITIAL NUMBER',5X,
     &'PERCENT TRANSPORTED CUT',5X,'PERCENT DIED',5X,'RATIO')
C
CNOW CACLULATE
C
      DO 440 I=1,10
      TRANS=0.0
      TMCRT=0.C
      RATIO=0.0
      IF(SUM(I,1).EQ.0.0)GC TO 440
      TRANS=SUM(I,1)-SUM(I,2)
      TMCRT=SUM(I,1)-SUM(I,3)
      TRANS=(TRANS/SUM(I,1))*100.0
      TMORT=(TMORT/SUM(I,1))*100.0
      RATIC=TRANS/TMCRT
 440  WRITE(6,82C)INTELM(I),SUM(I,1),TRANS,TMORT, RATIO
```

```
 820  FORMAT(I7,5X,E13.4,5X,F13.5,10X,F13.5,5X,F10.4)
      RETURN
      END
C
C**************************************************************
C
      SUBROUTINE BYPASS(RCTCNT,EM10,EM11,EM12,EM13,EM14,EM15,EM16,
     $                 IDAY,DT2,DELTAT,EM,F,KYEAR,ICROP,CROPRT)
C
C*****************************************************************
C
      INTEGER SPILYR,SPILDA,SPLTYP
      COMMON /SPILL/ SPILYR,SPILDA,MPTDAY,MRTYR,IADV,IDALST,SPLTYP,
     $               SPLMAG
      COMMON /LOGIC/ DOSPWN,OIL
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $               FEC(18),PRED(18),PLARVA(365,10),
     $               SUMPN,EGGCHK(365)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $               YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $               RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
      COMMON /LINK/ PLVOLD(365),PLVTOX(365),OILCON(148),
     $              XOILMN,XOILMX,YOILMN,YOILMX,
     $              XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
C
C*************************************************
CHERE'S WHERE TO MAKE QUICK WORK OF A YEAR'S TIME WITHOUT
CDAILY TIMESTEPS, WHICH ARE UNNECESSARY IF PHYSICAL DISTRIBUTIONS
CARE NOT OF INTEREST.
C
C6 MONTHS OF SPAWNING: 16 DAYS AS EGGS, 10 DAYS AS YOLKSAC LARVAE,
C4 DAYS TO ADAPT, 100 DAYS AS FREEFEEDERS
CAMONGST THE OTHER PLANKTON, AND 235 DAYS DEMERSAL
C
      EXPO1=EXP(EM11*27.0/365.0)
      EXPO2=EXP(EM12*(C4.0/365.0)
      DUM1=(EM10/EM11)*(EXPO1-1.0)
      DUM2=(EM13/EM12)*(EXPO2-1.0)
      DO 227 I=1,365
      TIME=I
      CALL SPNTIM(TIME,DELTAT,DISTRB)
      PLARVA(I,1)=POPN(1)*DISTRB
      PLARVA(I,2)=5.0
      PLARVA(I,1)=PLARVA(I,1)/(DUM1*PLARVA(I,1) + EXPO1)
      PLARVA(I,1)=PLARVA(I,1)/(DUM2*PLARVA(I,1) + EXPO2)
 227  CONTINUE
      SUMPN=0.0
      DO 219 IJ=2,18
 219  SUMPN=SUMPN + (PRED(IJ)*POPNEW(IJ))
      Z=EM + F
      IDUMMY=235.0/DT2
      DO 228 I=1,IDUMMY

 228 CALL OTHMRT(Z,EM14,EM15,EM16,IDAY,DT2)
      DO 229 I=1,365
 229  RCTCNT=RCTCNT + PLARVA(I,1)
      IF(ICROP.EQ.1.AND.KYEAR.EQ.SPILYR)RCTCNT=RCTCNT*CROPRT
C
CNOW CYCLE THE ADULTS
C
      DO 221 I=3,17
      J=I-1
 221  POPNEW(I)=POPN(J)
      POPNEW(18)=POPN(17)+POPN(18)
      POPNEW(2)=RCTCNT
C
      RETURN
      END
C
C**********************************************************
C
      SUBROUTINE MOROIL(SPILYR,MULTI,OILSTP,IRWND)
C
CWHENEVER MULTI GT 1 AND KYEAR GT SPILYR, CALL THIS SR TO SEE
CWHAT THE NEW VALUE FOR SPILYR IS.  SPILDA COULD BE RANDOMLY
CVARIED, BUT BEST LEAVE IT STEADY FOR NOW.
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL OIL,DOSPWN
      INTEGER ICNT/1/,OILSTP,SPILYR
C
      ICNT=ICNT+1
      IF(ICNT.GT.MULTI)RETURN
      SPILYR=SPILYR + OILSTP
      OIL=.TRUE.
      IF(IRWND.EQ.1)REWIND 3
      CALL INIT
      RETURN
      END
C
C**********************************************************
C************************************************
C
      SUBROUTINE WEIGHT
C
C************************************************
C        THE CONVERSION FROM AGE TO WEIGHT IS
C         ACCOMPLISHED VIA GIFFORD ASND PENTILLA (1976)
C         AND BIGELOW AND SCHROEDER(1955)
C
C       THE FORMER IS A VON BERTALANFFY FIT,
C       THE  LATTER IS A LOGISTI CGROWTH CURVE
C       FITTED BY LEAST SQUARES
C
C
C   USE PENTILLA AND GIFFORD TO CAL CLENGTH AT AGE
```

```
C     THEN USE THOSE LENGTHS TO CAL CORRESPONDING WEIGHTS
C     FOR SUCCESSIVE AGE CLASSES, AND MULTIPLY BY THE
C     INPUT DISTRIBUTION
C*************************************************
      DIMENSION ALTCAL(18)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $                YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $                 RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
C
      WRITE(6,15)
      DO 30 I=1,18
      T=FLOAT(I)
      Z=(-0.12)*(T+0.616)
      ALTCAL(I)=148.1*(1.0-EXP(Z))
      XX=(-0.0501)*ALTCAL(I)
      WTCALC(I)=30.35/(1.0 + (301.0*EXP(XX)))
      JJ=I-1
      WRITE(6,16)JJ,WTCALC(I),ALTCAL(I)
  15  FORMAT(12X,' AGE',7X,'CALCULATED WEIGHT (KG)',7X,
     $'CALCULATED LENGTH (CM)')
  16  FORMAT(12X,I3,10X,F15.3,11X,F15.3)
  20  CONTINUE
  30  CONTINUE
      RETURN
      END
C*************************************************
C
      SUBROUTINE AVGFEC(EGGS)
C
C   B AND S (1953) REPORT AN AVG OF 1 MILLLION
C    AND A MAX OF 9 MILLION
C
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $  FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
C
      WRITE(6,5)
      WRITE(6,2)EGGS
   2  FORMAT(' THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  ',E10.4)
C
C   CALCULATE THE AVG PER FEMALE
C
      SPAWNR=0.0
        DO 4 I=5,18
   4  SPAWNR=SPAWNR + (POPN(I)/2.0)
      AVERAG=EGGS/SPAWNR
      WRITE(6,5)
   5  FORMAT('  ')
      WRITE(6,6)AVERAG
   6  FORMAT(' THE AVERAGE NUMBER OF EGGS PER FEMALE IS',E10.3)
      WRITE(6,5)
      RETURN
      END


C
C
C*************************************************
C
      SUBROUTINE SPNTIM(TIME,DELTAT,DSTRBT)
C
C*************************************************
C
C CALCULATES THE SPAWNING DISTRIBUTION IN TIME
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL DOSPWN,OIL
C
      DOSPWN=.TRUE.
      IF(0.0.LE.TIME.AND.TIME.LE.30.0)DSTRBT=0.05*(DELTAT/30.0)
      IF(30.0.LT.TIME.AND.TIME.LE.60.0)DSTRBT=0.05*(DELTAT/30.0)
      IF(60.0.LT.TIME.AND.TIME.LE.90.0)DSTRBT=0.4*(DELTAT/30.0)
      IF(90.0.LT.TIME.AND.TIME.LE.120.0)DSTRBT=0.10*DELTAT/30.0
      IF(120.0.LT.TIME.AND.TIME.LE.300.0)DSTRBT=0.C
      IF(300.LT.TIME.AND.TIME.LE.330)DSTRBT=0.3*DELTAT/30.0
      IF(330.0.LT.TIME)DSTRBT=0.10*DELTAT/30.0
      IF(DSTRBT.EQ.0.0)DOSPWN=.FALSE.
      RETURN
      END
C
C**************************************
C
      SUBROUTINE DEVELP(IDAY,RECRUT)
C
C**************************************
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $  FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
C  THE FIRST YEAR THROUGH, ESTABLISH VALUES FOR
C  PLARVA(I,5) :  THE HATCH TIME
C  PLARVA(I,6) :  THE YOLK TIME
C  PLARVA(I,7) :  THE PLANKTONI CFREEFEEDING ADAPTION TIME
C  PLARVA(I,8) : THE PLANKTONI CTIME
      INTEGER ICOUNT/0/
      IF(ICOUNT.GT.364)GO TO 2
      ICOUNT=ICOUNT+1
      SUM=0.0
      DO 3 I=1,42
C  TAVE WILL STORE A RUNNING AVERAGE TEMPERATURE
      CALL TEMP(IDAY,DEGC)
      ANUM=FLOAT(I)
      SUM = SUM + DEGC
      TAVE=SUM/ANUM
      CALL HATCH(TAVE,DAYS)
      IF(ANUM.GE.DAYS)PLARVA(IDAY,5)=DAYS
      IF(ANUM.GE.DAYS) GO TO 1
    3 CONTINUE
C  THAT WAS HATCHTIME
C  YOLKTIME NEXT
```

```
    1  PLARVA(IDAY,6)=1C.0
C
C  ADAPTATICN TIME
       PLARVA(IDAY,7)=4.0
C  PLANKTONIC TIME
       PLARVA(IDAY,8)=1C0.0
    2  RECRUT=0.0
       DO 100 I=1,365
C SORT 'EM OUT BY STAGE, OR IF THERE AREN'T ANY FRCM THAT DAY
C             GO CN TC THE NEXT
       IF(PLARVA(I,1).EQ.0.0)GO TC 100
       IF(PLARVA(I,2).EQ.1.0)GO TO 10
       IF(PLARVA(I,2).EQ.2.0)GO TC 20
       IF(PLARVA(I,2).EQ.3.C)GO TO 30
       IF(PLARVA(I,2).EQ.4.C)GO TO 40
       IF(PLARVA(I,2).EC.5.0)GO TC 50
C  THE HATCH CHECK
   10  IF(PLARVA(I,4).GE.PLARVA(I,5))PLARVA(I,2)=2.0
       IF(PLARVA(I,2).EQ.2.0)PLARVA(I,4)=0.0
       IF(PLARVA(I,2).EQ.2.0)EGGCHK(I)=PLARVA(I,1)
       GO TO 100
C  HAS THE YOLK SA CBEEN RESORBED?
   20  IF(PLARVA(I,4).GE.PLARVA(I,6))PLARVA(I,2)=3.0
       IF(PLARVA(I,2).EC.3.0)PLARVA(I,4)=0.0
       GO TO 100
C  ARE THE LARVAE STILL ADAPTING TC FREEFEEDING?
   30  IF(PLARVA(I,4).GE.PLARVA(I,7))PLARVA(I,2)=4.0
       IF(PLARVA(I,2).EC.4.0)PLARVA(I,4)=0.0
       GO TO 100
C  ARE THE LARVAE STILL PLANKTCNIC?
   40  IF(PLARVA(I,4).GE.PLARVA(I,8))PLARVA(I,2)=5.0
       IF(PLARVA(I,2).EQ.5.0)PLARVA(I,4)=0.0
       GO TO 100
C  ARE THE DEMERSAL JUVENILES 1 YEAR CLD?
   50  IF(PLARVA(I,3).LT.36C.0)GO TO 10C
       RECRUT=RECRUT+PLARVA(I,1)
       PLARVA(I,1)=0.0
       PLARVA(I,2)=C.0
       PLARVA(I,3)=0.0
       PLARVA(I,4)=0.0
  100  CONTINUE
       RETURN
       END
C*************************************
       SUBROUTINE TEMP(IDAY,DEGC)
C*************************************
       DEGC=6.0
C       EVENTUALLY PUT IN WEEKLY OR MONTHELY AVERAGES FOR
C       GEORGES BANK.
        RETURN
       END
C*************************************


       SUBROUTINE TOXIC(STAGE,IDAY)
C*******************************************
       COMMCN /SPILL/ SPILYR,SPILCA,SPILON,SPILAT,IADV,IDALST,SPLTYP,
     $                SPLMAG
       INTEGER SPILYR,SPILCA , IDALST, SPLTYP
       COMMON /LINK/ PLVOLD(365), PLVTOX(365), OILCCN(148),
     $               XOILMN,XOILMX,YOILMN,YOILMX
     $                ,XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
       REAL LRVSUM(365)
       COMMON /LOGIC/ DCSPWN,OIL
       LOGICAL DOSPWN,OIL
       COMMCN /I2ARR/ ICCN,IEN,INC,INOD,IELP,ITMP
       INTEGER*2 ICCN(2,251),IEN(3,251),INO(3400),INOD(2,153)
       INTEGER*2 IELP(2C19),ITMP(2,2019)
       COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
       REAL*4 PART(7,2019),CATN(3,153),RSLP(3,251),SVEL(3,153)
       REAL*4 PRTCLD(2,2019),UVNET(2,153)
       CCMMCN /L1ARR/ SGNDY,SGNPT
       LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
       CCMMCN /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IOP,IPOND,INTKA,INTKB,NPLT,
     *                NWPT,IATKI,NVR,NVRC,ISTRT,JPLT,NKLT,
     *                IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
       COMMCN /L1VAR/ TF
       COMMCN /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *                XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNLI,VNET,
     *                APX,APY,ARW,APH,ARA,TWKI,IPLT,DTWKI,DTPLT,
     *                DT,TIME,TIMEV,RKA,RNB,HGT,SFX,SFY,XUFF,YUFF
C
C
       COMMCN/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $ FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
       COMMCN /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $                  VRMASS(79), WTCALC(18), EXFM(18),EXPF(18),
     $                   RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
       COMMON /BLWOUT/ CONC(398,3),NUMELM,THRSLD,DX,DY,IDAYZ(12)
CFILE 3 WILL BE THE OIL CCNCENTRATICNS
CREMOVE THE NATURAL MORTALITY EFFECTS
       IF(NP.EQ.0)GO TO 283
       DO 200 I=1,NP
       J=PART(7,I)
       IF(J.EQ.ICAY)GC TC 200
       IF(PLVOLD(J).EC.0.0)GC TO 20C
       IF(PLARVA(J,1).LE.1.0)GC TO 2C0
       PART(3,I)=PART(3,I)*PLARVA(J,1)/PLVOLD(J)
  200  CCNTINUE
       IF(IACV.EQ.1)GC TO 283
       IF(NSPIL.EQ.0)GO TO 283
CGO THRU ALL PARTICLES, CHECKING FCR OIL AT THEIR LOCATIONS,
CCHECKING STAGE, APPLYING MORTALITIES, AND UPDATING BOTH
CPART(7,2019) AND PLARVA(365,10).
       DO 100 I=1,NP
       IF(PART(7,I).EC.0.0)GO TO 100
```

```
       IF(PLARVA(PART(7,I),2).EC.5.C)GO TO 100
       IF(.NOT.SGNPT(I))GC TO 100
CWE'LL WHECK TC SEE IF PART(1,I) AND PART(2,I)
CPUT THE CLUSTER IN THE OILSPILL. THAT'LL GIVE US A FIRST
CCRACK GUESS.
       IF(NSPIL.EC.0)GO TO 100
       IMDED=0
       IF(SPLTYP.EC.2)GC TO 210
       IF(PART(1,I).GE.XOILMN.AND.PART(1,I).LE.XOILMX.
     $          AND.PART(2,I).GE.YOILMN.AND.PART(2,I).LE.YOILMX)
     $           IMDED=1
       GO TC 218
CCHECK ALL THE CELLS
  210  DO 212 JJ=1,NUMELM
       IF(CONC(JJ,3).LT.THRSLD)GC TO 212
       XLCW=CCNC(JJ,1)-DX/2.
       XHI =CONC(JJ,1)+DX/2.
       YLOW=CCNC(JJ,2)-DY/2.
       YHI = CONC(JJ,2)+DY/2.
       IF(XLOW.LE.PART(1,I).AND.XHI.GE.PART(1,I).
     $  AND.YLOW.LE.PART(2,I).AND.YHI.GE.PART(2,I))IMDED=1
       IF(IMDED.EQ.1)GO TC 222
  212  CONTINUE
  218  CONTINUE
CA LITTLE LOOP TO SEE IF CNE OF THE SPILLETS GOT HIM.......
       IF(IMDED.EQ.1)GO TO 222
       DO 220 JAKE=1,NSPIL
       XLOW=XOSPIL(JAKE)-ROSPIL(JAKE)
       XHI=XOSPIL(JAKE)+ROSPIL(JAKE)
       YLOW=YOSPIL(JAKE)-RCSPIL(JAKE)
       YHI=YOSPIL(JAKE)+RCSPIL(JAKE)
       IF(PART(1,I).GE.XLOW.AND.PART(1,I).LE.XHI.
     $ AND.PART(2,I).GE.YLCW.AND.PART(2,I).LE.YHI)IMDED=1
       IF(IMDED.EC.1)GO TO 222
  220  CONTINUE
  222  CONTINUE
       IF(IMDED.EQ.0)GO TO 100
       IF(IMDED.EQ.1)SGNPT(I)=.FALSE.
       IF(IMDED.EC.1)PLVTOX(PART(7,I))=PLVTOX(PART(7,I)) +
     $          PART(3,I)
       IF(IMDED.EC.1)PLARVA(PART(7,I),1)=PLARVA(PART(7,I),1) -
     $          PART(3,I)
       I1=IFIX(PART(7,I))
       I2=IFIX(PLARVA(I1,2))
       IF(IMDED.EQ.1)WRITE(6,800)I1,I2,IELP(I),
     $          PART(3,I)
  800  FORMAT(4X,' OILED: A CLUSTER SPAWNED ON CAY ',I4,' NOW IN STAGE ',
     $ I4,' AND IN ELEMENT NUMBER ',I4,' REPRESENTING ',E12.4,
     $' ICHTHYOPLANKTCN ')
CIF NO OIL, GO TC 100
COTHERWISE, DO MORTALITY UPDATES
CBE SURE SUM OF LARVAE IN PART FOR A GIVEN DAY


CIS SAME AS PLARVA(THAT DAY,1).
  100  CONTINUE
CNOW SEE THAT THE TOTALS FCR A GIVEN DAY ARE EQUAL
  283  CCNTINUE
       DO 240 I=1,365
  240  LRVSUM(I)=0.0
       IF(NP.EQ.0)GC TO 281
       DO 250 I=1,NP
       IF(.NOT.SGNPT(I))GO TO 250
       J=PART(7,I)
       LRVSUM(J)=LRVSUM(J) + PART(3,I)
  250  CONTINUE
       DO 255 J=1,365,1C
       IF(PLARVA(J,2).EQ.5.)GC TO 255
       IF(ABS(LRVSUM(J)-PLARVA(J,1)).GT.(PLARVA(J,1)/1000.0))
     $ WRITE(6,811)LRVSUM(J), PLARVA(J,1),J
  811  FORMAT('     LRVSUM IS ',E12.4, ' AND PLARVA ENTRY IS ',E12.4,
     $ '   FCR CAY ',I4)
  255  CONTINUE
CSAVE THE NUMBER FRCM TOCAY FOR TCMORROW'S MORTALITY TRANSFERR
  281  CCNTINUE
       DO 28C I=1,365
       PLVOLD(I)=PLARVA(I,1)
  280  CONTINUE
       RETURN
       END
C*************************************************
       SUBROUTINE VERTOS
       RETURN
       END
C*************************************************
       SUBROUTINE MCCONC(KYEAR,IDAY)
C
CREADS THE OIL CONCENTRATICNS, AND WRITES THEM OUT TC
CDATA SET 4 ALCNG WITH THE PRESENT LARVAL CONCENTRATIONS,
C FOR EVERY CAY OF THE SPILL
       CCMMON /SPILL/ SPILYR,SPILCA,SPILON,SPILAT,IADV,IDALST,SPLTYP,
     $                SPLMAG
       COMMCN /LINK/ PLVOLD(365), PLVTOX(365), OILCCN(148),
     $               XOILMN,XOILMX,YOILMN,YOILMX
     $                ,XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
       COMMON /LOGIC/ DOSPWN,OIL
       LOGICAL DOSPWN,OIL
       COMMCN /I2ARR/ ICCN,IEN,INC,INOD,IELP,ITMP
       INTEGER*2 ICCN(2,251),IEN(3,251),IND(3400),INOD(2,153)
       INTEGER*2 IELP(2C19),ITMP(2,2019)
       COMMCN /R4ARR/ PART,CATA,RSLP,SVEL,PRTOLD,UVNET
       REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
       REAL*4 PRTOLD(2,2019),UVNET(2,153)
       CCMMCN /L1ARR/ SGNCY,SGNPT
       LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
       COMMCN /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IOP,IPCND,INTKA,INTKB,NPLT,
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     *                NWPT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *                IPLT,ISTOP,ISFED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/  TF
      COMMON /R4VAR/  UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *                XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *                ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DT=RT,DTPLT,
     *                DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $ FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $                 YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $                  RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
      INTEGER IDALST,SPLTYP,SPILYR,SPILCA,IDAY,ICNT/0/,I2CNT/0/
      IF(.NOT.OIL)RETURN
      IF(KYEAR.EQ.SPILYR.AND.IDAY.LT.SPILCA)RETURN
      IF(KYEAR.GE.SPILYR)GO TO 1
      RETURN
    1 CONTINUE
CREAD IN THE DAY, THE OIL MODEL DAY, NUMBER OF SPILLETS
      OFFSET=4.0*COS(39.0*3.14159/180.0)
      READ(3,END=1000)IDAY1,IDAY2,NSPIL
      WRITE(6,800)IDAY1,IDAY2,NSPIL
  800 FORMAT(' ',//,'  IDAY  IS', I4,'  IT HAS BEEN ',I4,'DAYS SINCE ',
     $ 'THE SPILL. THE NUMBER OF SPILLETS IS', I4,//)
CTHE CENTER AND RADIUS OF EACH
      WRITE(6,803)
  803 FORMAT(' ',///,'  SPILLET   XLO C  YLO C  RADIUS')
      DO 12 I=1,NSPIL
      READ(3,END=1000)XOSPIL(I),YOSPIL(I),ROSPIL(I)
      XOSPIL(I)=(68.0-XOSPIL(I))*COS(3.14159*YOSPIL(I)/180.0)
     $ + OFFSET
      YOSPIL(I)=YOSPIL(I)-39.0
      ROSPIL(I)=ROSPIL(I)/1.11E+05
C60 NM PER INCH (MODEL UNITS) = 1.11E5 METERS PER INCH
      WRITE(6,801)I,XOSPIL(I),YOSPIL(I),ROSPIL(I)
  801 FORMAT(' ',I4,3F12.4)
   12 CONTINUE
CREAD IN THE SUBSURFACE PARTICLE LIMITS
      READ(3,END=1000)XOILMN,XOILMX,YOILMN,YOILMX,AREA
CAREA IN SQ KILOMETERS;  60 N M PER INCH MEANS
C12347.7 SQ KM PER SQ INCH (SQ MAP UNITS)
      AREA=AREA/12347.7
      SCALE=COS(3.14159*(YOILMN+YOILMX)/360.0)
      XOILMN=SCALE*(68.0-XOILMN) + OFFSET
      XOILMX=SCALE*(68.0-XOILMX) + OFFSET
      YOILMN=YOILMN-39.0
      YOILMX=YOILMX-39.0
      WRITE(6,814)IDAY,XOILMN,XOILMX,YOILMN,YOILMX
  814 FORMAT(' ',//,'  IDAY IS ',I4,' AND THE VALUES OF',
     $' XOILMN,XOILMX,YOILMN,YOILMX ARE',4F8.3,//)

CNOW CHECK TO SEE THAT WE'RE NOT EXCEEDING THE STIPULATED AREA
      ARCALC=(XOILMX-XOILMN)*(YOILMX-YOILMN)
      WRITE(6,820)ARCALC,AREA
  820 FORMAT(//,'      THE CALCULATED AREA IS',F12.5,'  MAP UNITS',
     $', AND SHOULD BE', F12.5)
      DELTA=SQRT(AREA)/2.0
      CX=(XOILMX+XOILMN)/2.0
      CY=(YOILMN+YOILMX)/2.0
      XOILMX=CX+DELTA
      XOILMN=CX-DELTA
      YOILMN=CY-DELTA
      YOILMX=CY+DELTA
CNOW WRITE TO DATA SET 4 TODAY'S LARVAL AND OIL DISTRIBUTIONS
      IF(I2CNT.GT.0)GO TO 10
      I2CNT=1
      WRITE(4,810)SPILYR,SPILDA,SPILON,SPILAT,IADV,IDALST,SPLTYP,THRSLD
  810 FORMAT(2I5,2F6.2,3I4,E10.3)
   10 WRITE(4,811)IDAY,XOILMN,XOILMX,YOILMN,YOILMX,NP
  811 FORMAT(I4,4F8.3,I4)
      WRITE(4,811)NSPIL
      DO 30 I=1,NSPIL
      WRITE(4,813)XOSPIL(I),YOSPIL(I),ROSPIL(I)
  813 FORMAT(3F10.5)
   30 CONTINUE
      DO 20 I=1,NP
      IMDUM=PART(7,I)
      WRITE(4,812)(PART(J,I),J=1,3),IMDUM,IELP(I)
  812 FORMAT(2F8.4,E11.4,2I4)
CXLOC, YLOC, #, DAY SPAWNED, ELEMENT NUMBER
   20 CONTINUE
      RETURN
 1000 ICNT=1
      XOILMN=100.0
      XOILMX=-100.0
      YOILMN=100.0
      YOILMX=-100.0
      OIL=.FALSE.
      NSPIL=0
      WRITE(6,802)SPILCA,IDAY
  802 FORMAT(//,'      THE OILSPILL BEGAN ON DAY',I5,
     $ ', AND ITS DIRECT EFFECTS ON THE FISHERY ENDED ON DAY',I5,'.',//)
      RETURN
      END
C**************************************************************
      SUBROUTINE OUTPUT(YIELD,B,F,EM,IYR)
CWRITES ON THE PRINTER, AND ALSO OUTPUTS CATCH DATA TO
CDIS CALCNG WITH OILSPILL CASE IDENTIFICATION DATA.
CTHIS IS DONE VIA DATA SET 8.
C**************************************************************
      COMMON /SPILL/ SPILYR,SPILCA,SPILON,SPILAT,IADV,IDALST,SPLTYP,
     $                SFLMAG
      COMMON /LINK/ PLVOLU(365), PLVTOX(365),OILCON(148),
     $                XOILMN,XOILMX,YOILMN,YOILMX
     $                 ,XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL DOSPWN,OIL
      COMMON /I2ARR/ ICON,IEN,INC,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNK
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPCND,INTKA,INTKB,NPLT,
     *                NWPT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *                IPLT,ISTOP,ISFED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/  TF
      COMMON /R4VAR/  UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *                XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *                ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DT=RT,DTPLT,
     *                DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $ FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $                 YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $                  RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
      COMMON /BLWOUT/ CONC(398,2),NUMFLM,THRSLD,DX,DY,IDAYZ(12)
      INTEGER ICNT/0/,SPILYR,SPILCA,IDALST,SPLTYP
      IF(ICNT.GT.0)GO TO 1
      ICNT=1
      WRITE(8,800)SPLTYP,SPILCA,THRSLD
  800 FORMAT(2I4,E10.3)
      WRITE(6,801)SPILYR,SPILDA,IADV,IDALST,SPLTYP,THRSLD
  801 FORMAT(2X,//,' SPILYR = ',I4,' SPILDA = ',I4,
     $ ' IADV = ',I4,' IDALST = ',I4,' SPLTYP = ',I4,
     $ ' THRSLD = ',E10.3, '  PARTS PER BILLION')
    1 CONTINUE
      WRITE(6,2)IYR
    2 FORMAT('1',40X,'YEAR',I7)
      WRITE(6,5)
    5 FORMAT('     ')
      WRITE(6,4)
    4 FORMAT(4X,'AGE GROUP',10X,'SIZE',10X,'FISHING MORTALITY'
     $,4X,'NATURAL MORTALITY')
      DO 30 I=2,18
      J=I-1
      EF=F*SEL(I)
      WRITE(6,6)J,POPNEW(I),EF,EM
    6 FORMAT(8X,I2,8X,E10.4,14X,F6.3,14X,F6.2)
   30 CONTINUE
      WRITE(6,5)

      WRITE(6,7)
    7 FORMAT(4X,'AGE GROUP',7X,'TOTAL BIOMASS LOST',5X,
     $'CONTRIBUTION TO CATCH')
      WRITE(6,8)
    8 FORMAT(24X,'(KG)',18X,'(KG)       PERCENT')
      DO 60 I=2,18
      J=I-1
      WLOST=WTDIST(I)*((F*SEL(I)+EM)/(F*SEL(I)))
      PCNT=WTDIST(I)/YIELD
      WRITE(6,9)J,WLOST,WTDIST(I),PCNT
    9 FORMAT(8X,I2,15X,F10.4,9X,E10.4,5X,F5.3)
   60 CONTINUE
      CACH=YIELD/1.0E6
      WRITE(6,5)
      WRITE(8,802)IYR,CACH
  802 FORMAT(I4,F7.3)
      WRITE(6,12)CACH
   12 FORMAT(' THE ANNUAL YIELD IS',F10.3,' THOUSAND METRIC TONS')
      RETURN
      END
C*****************************************************
      SUBROUTINE EGGMRT(EM10,EM11,T1,T2,IDAY,DELTAT)
C*****************************************************
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $  FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      INTEGER ICOUNT/0/
      IF(ICOUNT.EQ.0)GO TO 1
      GO TO 2
    1 EXPON=EXP(EM11*DELTAT/365.0)
      ICOUNT=1
    2 DO 30 I=1,365
      IF(PLARVA(I,2).NE.1.0.AND.PLARVA(I,2).NE.2.0)GO TO 30
      IF(PLARVA(I,1).LT.1.0)PLARVA(I,1)=0.0
      IF(PLARVA(I,1).EQ.0.0)PLARVA(I,2)=0.0
      IF(PLARVA(I,1).EQ.0.0)GO TO 30
      IF(T1.EQ.0.0.AND.T2.EQ.0.0)GO TO 4
      GO TO 6
    4 PLARVA(I,1)=PLARVA(I,1)/(((EM10/EM11)*PLARVA(I,1)*
     $ (EXPON-1.0))+EXPON)
      GO TO 30
C HERE TO DEAL WITH TOXICITY
    6 IF(PLARVA(I,2).EQ.1.0)Z11=EM11+T1
      IF(PLARVA(I,2).EQ.2.0)Z11=EM11+T2
      EXPONE=EXP(Z11*DELTAT/365.0)
      PLARVA(I,1)=PLARVA(I,1)/(((EM10/Z11)*PLARVA(I,1)*
     $ (EXPONE-1.0)) + EXPONE)
   30  CONTINUE
      RETURN
      END
C*****************************************************
      SUBROUTINE PLNMRT(EM12,EM13,T3,T4,IDAY,DELTAT)
C*****************************************************
```

```
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $  FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      INTEGER ICOUNT/0/
      IF(ICOUNT.EQ.0)GO TO 1
      GO TO 2
    1 EXPON=EXP(EM12*DELTAT/365.0)
      ICOUNT=1
    2 DO 30 I=1,365
      IF(PLARVA(I,2).NE.3.0.AND.PLARVA(I,2).NE.4.0)GO TO 30
      IF(PLARVA(I,1).LT.1.0)PLARVA(I,1)=0.0
      IF(PLARVA(I,1).EQ.0.0)PLARVA(I,2)=0.0
      IF(PLARVA(I,1).EQ.0.0)GO TO 30
      IF(T3.EQ.0.0.AND.T4.EQ.0.0)GO TO 4
      GO TO 6
    4 PLARVA(I,1)=PLARVA(I,1)/(((EM13/EM12)*PLARVA(I,1)*
     $ (EXPON-1.0))+EXPON)
C   MIGHT THAT BE NEGATIVE??
      GO TO 30
    6 IF(PLARVA(I,2).EQ.3.0)Z12=EM12+T3
      IF(PLARVA(I,2).EQ.4.0)Z12=EM12+T4
      EXPONE=EXP(Z12*DELTAT/365.0)
      PLARVA(I,1)=PLARVA(I,1)/(((EM13/Z12)*PLARVA(I,1)*(EXPONE-1.0))
     $ + EXPONE)
C NEGATIVE VALUES POSSIB;LE??
      WRITE(6,40)ICAY,EXPON,EXPONE
   40 FORMAT(' PLMMRT      ',I10,4X,E10.4,4X,E10.4)
   30 CONTINUE
      RETURN
      END
C**********************************************************
      SUBROUTINE BTMMRT(Z,EM14,EM15,EM16,IDAY,DELTAT)
C**********************************************************
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $  FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      DO 30 I=1,365
      IF(PLARVA(I,2).NE.5.0)GO TO 30
      IF(PLARVA(I,1).EQ.0.0)GO TO 30
C   SAVE TIME WITH DUMMY VARIABLES
      A=EM14+(EM15*PLARVA(I,1))+(EM16*SUMPN)
      DT=DELTAT/365.0
      PLARVA(I,1)=PLARVA(I,1)*(1.0-(A*DT)+(((A*A)+
     $   (EM15*A*PLARVA(I,1)) + (EM16*Z*SUMPN))*DT*DT/2.0))
C   NOTE: IN THE PREVIOUS LINE, Z*SUMPN SHOOULD REALLY BE
C             SUM OF P(I)*Z(I)*N(I) IF YOU KNOW WHAT I MEAN....
   30 CONTINUE
      RETURN
      END
      SUBROUTINE REDIST
      RETURN
      END
C
      SUBROUTINE MATCH(TEMP,DAYS)

      DAYS=-9.957*ALOG((TEMP + 0.3391)/31.952)
      RETURN
      END
      SUBROUTINE SPNPLC(IDAY)
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL DOSPWN,OIL
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,CATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),CATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTCLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPOND,INTKA,INTKB,NPLT,
     *               NWAT,INTKT,NVR,NVRC,ISTRT,JPLT,NACT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTY,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARM,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $ FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $                VRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $                  RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
      INTEGER ICNT/0/
      IF(NP.EQ.NPMAX)RETURN
      IF(.NOT.DOSPWN)RETURN
      IF(ICNT.GT.0)GO TO 10
      READ(9,800)NGRPS
  800 FORMAT(7X,I3)
      READ(9,805)XCLOC,YCLOC,RADIUS
  805 FORMAT(3(7X,F6.3))
CXCLOC,YCLOC (IN LONG, LAT ) RADIUS IN MAP UNITS (INCHES)
      XCLOC=(68.0-XCLOC)*COS(YCLOC*3.14159/180.0)
      XCLOC=XCLOC + 4.0*COS(39.0*3.14159/180.0)
      YCLOC=YCLOC-39.0
      WRITE(6,810)NGRPS,XCLOC,YCLOC,RADIUS
  810 FORMAT(//,2X,'NGRPS= ',I4,'  XCLOC= ',F10.5,'  YCLOC= ',
     $  F10.5,' RADIUS= ',F10.5,//)
      RADSQ=RADIUS*RADIUS
      ICNT=1
   10 CONTINUE
CPART(7,2019):
C             1  XCLOCATION OF THE PARTICLE
C             2  Y LOCATION
C             3  NUMBER OF LARVAE OR EGGS
C             4  AVG NCON OF TOXIN TO WHICH THIS GROUP HAS BEEEN EXPSD
C             5  PEAK CONC
C             6  EXPOSURE DURATION
C             7  DAY SPAWNED (FOR KEYING IN TO PLARVA MATRIX)
      XNUM=PLARVA(IDAY,1)/FLOAT(NGRPS)
      DO 30 I=1,NGRPS
      NP=NP+1
   15 CALL RANDU(YFLT1,RADIUS)
      CALL RANDU(YFLT2,RADIUS)
      PART(1,NP)=XCLOC + YFLT1
      PART(2,NP)=YCLOC + YFLT2
      PART(3,NP)=XNUM
      PART(4,NP)=0.0
      PART(5,NP)=0.0
      PART(6,NP)=0.0
      PART(7,NP)=ICAY
      SGNPT(NP)=.TRUE.
      ITMP(1,NP)=ICAY
      IF(NP.EQ.NPMAX)RETURN
   30 CONTINUE
      RETURN
      END
C
      SUBROUTINE RANDU(YFLT,RADIUS)
C
      INTEGER ICNT/0/
      IF(ICNT.GT.0)GO TO 2
      ICNT=1
      IXX=73543
    2 IYY=IXX*65539
      IF(IYY)5,6,6
    5 IYY=IYY + 2147483647+ 1
    6 YFLT=IYY
      YFLT=YFLT*0.4656613E-09
      IXX=IYY
      YFLT=(YFLT-0.5)*RADIUS
      RETURN
      END
C
      SUBROUTINE MCCON2(KYEAR,IDAY)
C
CREADS THE OIL CONCENTRATIONS, AND WRITES THEM OUT TO
CDATA SET 4 ALONG WITH THE PRESENT LARVAL CONCENTRATIONS
C FOR EVERY DAY OF THE SPILL
C*****************************************************************
      COMMON /SPILL/ SPILYR,SPILDA,SPILON,SPBLAT,IADV,IDALST,SPLTYP,
     $               SPLMAG
      COMMON /LINK/ PLVOLD(365), PLVTOX(365), OILCON(148),
     $              XOILMN,XOILMX,YOILMN,YOILMX
     $                ,XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL DOSPWN,OIL
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP


      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,CATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),CATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTCLD(2,2019),UVNET(2,153)
      COMMON /L1APR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPOND,INTKA,INTKB,NPLT,
     *               NWAT,INTKT,NVR,NVRC,ISTRT,JPLT,NACT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTY,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARM,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $ FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $                VRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $                  RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
      INTEGER IDALST,SPLTYP,SPILYR,SPILDA,IDAY,ICNT/0/,I2CNT/0/
      COMMON /BLKOUT/ CONC(398,3),NUMELM,THPSLD,DX,DY,IDAYZ(12)
      IF(.NOT.OIL)RETURN
      IF(KYEAR.EQ.SPILYR.AND.ICAY.LT.SPILDA)RETURN
      IF(KYEAR.GE.SPILYR)GO TO 1
      RETURN
    1 CONTINUE
CREAD IN THE DAY, THE OIL MODEL DAY, NUMBER OF SPILLETS
      OFFSET=4.0*COS(39.0*3.14159/180.0)
      THRSLC=50.0
      READ(3,END=1000)IDAY1,IDAY2,NSPIL
      WRITE(6,800)IDAY1,IDAY2,NSPIL
  800 FORMAT(' ',//,'  ICAY  IS', I4,'  IT HAS BEEN ',I4,'DAYS SINCE ',
     $ 'THE SPILL. THE NUMBER OF SPILLETS IS', I4,//)
C
CTHE CENTER AND RADIUS OF EACH
      WRITE(6,803)
  803 FORMAT(' ',///,'  SPILLET   XLOC   YLOC   RADIUS')
      DO 12 I=1,NSPIL
      READ(3,END=1000)XOSPIL(I),YOSPIL(I),ROSPIL(I)
      XOSPIL(I)=(68.0-XOSPIL(I))*COS(3.14159*YOSPIL(I)/180.0)
     $ + OFFSET
      YOSPIL(I)=YOSPIL(I)-39.0
      ROSPIL(I)=ROSPIL(I)/1.11E+05
C60 NM PER INCH (MODEL UNITS) = 1.11E5 METERS PER INCH
      WRITE(6,801)I,XOSPIL(I),YOSPIL(I),ROSPIL(I)
  801 FORMAT(' ',I4,3F12.4)
   12 CONTINUE
CREAD IN THE SUBSURFACE PARTICLE LIMITS
      READ(3,END=1000)XOILMN,XOILMX,YOILMN,YOILMX,DX,DY,NUMELM
```

```
      DX=DX/1.111E+05
      DY=DY/1.111E+05
      SCALE=COS(3.14159*(YOILMN+YOILMX)/360.0)
      XOILMX=SCALE*(68.0-XOILMX) + OFFSET
      YOILMN=YOILMN-39.0
      YOILMX=YOILMX-39.0
      WRITE(6,814)IDAY,XOILMN,XOILMX,YOILMN,YOILMX
 814  FORMAT(' ',//,'  IDAY IS ',I4,' AND THE VALUES OF',
     &' XOILMN,XOILMX,YOILMN,YOILMX ARE',4F8.3,//)
      CMAX=0.0
      DO 14 I=1,NUMELM
      READ(3,END=1000)(CONC(I,JK),JK=1,3)
      X=68.0-CONC(I,1)
      Y=CONC(I,2)-39.0
      DEG=CONC(I,2)*3.14159/180.0
      CONC(I,1)=X*COS(DEG) + OFFSET
      IF(CONC(I,3).GT.CMAX)CMAX=CONC(I,3)
  14  CONTINUE
      WRITE(6,806)CMAX
 806  FORMAT(//,' THE MAXIMUM SUBSURFACE CONCENTRATION IS ',
     &  F10.2,' PARTS PER BILLION ABOVE BACKGROUND LEVELS.',//)
      WRITE(6,807)NUMELM,DX,DY
 807  FORMAT('     THERE ARE',I5,' ELEMENTS OUT THERE, WITH GRID',
     & ' SPACING DX,DY = ',2E10.3, 'MAP UNITS.')
CNOW WRITE TO DATA SET 4 TODAY'S LARVAL AND OIL DISTRIBUTIONS
      DO 9 I=1,12
      IF(IDAY.EQ.IDAYZ(I))GO TO 11
   9  CONTINUE
      RETURN
  11  CONTINUE
      IF(I2CNT.GT.0)GO TO 10
      I2CNT=1
      WRITE(4)SPILYR,SPILDA,IADV,IDALST,SPLTYP, THRSLD
  10  WRITE(4)IDAY,XOILMN,XOILMX,YOILMN,YOILMX,NP,DX,DY,NUMELM
      WRITE(4)NSPIL
      DO 30 I=1,NSPIL
      WRITE(4)XOSPIL(I),YOSPIL(I),ROSPIL(I)
  30  CONTINUE
      DO 35 I=1,NUMELM
  35  WRITE(4)(CONC(I,JK),JK=1,3)
      DO 20 I=1,NP
      IMDUM=PART(7,I)
      IF(IMDUM.LT.1.OR.IMDUM.GT.365)GO TO 41
      IMDUM=IFIX(PLARVA(IMDUM,2))
      GO TO 42
  41  IMDUM=5
  42  CONTINUE
      WRITE(4)(PART(J,I),J=1,3),IMDUM,PART(7,I)
CXLOC, YLOC, #, DAY SPAWNED, ELEMENT NUMBER
  20  CONTINUE
 900  RETURN
1000  ICNT=1


      XOILMN=100.0
      XOILMX=-100.0
      YOILMN=100.0
      YOILMX=-100.0
      OIL=.FALSE.
      NSPIL=0
      WRITE(6,802)SPILDA,IDAY
 802  FORMAT(//,'      THE OILSPILL BEGAN ON DAY',I5,
     & ', AND ITS DIRECT EFFECTS ON THE FISHERY ENDED ON DAY',I5,'.',//)
      RETURN
      END
C*************************************************
      SUBROUTINE DSCWRT(IDAY)
C*************************************************
      COMMON /LINK/ PLVOLD(365), PLVTOX(365),OILCON(148),
     &              XOILMN,XOILMX,YOILMN,YOILMX
     &              ,XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL DOSPWN,OIL
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IOP,IPCND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPULD(18),
     & FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     &               YRMASS(79), WTCALC(18), EXFM(18),EXPF(18),
     &                RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
      COMMON /BLWOUT/ CONC(398,3),NUMELM,THRSLD,DX,DY,IDAYZ(12)
      INTEGER INTRC/0/
      IF(NP.EQ.0)RETURN
      IF(INTRO.GT.0)GO TO 11
      INTRC=1
      READ(16,881)(IDAYZ(I),I=1,12)
 881  FORMAT(12(I4,1X))
  11  CONTINUE
      DO 12 I=1,12
      IF(IDAYZ(I).EQ.IDAY)GO TO 10
  12  CONTINUE
      RETURN
  10  CONTINUE
      WRITE(6,798)IDAY
 798  FORMAT('1',///,'  HERE IS THE DISTRIBUTION FOR DAY ',I4)
      WRITE(6,797)IDAY
 797  FORMAT(//,'  DAY',I8,' : LARVAL DISTRIBUTION WRITTEN TO',
     &' DISC.',//)
      WRITE(6,799)
 799  FORMAT(//,'  DAY',T12,'XLOC      YLOC',
     &T30,'NUMBER ',T4C,'DAY SPAWNED',2X,'STAGE',2X,' ELEMENT')
      DO 50 I=1,NP
      WRITE(2,800)IDAY,(PART(J,I),J=1,3),PART(7,I),
     & PLARVA(PART(7,I),2),IELP(I)
 800  FORMAT(2X,I4,2(2X,F7.5),2X,E12.5,2X,F7.2,2X,F7.2,2X,I4)
  50  CONTINUE
      RETURN
      END
      SUBROUTINE ADVDIF(IDAY,NPTMAX,IOFF)
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      INTEGER INTRC/0/
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IOP,IPCND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
      IF(INTRO.GT.0)GO TO 100
      CALL FEREAD
      CALL VAREAD
      CALL VARSET
      CALL CHECK
 100  CONTINUE
      INTRC=INTRO + 1
      WRITE(6,200)INTRC
 200  FORMAT(//,' THIS IS ENTRY NUMBER',
     & I4,' TO SUBROUTINE ADVDIF.')
      IF(NP.GT.NPTMAX)NPTMAX=NP
      IF(NP.NE.0)GO TO 300
      NRCT=0
      NOUT=0


      CALL SPNPLC(IDAY)
        IF(NP.GT.NPTMAX)NPTMAX=NP
 300  CONTINUE
      CALL MOVE(INTRO,IDAY)
      IF(NP.GT.NPTMAX)NPTMAX=NP
      CALL DEAD(IOFF)
      CALL COMPRS
      CALL DSCWRT(IDAY)
      RETURN
      END
      SUBROUTINE MOVE(INTRC,IDAY)
C    SUBROUTINE MOVE(INTRO,IDAY) IS THE MAIN SUBROUTINE WHICH ADVECTS
C    AND DIFFUSES THE PARTICLES
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL DOSPWN,OIL
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IOP,IPCND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
      IF(INTRO.GT.1)GO TO 5
      NRCT = 0
      NOUT = 0
      DEPMIN = 15.
      DEPMAX = 25.
      DEPSLP = 1./(DEPMAX - DEPMIN)
      UPD = 0.0
      VPD = 0.0
   5  CONTINUE
      IF(NP.EQ.0)RETURN
C
C     TIME LOOP
C
      DO 1000 IT=1,NT
      CALL VELIN(IDAY)
C
C   ADD NEW LARVAE
      IF(DOSPWN)CALL SPNPLC(IDAY)
      IF(NP.EQ.0) GO TO 3000
      DO 2000 IP=1,NP
      IF(.NOT.SGNPT(IP)) GO TO 2000
```

```
C
C     FIND ELEMENT WHERE PARTICLE IS LOCATED
C
C
C     CHECK SAME ELEMENT
C
      IE = IELP(IP)
      DO 11 I=1,3
      IN = IEN(I,IE)
      DXSP = (PART(2,IP) - DATN(2,IN))*RSLP(I,IE)
     *                   - (PART(1,IP) - DATN(1,IN))
      SGNX = .TRUE.
      IF(DXSP) 21,31,31
   21 CONTINUE
      SGNX = .FALSE.
   31 CONTINUE
      IF(SGNX.AND..NOT.SGNDY(I,IE)) GO TO 41
      IF(.NOT.SGNX.AND.SGNDY(I,IE)) GO TO 41
   11 CONTINUE
      GO TO 30
C
C     CHECK SURROUNDING ELEMENTS
C
   41 CONTINUE
      IST = ICON(1,IE)
      IFN = ICON(2,IE)
      DO 10 L=IST,IFN
      IE = IND(L)
      DO 12 I=1,3
      IN = IEN(I,IE)
      DXSP = (PART(2,IP) - DATN(2,IN))*RSLP(I,IE)
     *                   - (PART(1,IP) - DATN(1,IN))
      SGNX = .TRUE.
      IF(DXSP) 22,32,32
   22 CONTINUE
      SGNX = .FALSE.
   32 CONTINUE
      IF(SGNX.AND..NOT.SGNDY(I,IE)) GO TO 10
      IF(.NOT.SGNX.AND.SGNDY(I,IE)) GO TO 10
   12 CONTINUE
      IELP(IP) = IE
      GO TO 30
   10 CONTINUE
C
C     CHECK ALL ELEMENTS
C
      DO 20 IE=1,NE
      DO 13 I=1,3
      IN = IEN(I,IE)
      DXSP = (PART(2,IP) - DATN(2,IN))*RSLP(I,IE)
     *                   - (PART(1,IP) - DATN(1,IN))
      SGNX = .TRUE.


      IF(DXSP) 23,33,33
   23 CONTINUE
      SGNX = .FALSE.
   33 CONTINUE
      IF(SGNX.AND..NOT.SGNDY(I,IE)) GO TO 20
      IF(.NOT.SGNX.AND.SGNDY(I,IE)) GO TO 20
   13 CONTINUE
      IELP(IP) = IE
      GO TO 30
C
C     POINT OUTSIDE ALL ELEMENTS
C
   20 CONTINUE
      SGNPT(IP) = .FALSE.
      ITMP(2,IP) = IDAY
      NOUT = NOUT + 1
      XP = PART(1,IP) * CONL
      YP = PART(2,IP) * CONL
      WRITE(6,604) IP,XP,YP
   30 CONTINUE
      IF(.NOT.SGNPT(IP)) GO TO 2000
C
C     CALCULATE ADVECTIVE VELOCITIES
C
      IA = IEN(1,IE)
      IB = IEN(2,IE)
      IC = IEN(3,IE)
      XAB = DATN(1,IA) - DATN(1,IB)
      XAC = DATN(1,IA) - DATN(1,IC)
      IF(XAB) 40,50,40
   40 CONTINUE
      DXAB = (DATN(3,IA) - DATN(3,IB))/XAB
      UXAB = (SVEL(2,IA) - SVEL(2,IB))/XAB
      VXAB = (SVEL(3,IA) - SVEL(3,IB))/XAB
      YXAB = (DATN(2,IA)  - DATN(2,IB))/XAB
      DIFY = (DATN(2,IA) - DATN(2,IC) - YXAB*XAC)
      BD = -(DATN(3,IA) - DATN(3,IC) - DXAB*XAC) / DIFY
      BU = -(SVEL(2,IA) - SVEL(2,IC) - UXAB*XAC) / DIFY
      BV = -(SVEL(3,IA) - SVEL(3,IC) - VXAB*XAC) / DIFY
       BDC = BD*YXAB + DXAB
       BUC = BU*YXAB + UXAB
      BVC = BV*YXAB + VXAB
      GO TO 60
   50 CONTINUE
      DXAC = (DATN(3,IA) - DATN(3,IC))/XAC
      UXAC = (SVEL(2,IA) - SVEL(2,IC))/XAC
      VXAC = (SVEL(3,IA) - SVEL(3,IC))/XAC
      YXAC = (DATN(2,IA) - DATN(2,IC))/XAC
      DIFY = DATN(2,IA) - DATN(2,IB)
      BD = -(DATN(3,IA) - DATN(3,IB))/DIFY
      BU = -(SVEL(2,IA) - SVEL(2,IB))/DIFY
      BV = -(SVEL(3,IA) - SVEL(3,IB))/DIFY
      BDC = BD*YXAC + DXAC
      BUC = BU*YXAC + UXAC
      BVC = BV*YXAC + VXAC
   60 CONTINUE
      UPA = BUC*(PART(1,IP) - DATN(1,IA))
     *        - BU*(PART(2,IP) - DATN(2,IA)) + SVEL(2,IA)
      VPA = BVC*(PART(1,IP) - DATN(1,IA))
     *        - BV*(PART(2,IP) - DATN(2,IA)) + SVEL(3,IA)
C
C     CALCULATE DIFFUSION VELOCITIES
C
      IF(DXY.EQ.0.0) GO TO 78
      DEP = BDC*(PART(1,IP) - DATN(1,IA))
     *        - BD*(PART(2,IP) - DATN(2,IA)) + DATN(3,IA)
   70 CONTINUE
      IRA = IRB*IRA
      X = ( IRA / RNA ) * 2.
      IRA = IRB * IRA
      Y = ( IRA / RNA ) * 2.
      IF((X*X + Y*Y).GT.1.0) GO TO 70
      IF(DEP.GT.DEPMIN) GO TO 72
      UVC = 0.0
      GO TO 76
   72 CONTINUE
      IF(DEP.GT.DEPMAX) GO TO 74
      UVC = DEPSLP*(DEP - DEPMIN)
      GO TO 76
   74 CONTINUE
      UVC = 1.0
   76 CONTINUE
      UPD = X*UV*UVC
      VPD = Y*UV*UVC
C
C     CALCULATE TOTAL VELOCITIES
C
   78 CONTINUE
      UP = UPA + UPD
      VP = VPA + VPD
      XPOLD = PART(1,IP)
      YPOLD = PART(2,IP)
      PART(1,IP) = PART(1,IP) + UP*DT/CONL
      PART(2,IP) = PART(2,IP) + VP*DT/CONL
C
   90 CONTINUE
 2000 CONTINUE
 3000 CONTINUE
      TIME = FLOAT(IDAY)
      NNOW=NP
      WRITE(6,602) IT,TIME,NF,NNOW,NRCT,NOUT
      CALL WRTOUT
      IF(NNOW.LT.NP)NNOW=NP
      IF(IT.GT.ISTOP.AND.NNOW.EQ.0) GO TO 4000


 1000 CONTINUE
 4000 CONTINUE
      RETURN
C
C     FORMATS
C
  602 FORMAT(T5,'IT =',I5,T20,'TIME =',F15.3,' DAY',
     *   T50,'PARTICLE BUDGET: ',T70,'NP =',I5,T85,'NNOW=',I5,
     *   T100,'NRCT=',I5,T115,'NCUT=',I5)
  604 FORMAT(10X,'PARTICLE OUTSIDE',
     *   T30,'IP=',I5,T50,'XP=',F10.4,T70,'YP=',F10.4)
C 660 FORMAT(5X,7E12.5)
      END
C
      SUBROUTINE INIT
C
C     SUBROUTINE INIT INITIALIZES ARRAYS AND VARIABLES
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL OIL,DOSPWN
      COMMON /SPILL/ SPILYR,SPILDA,SPILON,SPILAT,IADV,IDALST,SPLTYP,
     $               SPLMAG
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $                FEC(18),PREDG(18),PLARVA(365,10),
     $                SUMFA,EGGCHK(365)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $                YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $                RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
      COMMON /LINK/ PLVOLD(365),PLVTOX(365),OILCON(148),
     $              XOILMN,XOILMX,YOILMN,YOILMX,
     $              XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IA,IT,IP,IE,IF,IRA,IRB,IOP,IPGND,INTKA,INTKB,NPLT,
     *               NWPT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTY,CONL,UNET,VNET,
     *               APX,APY,APW,APH,APA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
      COMMON /BLWOUT/ CONC(398,3),AUPELM,THRSLD,DX,DY,IDAYZ(12)
      INTEGER INTPC/0/
      INTPC=INTPC+1
      NP=0
      ZERO = 1.0E-20
      NNMAX = 153
```

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      NEMAX = 251
      NPMAX = 2019
      DO 1C I=1,NPMAX
      IELP(I) = 1
      SGNPT(I) = .TRUE.
      CO 11 II=1,7
11    PART(II,I)=0.0
      CO 12 J=1,2
      ITMP(J,I) = C
      PRTOLD(J,I) = 0.0
 12   CONTINUE
 10   CCNTINUE
      IF(INTHO.GT.1)GO TO 45
      DO 19 I=1,12
19    IDAYZ(I)=0.0
      DO 20 I=1,NEMAX
      DO 22 J=1,2
      ICCN(J,I) = 0
 22   CONTINUF
      DO 24 J=1,3
      IEN(J,I) = 0
      RSLP(J,I) = 0.0
      SGNDY(J,I) = .TRUF.
 24   CONTINUE
 20   CCNTINUE
      DO 26 J=1,3400
      IND(J) = 0
 26   CCNTINUE
      DO 30 I=1,NNMAX
      DO 32 J=1,2
      UVNET(J,I) = 0.0
      INOD(J,I) = C
 32   CCNTINUE
      DO 34 J=1,3
      SVEL(J,I) = 0.0
      CATN(J,I) = 0.0
 34   CONTINUF
 30   CONTINUE
      IRE = 5**15
      RNA = 2.0**32.0
      SGNX = .TRUE.
      IT = 0
      TIME = 0.0
      CCNL = 1.
      DO 40 I=1,365
40    PLVTOX(I)=C.0
45    CONTINUE
C THESE ARE THE STORAGE LOCATICNS FOR THE CENTROIDS AND RADII OF THE
C SPILLETS, AND THE EXTREMES OF THE SUBSURFACE DISTRIBUTION.
      DO 50 I=1,15
      XOSPIL(I)=C.0
      YOSPIL(I)=0.0

      ROSPIL(I)=C.0
50    CONTINUE
      XOILMN=100.0
      XOILMX=-10C.C
      YOILMN=100.0
      YOILMX=-100.0
      NSPIL=0
      CO 60 I=1,398
      CO 60 J=1,3
60    CONC(I,J)=0.0
      DX=0.0
      DY=0.C
      RETURN
      END
      SUBROUTINE FEREAD
C
C   SUBROUTINF FEREAC REACS THE FINITE ELEMENT DATA
C
      COMMCN /I2ARR/ ICCN,IEN,INC,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2C19)
      CCMMCN /R4ARR/ PART,CATN,RSLP,SVEL,PRTCLD,UVNET
      REAL*4 PART(7,2019),CATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMCN /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPCND,INTKA,INTKB,NPLT,
     *               NWPT,INTKT,NVR,NVRC,ISTRT,JPLT,NACT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      CCMMCN /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UVET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
      WRITE(6,603)
C
C   NN    NUMBER CF NCDES
C   NE    NUMBER CF ELEMENTS
C
      READ(10,100)NN,NE
    5 CONTINUE
    7 WRITE(6,600) NN,NE
      OFFSET=4.0*CCS(39.0*3.14159/180.0)
      DO 10 I=1,NN
C
C   INOD(1,I)          NODE NUMBER.
C   DATN(IL=1,3),I)    XLCC,YLCC,DEPTH OF NODE I
C   INOD(2,I)          NODE TYPE
C
      READ(11,101)INOD(1,I),YLAT,XLONG
      CATN(3,I)=10C.0
      INOD(2,I)=0
      CATN(1,I)=68.0-XLCNG
      CATN(2,I)=YLAT-35.0
      FLAT=YLAT*3.14159/180.0
      CATN(1,I)=CATN(1,I)*CCS(FLAT) + CFFSET
      DATN(1,I) = CATN(1,I)*CCNL
      DATN(2,I) = CATN(2,I)*CCNL
      DATN(1,I) = DATN(1,I) / CCNL
      CATN(2,I) = DATN(2,I) / CCNL
   10 CONTINUE
      XMIN = 1.E20
      YMIN = 1.E20
      XMAX = -1.E20
      YMAX = -1.E20
      DO 20 I=1,NE
C
C   IEN(IL=1,3),I)   NCDES FOR ELEMENT I
C
      READ(1,102)KDUM,(IEN(L,I),L=1,3)
      DO 30 L=1,3
      II = IEN(L,I)
      XMIN = AMIN1(XMIN,DATN(1,II))
      YMIN = AMIN1(YMIN,DATN(2,II))
      XMAX = AMAX1(XMAX,CATN(1,II))
      YMAX = AMAX1(YMAX,DATN(2,II))
   30 CCNTINUE
   20 CCNTINUE
      XMIN = XMIN * CONL
      XMAX = XMAX * CCNL
      YMIN = YMIN * CCNL
      YMAX = YMAX * CONL
      WRITE(6,606) XMIN,YMIN,XMAX,YMAX
      RETURN
C
C   FORMATS
C
  100 FORMAT(2I5)
 101  FORMAT(I5,4X,F6.3,4X,F6.3)
 102  FORMAT(2X,4(I3,3X))
  600 FORMAT(T10,'NUMBER OF NODES =',I5,T40,
     *  'NUMBER CF TRIANGULAR ELEMENTS =',I5//)
  601 FCRMAT(17X,I5,3F15.3,I10)
  602 FORMAT(19X,I5,5X,3I10)
  603 FORMAT(////,T10,'NUPERICAL PARTICLE TRAJECTORY PROGRAM'//,
     * T5,'FINITE ELEMENT CATA:'//)
  604 FORMAT(T20,'NODE',T31,'XLCC',T46,'YLCC',T62,'DEPTH',
     *  T75,'TYPE'/)
  605 FORMAT(//T21,'ELEMENT',T35,'NODE A',T45,'NODE B',
     * T55,'NODE C'/)
  606 FORMAT(//T10,'FIELD SIZE:',T30,'XMIN =',E10.4,T50,
     *   'YMIN =',E10.4,T7C,'XMAX =',E10.4,T90,'YMAX =',E10.4)
      END
C*************************************************************
C*************************************************************


      SUBROUTINE VELIN(IDAY)
C*************************************************************
C*************************************************************
C
C   SUBROUTINE VELIN READS THE VELCCITY CATA
C
      COMMCN /I2ARR/ ICCN,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      CCMMCN /R4ARR/ PART,CATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),CATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTCLD(2,2019),UVNET(2,153)
      COMMCN /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      CCMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPCND,INTKA,INTKB,NPLT,
     *               NWPT,INTKT,NVR,NVRC,ISTRT,JPLT,NACT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMCN /L1VAR/ TF
      COMMCN /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERC,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C WIND CURRENT FOR TOCAY
    5 READ(14,80C,END=10)IDAYWD,UWIND,VWIND
 800  FORMAT(I4,2F8.5)
      IF(IDAY.NE.IDAYWD)GC TO 5
      GO TO 20
  10  REWIND 14
      GO TO 5
C BUMPLS' NET DRIFT CATA
  20  CONTINUE
      CO 40 I=1,148
  30  READ(13,END=80)ICAYCK,NODNUM,SVEL(2,I),SVEL(3,I)
      IF(ICAY.NE.ICAYCK.OR.I.NE.NODNUM)GC TO 30
      SVEL(2,I)=SVEL(2,I) + UWINC
  40  SVEL(3,I)=SVEL(3,I) + VWIND
      RETURN
  80  REWIND 13
      GO TC 20
      END
      SUBROUTINE VAREAC
C
C   SUBROUTINE VAREAD  READS THE PARAMETER DATA, THE INITIAL
C   PARTICLE DATA, AND THE NET DRIFT DATA
C
      COMMCN /I2ARR/ ICON,IEN,IND,INCD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMCN /R4ARR/ PART,CATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),CATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLC(2,2019),UVNET(2,153)
      COMMCN /L1ARR/ SGNDY,SGNPT
```

```
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPOND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UFD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C     NT     NUMBER OF TIME STEPS
C     DT     TIME STEP (DAY)
C
      READ(10,500) NT,DT,DTV
      NV = DT/DTV
      IF(NV.GT.0) DT = NV*DTV
      NV = NV - 1
      NVRC = 0
      NVR = DTV/DT
      IF(NVR.GT.1) DT= DTV/FLOAT(NVR)
      WRITE(6,600) NT,DT,DTV
C
C     TWRT     WRITE ON MULTIPLES OF TWRT (DAY)
C     TPLT     PLOT ON MULTIPLES OF TPLT (DAY)
C     IPLT     0  PLOT ELEMENTS ONLY
C              1  PLOT ELEMENTS AND ELEMENT NUMBERS
C              2  PLOT ELEMENTS AND NODE NUMBERS
C              3  PLOT ELEMENTS, ELEMENT NUMBERS, AND NODE NUMBERS
C     JPLT     0  CONNECT ALL PARTICLES FOR ONE TIME
C              1  CONNECT ONE PARTICLE FOR ALL TIME
C
      READ(10,504) TWRT,TPLT,IPLT,JPLT
      NWRT = TWRT/DT + 0.5
      NPLT = TPLT/DT + 0.5
      DTWRT = TWRT
      DTPLT = TPLT
      WRITE(6,605) TWRT,TPLT,IPLT,JPLT
C
C     DXY     HORIZONTAL DIFFUSION COEFFICIENT (M**2/DAY)
C     ISEED   RANDOM NUMBER GENERATOR SEED
C
      READ(10,503) DXY,ISEED
      IF(ISEED.EQ.0) ISEED = 783668
      IRA = ISEED
      IRA = IRA * 2 + 1
      WRITE(6,604) DXY,ISEED
      DCF = 0.25
      UV = SQRT(6.0*DXY/DT)
C
C     IPOND   POND EXIT LOCATION NODE
C     IDP     NUMBER OF PARTICLES EGRESSING FROM POND IN ONE TIME STEP
C             PER FT/DAY
C

C     TSTRT   START TIME FOR PARTICLES EGRESSING FROM POND (DAY)
C     TSTOP   STOP TIME FOR PARTICLES EGRESSING FROM POND (DAY)
C
      READ(10,501) IPOND,IDP,TSTRT,TSTOP
      ISTRT = TSTRT/DT + 0.5
      ISTOP = TSTOP/DT + 0.5
      WRITE(6,608) IPOND,IDP,TSTRT,TSTOP
C
C     INTKT = 0  CIRCULAR INTAKE WINDOW
C             1  RECTANGULAR INTAKE WINDOW
C     INTKA    NODE NUMBER OF INTAKE A
C     INTKB    NODE NUMBER OF INTAKE B
C
      READ(10,506) INTKT,INTKA,INTKB
      WRITE(6,607) INTKT,INTKA,INTKB
      ARX = CATN(1,INTKA)
      ARY = CATN(2,INTKA)
      ARH = 1.0
      ARW = 1.0
      ARA = 0.0
C
C     SFX      X SCALE FACTOR
C     SFY      Y SCALE FACTOR
C     XOFF     X OFFSET
C     YOFF     Y OFFSET
C     HGT      HEIGHT OF PARTICLE NUMBERS
C
      READ(10,502) SFX,SFY,XOFF,YOFF,HGT
      WRITE(6,603) SFX,SFY,XOFF,YOFF,HGT
      SFX = SFX * CONL
      SFY = SFY * CONL
      XOFF = XOFF / CONL
      YOFF = YOFF / CONL
      NP=0
      WRITE(6,609) NP
      IF(NP.EQ.0) GO TO 20
      WRITE(6,602)
      DO 10 I=1,NP
C
C     PART((L=1,2),I)    XLOC,YLOC OF PARTICLE I
C
      READ(2,201) (PART(L,I),L=1,2)
      WRITE(6,601) I,(PART(L,I),L=1,2)
      PART(1,I) = PART(1,I) / CONL
      PART(2,I) = PART(2,I) / CONL
   10 CONTINUE
   20 CONTINUE
      WRITE(6,610)
C
C     INET     0  ALL NODES HAVE SAME NET DRIFT
C              1  READ SEPARATE NETS FOR EACH NODE
C     UNET     EAST NET DRIFT (FT/DAY)
```

```
C     VNET     SOUTH NET DRIFT (FT/DAY)
C
      READ(10,405) INET,UNET,VNET
      WRITE(6,606) INET,UNET,VNET
      IF(INET.EQ.1) GO TO 40
      DO 50 IN=1,NN
      UVNET(1,IN) = UNET
      UVNET(2,IN) = VNET
   50 CONTINUE
      RETURN
   40 CONTINUE
      DO 30 IN=1,NN
      READ(4,401) (UVNET(J,IN),J=1,2)
   30 CONTINUE
      RETURN
C
C     FORMATS
C
  201 FORMAT(2F10.0)
  401 FORMAT(2F10.5)
  500 FORMAT(I5,2F10.5)
  501 FORMAT(2I5,2F10.0)
  502 FORMAT(2F10.5,2F10.0,F10.5)
  503 FORMAT(F10.5,I10)
  504 FORMAT(2F10.0,2I5)
  405 FORMAT(I5,2F10.5)
  506 FORMAT(3I5)
  600 FORMAT(///T5,'PARAMETER DATA:'//,T10,
     *  'NUMBER OF TIME STEPS =',I5,T40,'TIME STEP =',
     *   F10.5,' DAY',
     *   T80,'VELOCITY TIME STEP =',F10.5,' DAY')
  601 FORMAT(20X,I5,5X,2F15.5)
  602 FORMAT(T21,'PARTICLE',T38,'XLOC',T53,'YLOC'/)
  603 FORMAT(/T10,'PLOTTING PARAMETERS'//T5,'SFX =',F10.5,
     *   T30,'SFY =',F10.5,T55,'XOFF =',F10.0,T80,'YOFF =',
     *    F10.0,T105,'HGT =',F10.5/)
  604 FORMAT(/T10,'DXY =',F10.5,T30,'ISEED =',I10/)
  605 FORMAT(/T10,'TWRT =',F10.0,' DAY',T40,'TPLT =',F10.0,' DAY',
     *      T70,'IPLT =',I5,T90,'JPLT =',I5)
  606 FORMAT(/T10,'INET=',I5,T40,'UNET =',F10.5,T80,'VNET =',F10.5)
  607 FORMAT(/T10,'INTKT=',I5,T30,'INTKA=',I5,T60,'INTKB=',I5)
  608 FORMAT(/T10,'IPOND=',I5,T30,'IDP=',I5,T50,'TSTRT=',F10.0,
     *     ' DAY',T80,'TSTOP=',F10.0,' DAY'/)
  609 FORMAT(/T5,'PARTICLE DATA:',//T10,'NP =',I5/)
  610 FORMAT(/T5,'NET DRIFT DATA:'/)
      END
C*******************************************************
      SUBROUTINE DEAD(IOFF)
C*******************************************************
      COMMON /LINK/ PLVOLD(365), PLVTOT(365),OILCON(148),
     $                XOILMN,XOILMX,YOILMN,YOILMX
     $                  ,XOSPIL(51),YOSPIL(51),ROSPIL(51),NSPIL


       COMMON /LOGIC/ DOSPWN,OIL
       LOGICAL DOSPWN,OIL
       COMMON /I2APP/ ICON,IEN,IND,INOD,IELP,ITMP
       INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
       INTEGER*2 IELP(2019),ITMP(2,2019)
       COMMON /R4ARR/ PART,CATN,RSLP,SVEL,PRTOLD,UVNET
       REAL*4 PART(7,2019),CATN(3,153),RSLP(3,251),SVEL(3,153)
       REAL*4 PRTOLD(2,2019),UVNET(2,153)
       COMMON /L1ARR/ SGNDY,SGNPT
       LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
       COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPOND,INTKA,INTKB,NPLT,
     *                NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *                IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
       COMMON /L1VAR/ TF
       COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *                XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *                ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *                DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
       COMMON/ARRAYS/ POPNEW(18),FOPN(18),SURV(18),POPOLD(18),
     $ FEC(18),PREC(18),PLARVA(365,10),SUMPN,EGGCHK(365)
       COMMON /OUTPTS/ POPS1(79), WTDIST(18),CIFF(18),
     $                 YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $                  RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
       IF(IOFF.EQ.0)RETURN
       IF(NP.EQ.0)RETURN
C NOW REMOVE ANY THAT HAVE BEEN BLOWN OFF  THE BANK.
       DO 100 I=1,NP
       K=0
       J=IELP(I)
       IF(J.LT.26.OR.J.GT.139)K=1
       IF(45.LE.J.AND.J.LE.52)K=1
       IF(73.LE.J.AND.J.LE.78)K=1
       IF(84.LE.J.AND.J.LE.86)K=1
       IF(97.LE.J.AND.J.LE.100)K=1
       IF(111.LE.J.AND.J.LE.117)K=1
       IF(126.LE.J.AND.J.LE.129)K=1
       IF(130.LE.J.AND.J.LE.133)K=1
       IF(K.EQ.0)GO TO 100
C HERE WE KILL 'EM OFF
C I IS TH PARTICLE NUMBER OF AN 'OFF-THE-BANK-ER'
       SGNPT(I)=.FALSE.
C PART(7,I)=DAY SPAWNED
C PART(3,I)=# ORGANISMS
C PLARVA(J,I)=# ORGANISMS SPAWNED ON THE JTH DAY
       J=PART(7,I)
       PLARVA(J,1)=PLARVA(J,1) - PART(3,I)
  100  CONTINUE
       RETURN
       END
C*******************************************************
```

```
      SUBROUTINE GRAF(X,Y,XX,I)
      RETURN
      END
      SUBROUTINE FLOT(X,Y,I)
      RETURN
      END
      SUBROUTINE NUMPLT(X,Y,T,H,F,I)
      RETURN
      END
      SUBROUTINE PLTLN(X,Y,XX,YY)
      RETURN
      END
      SUBROUTINE CHAR(X,Y,YT,YY,CAT,I)
      RETURN
      END
      SUBROUTINE RESET
      RETURN
      END
      SUBROUTINE DIMEN(X,Y,I,Z)
      RETURN
      END
       SUBROUTINE AXIS(X,Y,NAM,I,H,J,K,T)
      RETURN
      END
      SUBROUTINE VECTOR(X,Y,NUM,INC,ICP,I)
      RETURN
      END
      SUBROUTINE SCALF(X,Y,N)
      RETURN
      END
      SUBROUTINE OFFST(X,Y,I)
       RETURN
       END
      SUBROUTINE DOTLN(X,Y,Z,W,L)
      RETURN
      END
      SUBROUTINE MATH(X,Y,Z,T,I)
      RETURN
      END
      SUBROUTINE DATE(X,Y,Z)
      RETURN
      END
      SUBROUTINE TIME(X,Y,Z)
      RETURN
      END
C
      SUBROUTINE COMPRS
C
C
      COMMON /LOGIC/ DOSPWN,OIL
      LOGICAL DOSPWN,OIL
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP


      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPOND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C
      COMMON/ARRAYS/ POPNEW(18),POPN(18),SURV(18),POPOLD(18),
     $ FEC(18),PRED(18),PLARVA(365,10),SUMPN,EGGCHK(365)
      COMMON /OUTPTS/ POPSIZ(79), WTDIST(18),DIFF(18),
     $               YRMASS(79), WTCALC(18), EXPM(18),EXPF(18),
     $                RLCTCH(79), EFFORT(79),SEL(18), CCATCH(79)
C
C
C COMPRESSES ALL PARTICLE ARRAYS TO ELIMINATE THOSE W/
C SGNPT=.FALSE. OR IF THE STAAGE IS 5 IN PLARVA.
C
C TAKE PARTICLES FROM THE END OF THE ARRAY AND
C INSERT THEM WHERE OTHERS HAVE DISSAPPEARED.
C
      IF(NP.EQ.1.AND..NOT.SGNPT(1))NP=0
      IF(NP.EQ.0)RETURN
      NNPP=NP
      DO 100 I=1,NNPP
      IF(PLARVA(PART(7,I),2).EQ.5.0)SGNPT(I)=.FALSE.
      IF(SGNPT(I)) GO TO 100
      IF(.NOT.SGNPT(I).AND.I.GE.NP)GO TO 200
C
C I IS THE FLAG OF AN OUTSIDE (GONE) PARTICLE
C
C
      DO 50 J=1,NNPP
      IF(NP.LE.I)GO TO 200
      IF(.NOT.SGNPT(NP))NP=NP-1
      IF(SGNPT(NP))GO TO 40
   50 CONTINUE
   40 CONTINUE
C
C NP IS THE FLAG OF THE LAST "INSIDE" PARTICLE IN THE ARRAY
C
      DO 45 K=1,2
      PART(K,I)=PART(K,NP)
```

```
      PRTOLD(K,I)=PRTOLD(K,NP)
   45 CONTINUE
      SGNPT(I)=SGNPT(NP)
      IELP(I)=IELP(NP)
      SGNPT(NP)=.FALSE.
      DO 47 K=3,7
   47 PART(K,I)=PART(K,NP)
C
   60 NP=NP-1
      IF(NP.EQ.0)GO TO 200
  100 CONTINUE
  200 CONTINUE
      RETURN
      END
C
      SUBROUTINE CHECK
C
C   SUBROUTINE CHECK CHECKS WHETHER THE THREE NODES ARE ORDERED
C   COUNTERCLOCKWISE AROUND THE ELEMENT
C
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPOND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
      DO 10  IE=1,NE
      NA = IEN(1,IE)
      NB = IEN(2,IE)
      NC = IEN(3,IE)
      DXSP = (DATN(2,NC) - DATN(2,NA))*RSLP(1,IE)
     *       - (DATN(1,NC) - DATN(1,NA))
      SGNX = .TRUE.
      IF(DXSP) 20,30,30
   20 CONTINUE
      SGNX = .FALSE.
   30 CONTINUE
      IF(SGNX.AND..NOT.SGNDY(1,IE)) GO TO 40
      IF(.NOT.SGNX.AND.SGNDY(1,IE)) GO TO 40
   10 CONTINUE
   11 CONTINUE
      RETURN


   40 CONTINUE
      WRITE(6,600) IE,(IEN(L,IE),L=1,3),DXSP
      IEN(2,IE) = NC
      IEN(3,IE) = NB
      SGNX = SGNDY(2,IE)
      SGNDY(2,IE) = SGNDY(3,IE)
      SGNDY(3,IE) = SGNX
      RR = RSLP(2,IE)
      RSLP(2,IE) = RSLP(3,IE)
      RSLP(3,IE) = RR
      GO TO 11
  600 FORMAT(5X,'CHECK',T20,4I5,F15.5)
      END
      SUBROUTINE VARSET
C
C   SUBROUTINE VARSET CALCULATES ELEMENT VARIABLES
C
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,DATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,153),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTOLD(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPOND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,NNMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
C
C   CALCULATE RECIPROCAL SLOPE AND DIRECTION
C
      DO 10 IE=1,NE
      NA = IEN(1,IE)
      NB = IEN(2,IE)
      NC = IEN(3,IE)
      CALL SLPDIR(DATN(2,NB),DATN(2,NA),DATN(1,NB),DATN(1,NA),
     *     RSLP(1,IE),SGNDY(1,IE),ZERO)
      CALL SLPDIR(DATN(2,NC),DATN(2,NB),DATN(1,NC),DATN(1,NB),
     *     RSLP(2,IE),SGNDY(2,IE),ZERO)
      CALL SLPDIR(DATN(2,NA),DATN(2,NC),DATN(1,NA),DATN(1,NC),
     *     RSLP(3,IE),SGNDY(3,IE),ZERO)
C     WRITE(6,600) IE,(RSLP(L,IE),L=1,3),(SGNDY(L,IE),L=1,3),
C    *     (IEN(L,IE),L=1,3)
   10 CONTINUE
C
C   CALCULATE ADJACENT ELEMENTS
C
```

```
      ICT = 0
      DO 20 I=1,NE
      ICON(1,I) = ICT + 1
      DO 30 J=1,NE
      IF(I.EQ.J) GO TO 30
      DO 40 K=1,3
      DO 50 L=1,3
      IF(IEN(K,I).NE.IEN(L,J)) GO TO 50
      ICT = ICT + 1
      INC(ICT) = J
      GO TO 30
   50 CONTINUE
   40 CONTINUE
   30 CONTINUE
      ICON(2,I) = ICT
      IS = ICON(1,I)
      IF = ICON(2,I)
C     WRITE(6,601) I,(ICON(L,I),L=1,2),(IND(L),L=IS,IF)
   20 CONTINUE
      WRITE(6,602) ICT
      RETURN
C
C   FORMATS
C
  602 FORMAT(///5X,'TOTAL NUMBER OF ADJACENT ELEMENTS',I10)
      END
      SUBROUTINE SLPDIR(YNN,YN,XNN,XN,RSLP,SGN,ZERO)
C
C   SUBROUTINE SLPDIR CALCULATES RECIPROCAL SLOPE AND DIRECTION
C   OF EACH SIDE OF EACH ELEMENT
C
      LOGICAL*1 SGN
      SGN = .TRUE.
      DY = YNN - YN
      IF(DY) 10,20,10
   20 CONTINUE
      DY = ZERO
   10 CONTINUE
      RSLP = (XNN-XN)/DY
      IF(DY) 30,40,40
   30 CONTINUE
      SGN = .FALSE.
   40 CONTINUE
      RETURN
      END
      SUBROUTINE WRTOUT
C
C   SUBROUTINE WRTOUT GENERATES PRINTED OUTPUT AT DESIRED
C   TIME STEPS
C
      COMMON /I2ARR/ ICON,IEN,IND,INCO,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)


      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,CATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),CATN(3,1:3),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTCLO(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPCND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,INMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
      CTWRT=DTWRT + TWRT
      IF(NP.EQ.0)RETURN
      WRITE(6,600)
      DO 10 IP=1,NP
      XP = PART(1,IP) * CONL
      YP = PART(2,IP) * CONL
      IF(.NOT.SGNPT(IP))WRITE(6,601) IP,XP,YP,IELP(IP),
     *    ITMP(1,IP),ITMP(2,IP),SGNPT(IP)
   10 CONTINUE
   20 CONTINUE
      IF(DXY.LT.0.0) CALL STATS
      RETURN
  600 FORMAT(/,T5,'IP',T20,'XP',T35,'YP',T48,'IELP',T58,
     *   'ITMPS',T68,'ITMPE',T78,'SGNPT'/)
  601 FORMAT(I10,2F15.5,3I10,L10)
      END
      SUBROUTINE STATS
C
C   SUBROUTINE STATS CALCULATES PARTICLE STATISTICS
C
      COMMON /I2ARR/ ICON,IEN,IND,INOD,IELP,ITMP
      INTEGER*2 ICON(2,251),IEN(3,251),IND(3400),INOD(2,153)
      INTEGER*2 IELP(2019),ITMP(2,2019)
      COMMON /R4ARR/ PART,CATN,RSLP,SVEL,PRTOLD,UVNET
      REAL*4 PART(7,2019),DATN(3,1:3),RSLP(3,251),SVEL(3,153)
      REAL*4 PRTCLO(2,2019),UVNET(2,153)
      COMMON /L1ARR/ SGNDY,SGNPT
      LOGICAL*1 SGNDY(3,251),SGNPT(2019),TF,SGNX
      COMMON /I4VAR/ IN,IT,IP,IE,IF,IRA,IRB,IDP,IPCND,INTKA,INTKB,NPLT,
     *               NWRT,INTKT,NVR,NVRC,ISTRT,JPLT,NRCT,
     *               IPLT,ISTOP,ISEED,NN,NE,NP,NT,NV,INMAX,NEMAX,NPMAX
      COMMON /L1VAR/ TF
      COMMON /R4VAR/ UP,VP,UPA,VPA,UPD,VPD,UV,ZERO,XMIN,YMIN,
     *               XMEAN,YMEAN,XMAX,YMAX,DXY,DTV,CONL,UNET,VNET,
     *               ARX,ARY,ARW,ARH,ARA,TWRT,TPLT,DTWRT,DTPLT,
     *               DT,TIME,TIMEV,RNA,RNB,HGT,SFX,SFY,XOFF,YOFF
      REAL*4 RMX(4),RMY(4)
      INTEGER*2 XBIN(300),YBIN(300)
```

```
      IF(NP.LT.10)RETURN
      DO 60 I=1,300
      XBIN(I) = 0
      YBIN(I) = 0
   60 CONTINUE
      IBT = 0
      DO 10 I=1,4
      RMX(I) = 0.0
      RMY(I) = 0.0
   10 CONTINUE
      XMEAN = 0.0
      YMEAN = 0.0
      ICT = 0
      DO 50 IP=1,NP
      IF(.NOT.SGNPT(IP)) GO TO 50
      ICT = ICT + 1
      XMEAN = XMEAN + PART(1,IP)
      YMEAN = YMEAN + PART(2,IP)
   50 CONTINUE
      XMEAN = XMEAN/FLOAT(ICT)
      YMEAN = YMEAN/FLOAT(ICT)
      DO 20 IP=1,NP
      IF(.NOT.SGNPT(IP)) GO TO 20
      DELX = (PART(1,IP) - XMEAN) * CONL
      DELY = (PART(2,IP) - YMEAN) * CONL
C     IX = (DELX + 15.)*10.
C     IY = (DELY + 15.)*10.
C     IF(IX.LT.1.OR.IX.GT.300) GO TO 70
C     IF(IY.LT.1.OR.IY.GT.300) GO TO 70
C     XBIN(IX) = XBIN(IX) + 1
C     YBIN(IY) = YBIN(IY) + 1
C     IBT = IBT + 1
   70 CONTINUE
      XT = 1.0
      YT = 1.0
      DO 30 J=1,4
      XT = XT*DELX
      YT = YT*DELY
      RMX(J) = RMX(J) + XT
      RMY(J) = RMY(J) + YT
   30 CONTINUE
   20 CONTINUE
      DO 40 J=1,4
      RMX(J) = RMX(J)/FLOAT(ICT)
      RMY(J) = RMY(J)/FLOAT(ICT)
   40 CONTINUE
      XMEAN = XMEAN * CONL
      YMEAN = YMEAN * CONL
      WRITE(6,600) IT,TIME,NP,ICT,XMEAN,YMEAN,(RMX(I),I=1,4),
     *    (RMY(I),I=1,4)
      SDX = SQRT(RMX(2))
      DX = RMX(2)/(2.*TIME)


      SDY = SQRT(RMY(2))
      DY = RMY(2)/(2.*TIME)
      CSX = RMX(3)/RMX(2)**(1.5)
      CEX = RMX(4)/RMX(2)**2 - 3
      CSY = RMY(3)/RMY(2)**(1.5)
      CEY = RMY(4)/RMY(2)**2 - 3
      WRITE(6,601) SDX,CSX,CEX,DX,SDY,CSY,CEY,DY
C     WRITE(6,603) IBT
C     WRITE(6,604) (XBIN(I),I=1,300)
C     WRITE(6,604) (YBIN(I),I=1,300)
      RETURN
  600 FORMAT(5X,'STATS',I10,F10.3,2I10,2E15.5/
     *       5X,8E15.5)
  601 FORMAT(5X,8E15.5)
      END
/GO
//FT01F001 DD DSN=UR1.LCF1.ELEMNCS,DISP=SHR
//FT02F001 DD DUMMY
//* THAT'S THE LARVAL CUTPUT TO DISC
//FT03F001 DD DSN=UR1.EXA1.BLOCIL.F2ND350.CUT50,DISP=SHR
//* THAT IS THE CIL DISTRIBUTICN INPUT
//FT04F001 DD DUMMY
//*THAT IS THE CIL-LARVAE CUTPUT DSN
//FT06F001 DD SYSOUT=A
//FT08F001 DD DUMMY
//* PUT THE OIL AFFECTED CATCH DATASET THERE FOR THE REAL RUNS
//FT09F001 DD *
OILCOD= 0001aIOFF  =00C0&YEARLY=1901 IRWND= 0001#INTPOP=0000$OUTPOP=00C0*
FRSTYR= 1977 LASTYR=2020 ISTART=1976&MULTI= 0001*OILSTP=0004a
SPILYR= 1979aSPILDA= 350#MRTCAY=C3503MRTYR= 1903
IADV  = 0000#ICALST=01CC$SFLTYP=0002&THRSLD=5.0E+01
   EM1C=15.CE-05   EM11=00.2E+00   EM12=00.2E+0C   EM13=01.0E-20
   EM14=00.2E+00   EM15=01.0E-20   EM16=01.5E-2C   MODEL1
  RATIO=0.5000     EP=C.2000 FINITL=0.2000 FFOLEP=0.3000      Q=J.0125
DELTAT =001.0000 DT2  = 0C5.0000
  MINYR=1932  MAXYR=1934
  63  C4  67  68  91  92 1C7 108 122 123
 363      THOSE ARE ELEMENTS AND THE DAY FOR DIFFUSION/MORTALITY COMPUTATIC
  0.0 E+00
  10.0E+C6    RETURN TO 10.0E+06 FOR THE REGULAR RUNS
  08.0E+06
  05.7E+06
  3.6 E+C6
  2.3 E+06
  1.6 E+C6
  1.2 E+C6
  0.9 E+C6
  0.7 E+C6
  5.7 E+C5
  4.3 E+05
  3.1 E+C5
  2.2 E+05
```

```
  1.4 E+05
  9.1 E+04
  5.4 E+04
  7.2 E+04
 NEXT COME THE FECUNDITY FACTORS AND SELECTIVITY FACTORS, RESPECTIVELY:
 0.0 0.0 0.0 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 0.020.541.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 AND THEN THE NUMBER OF EGGS PER GRAM  MATURE FEMALE:
 2.00E+05
1976 17.4 25.0
1977 20.0 25.0
1978 20.0 24.4
1979 20.0 25.2
1980 20.0 24.4
1981 20.0 25.76
1982 20.0 24.8
1983 20.0 24.24
1984 20.0 24.8
1985 20.0 25.6
1986 20.0 25.52
1987 20.0 24.8
1988 20.0 24.16
1989 20.0 24.32
1990 20.0 26.16
1991 20.0 25.36
1992 20.0 24.24
1993 20.0 25.12
1994 25.2 25.2
1995 20.0 26.16
1996 20.0 24.4
1997 20.0 26.24
1998 20.0 24.88
1999 20.0 25.92
2000 20.0 23.92
2001 20.0 25.76
2002 20.0 23.84
2003 20.0 24.16
2004 20.0 25.12
2005 20.0 26.08
2006 20.0 24.96
2007 20.0 25.36
2008 20.0 24.72
2009 20.0 24.96
2010 20.0 24.8
2011 25.0 25.0
2012 25.0 25.0
2013 25.0 24.4
2014 25.0 25.2
2015 25.0 24.4
2016 25.0 25.76
2017 25.0 24.8
2018 25.0 24.24
```

```
2019 25.0 24.8
2020 25.0 25.6
2021 25.0 25.52
2022 25.0 24.8
2023 25.0 24.16
2024 25.0 24.32
2025 25.0 26.16
2026 25.0 24.4
2027 25.0 26.24
2028 25.0 24.88
2029 25.0 25.92
2030 25.0 23.92
2031 25.0 25.76
2032 25.0 23.84
2033 25.0 24.16
2034 25.0 25.12
2035 25.0 26.08
2036 25.0 24.96
2037 25.0 25.36
2038 25.0 24.72
2039 25.0 24.96
2040 25.0 24.8
2041 25.0 25.0
2042 25.0 25.0
2043 25.0 24.4
2044 25.0 25.2
2045 25.0 24.4
2046 25.0 25.76
2047 25.0 24.8
2048 25.0 24.24
2049 25.0 24.8
2050 25.0 25.6
HERE ARE THE PREDATION MORTALITIES OF OLDER FISH ON THE ZEROTH
00000.00 0003.50 0008.50 0013.00 0019.00 0026.00 0034.00 0043.00
00053.00 0053.00 0053.00 0053.00 0053.00 0053.00 0053.00 0053.00 0053.00
 NGRPS=030
XCLOC =67.200,YCLOC=41.500RADIUS=00.500
/*
//FT10F001 DD *
00151 0246
   01    1.00000 001.00000
        10.  2000000.     0     1
  00.00100    7E3C6AA
  149     0      1000.      1000.
    1  150  151
   0.10000    0.10000   171000.     90000.    0.08000
00000    1.00000    1.00000
/*
//FT11F001 DD DSN=URI.LCF1.NODES,DISP=SHR
//FT12F001 DD DUMMY
//FT13F001 DD DSN=URI.LCF1.BUMPUS.ONEYEAR,DISP=SHR
//FT14F001 DD DSN=URI.LCF1.WINDCUR1,DISP=SHR
```

```
//FT15F001 DD DUMMY
//*
//* HERE COME THE DAYS FOR OUTPUT OF LARVAL DISTRIBUTIONS TO DISC
//FT16F001 DD *
0350 0360 0005 0015 0025 0045 0060 0075 0090 01050120*0000*0000#
/*
```

V. Sample Output

```
FRSTYR= 1977 LASTYR=2020 ISTART=1976

 THERE WILL BE   1 OILSPILLS SEPARATED BY   4 YEARS EACH.

RATIO OF FEMALES IN THE POPULATION = 0.5000
ADULT NATURAL MORTALITY = 0.2000
STARTUP FISHING MORTALITY = 0.2000
EQUILIBRIUM FISHING MORTALITY = 0.3000
CATCHABILITY COEFFICIENT = 0.0125
DELTAT FOR THE FISHERY MODEL IS   1.0000 DAYS.

THE SHORTCUT TIMESTEP IS   5.0000  DAYS.
HISTOGRAMS WILL BE PRODUCED FOR YEARS 1932 TO 1934.

          HERE ARE THE ELEMENTS IN WHICH MORTALITY AND DIFFUSION RATES WILL BE COMPARED ON DAY 365
 48  66  67  68  81  92 107 108 122 123


                        ******* THE CONTROL VARIABLES *******

       IS ADVECTION INCLUDED (LILCUD)?                                              1
       IS OFF-THE-BANK MORTALITY INCLUDED (IOFF)?                                   0
       USE THE BYPASS TIMESTEP AFTER YEAR (YEARLY)                               1981
       REWIND DATASET 3 OR USE A NEW ONE FOR MULTIPLE RUNS (IRWND)                  1
       READ INITIAL POPULATION FROM CARDS (0) OR FT15 (1) (INTPOP)                  0
       WRITE OUT THE LAST YEAR POPULATION TO FT15 (OUTPOP)?                         0
       FIRST YEAR OF THE RUN (FRSTYR)                                            1977
       LAST YEAR OF THE RUN (LASTYR)                                             2020
       STARTUP YEAR (ISTART)                                                     1976
       NUMBER OF OILSPILLS IN THE SERIES (MULTI)                                    1
       NUMBER OF YEARS BETWEEN SPILLS (OILSTP)                                      4
       YEAR OF THE FIRST SPILL (SPILYR)                                          1979
       JULIAN DAY OF THE SPILL (SPILDA)                                           350

       DAY TO BEGIN TRACING DAILY MORTALITY OF EGGS AND LARVAE (MRTDAY)           350
       YEAR IN WHICH THE TRACING BEGINS (OUTPUT TO FT13...MRTYR)                 1981
       LAST DAY FOR ADVECTION (IDALST)                                            100
       ADVECTION WITHOUT OIL (IADV)?                                                0
       SPLTYP = 1 THEN ITS SHORT, =2 THEN A BLOWOUT                                 2
       THE THRESHOLD TOXICITY IN PARTS PER BILLION IS                           50.00
       IS THIS AN ARTIFICIAL CROPPING RUN? (ICROP)                                  0
       CROPPING RATE FOR RECRUITS DURING SPILYR (CROPRT)                          0.0
 EM10 =   0.1500E-03  EM11 =   0.2000E 00  EM12 =   0.2000E 00  EM13 =   0.1000E-19

 EM14 =   0.2000E 00  EM15 =   0.1000E-19  EM16 =   C.1500E-19

       AGE GROUP      INITIAL NUMBERS
          0            0.0
          1            0.10E 08
          2            0.80E 07
          3            0.57E 07
          4            0.36E 07
          5            0.23E 07
          6            0.16E 07
          7            0.12E 07
          8            0.90E 06
          9            0.70E 06
         10            0.57E 06
         11            0.43E 06
         12            0.31E 06
         13            0.22E 06
         14            0.14E 06
         15            0.91E 05
         16            0.55E 05
         17            0.37E 05
        AGE          CALCULATED WEIGHT (KG)        CALCULATED LENGTH (CM)
          0                    0.368                      26.106
          1                    0.737                      39.901
          2                    1.316                      52.136
          3                    2.155                      62.988
          4                    3.403                      72.612
          5                    4.974                      81.149
          6                    6.455                      88.719
          7                    8.612                      95.414
          8                   10.564                     101.390
          9                   12.452                     106.672
         10                   14.206                     111.339
         11                   15.782                     115.511
         12                   17.171                     119.196
         13                   18.370                     122.465
         14                   19.412                     [illegible]
         15                   20.296                     [illegible]
         16                   21.046                     130.215
         17                   21.689                     132.233

                 AGE                FECUNDITY
                   1                0.0
                   2                0.0
                   3                0.0
                   4                0.6006E 06
                   5                0.9549E 06
                   6                0.1339E 07
                   7                0.1722E 07
                   8                0.2113E 07
                   9                0.2443E 07
                  10                0.2851E 07
                  11                0.3196E 07
                  12                0.3434E 07
                  13                0.3719E 07
                  14                0.3862E 07
                  15                0.4059E 07
                  16                0.4210E 07
                  17                0.4338E 07
```

```
YEAR                 CATCH                       EFFORT
           (THOUS. METRIC TONS)     (THOUS. STANDARD DAYS)
1976              17.40                       25.00
1977              20.00                       25.00
1978              20.00                       24.40
1979              20.00                       25.70
1980              20.30                       24.60
1981              20.00                       24.70
1982              20.00                       24.40
1983              20.00                       24.70
1984              20.00                       24.80
1985              20.00                       25.60
1986              20.00                       25.50
1987              20.00                       24.60
1988              20.00                       24.10
1989              20.00                       24.30
1990              20.00                       26.10
1991              20.00                       25.10
1992              20.00                       24.20
1993              20.00                       25.10
1994              25.20                       25.20
1995              20.00                       26.10
1996              20.00                       24.40
1997              20.00                       26.20
1998              20.00                       24.80
1999              20.00                       25.90
2000              20.00                       23.90
2001              20.00                       25.70
2002              20.00                       23.80
2003              20.00                       24.10
2004              20.00                       25.10
2005              20.00                       26.00
2006              20.00                       24.90
2007              20.00                       25.30
2008              20.00                       24.70
2009              20.00                       24.90
2010              20.00                       24.80
2011              25.00                       25.30
2012              25.00                       25.00
2013              25.00                       24.40
2014              25.00                       25.20
2015              25.00                       24.60
2016              25.00                       25.70
2017              25.00                       24.80
2018              25.00                       24.20
2019              25.00                       25.60
2020              25.00                       25.60
2021              25.00                       25.50
2022              25.00                       24.80
2023              25.00                       24.10
2024              25.00                       24.30
2025              25.00                       26.10
2026              25.00                       24.40
2027              25.00                       26.70
2028              25.00                       24.80
2029              25.00                       25.90
2030              25.00                       23.90
2031              25.00                       25.70
2032              25.00                       23.80
2033              25.00                       24.10
2034              25.00                       24.10
2035              25.00                       26.00
2036              25.00                       24.90
2037              25.00                       25.30
2038              25.00                       24.70
2039              25.00                       24.90
2040              25.00                       24.80
2041              25.00                       25.00
2042              25.00                       25.00
2043              25.00                       24.40
2044              25.00                       25.20
2045              25.00                       24.40
2046              25.00                       25.70
2047              25.00                       24.60
2048              25.00                       24.20
2049              25.00                       24.80
2050              25.00                       25.60

FOLLOWING ARE THE PREDATION RATES OF THE OLDER COHORTS THE JUVENILES OF THE YEAR:
   0.0      3.50     8.50    13.00    19.00    26.00    34.00    43.00     3.0
  53.00    53.00    53.00    53.00    53.00    53.00    53.00    53.00    53.00

SPILYR = 1979 SPILDA =  350 IACV =     0 ICALST =  100 SPLTYP =    2THRSLD =  0.500E 02  PARTS PER BILLION

                                  YEAR   1977

AGE GROUP           SIZE                FISHING MORTALITY    NATURAL MORTALITY
     1          0.1000E 08                    0.169                0.20
     2          0.8000E 07                    0.312                0.20
     3          0.5700E 07                    0.312                0.20
     4          0.3600E 07                    0.312                0.20
     5          0.2300E 07                    0.312                0.20
     6          0.1600E 07                    0.312                0.20
     7          0.1200E 07                    0.312                0.20
     8          0.9000E 06                    0.312                0.20
     9          0.7000E 06                    0.312                0.20
    10          0.5700E 06                    0.312                0.20
    11          0.4300E 06                    0.312                0.20
    12          0.3100E 06                    0.312                0.20
    13          0.2200E 06                    0.312                0.20
    14          0.1400E 06                    0.312                0.20
    15          0.9100E 05                    0.312                0.20
    16          0.5400E 05                    0.312                0.20
    17          0.7200E 05                    0.312                0.20
AGE GROUP           TOTAL BIOMASS LOST        CONTRIBUTION TO CATCH
                          (KG)                     (KG)          PERCENT
     1                0.2241E 07              0.1025E 07          0.034
     2                0.4217E 07              0.2571E 07          0.086
     3                0.5019E 07              0.3060E 07          0.103
     4                0.4913E 07              0.2995E 07          0.101
     5                0.4542E 07              0.2769E 07          0.093
     6                0.4295E 07              0.2619E 07          0.088
     7                0.4144E 07              0.2527E 07          0.085
     8                0.3813E 07              0.2325E 07          0.078
     9                0.3455E 07              0.2131E 07          0.072
    10                0.3247E 07              0.1980E 07          0.067
    11                0.2721E 07              0.1659E 07          0.056
    12                0.2135E 07              0.1302E 07          0.044
    13                0.1621E 07              0.9885E 06          0.033
    14                0.1090E 07              0.6645E 06          0.022
    15                0.7560E 06              0.4610E 06          0.015
    16                0.4558E 06              0.2779E 06          0.009
    17                0.6262E 06              0.3818E 06          0.013
THE ANNUAL YIELD IS    29.728 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.7544E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.207E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.2974E-05

                                  YEAR   1978

AGE GROUP           SIZE                FISHING MORTALITY    NATURAL MORTALITY
     1          0.1072E 08                    0.169                0.20
     2          0.7188E 07                    0.312                0.20
     3          0.5047E 07                    0.312                0.20
     4          0.3510E 07                    0.312                0.20
     5          0.2351E 07                    0.312                0.20
     6          0.1543E 07                    0.312                0.20
     7          0.1075E 07                    0.312                0.20
     8          0.7694E 06                    0.312                0.20
     9          0.5715E 06                    0.312                0.20
    10          0.4436E 06                    0.312                0.20
    11          0.3455E 06                    0.312                0.20
    12          0.2620E 06                    0.312                0.20
    13          0.1937E 06                    0.312                0.20
    14          0.1361E 06                    0.312                0.20
    15          0.9175E 05                    0.312                0.20
    16          0.5927E 05                    0.312                0.20
    17          0.8798E 05                    0.312                0.20
AGE GROUP           TOTAL BIOMASS LOST        CONTRIBUTION TO CATCH
                          (KG)                     (KG)          PERCENT
     1                0.2402E 07              0.1099E 07          0.040
     2                0.3789E 07              0.2310E 07          0.085
     3                0.4443E 07              0.2709E 07          0.100
     4                0.4789E 07              0.2920E 07          0.108
     5                0.4646E 07              0.2833E 07          0.104
     6                0.4195E 07              0.2558E 07          0.094
     7                0.3705E 07              0.2259E 07          0.083
     8                0.3261E 07              0.1989E 07          0.073
     9                0.2864E 07              0.1746E 07          0.064
    10                0.2526E 07              0.1540E 07          0.057
    11                0.2187E 07              0.1333E 07          0.049
    12                0.1809E 07              0.1103E 07          0.041
    13                0.1427E 07              0.8702E 06          0.032
    14                0.1060E 07              0.6461E 06          0.024
    15                0.7467E 06              0.4555E 06          0.017
    16                0.5003E 06              0.3051E 06          0.011
    17                0.7652E 06              0.4666E 06          0.017
THE ANNUAL YIELD IS    27.145 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.6875E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.200E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.3598E-05
```

```
                                   YEAR   1979
AGE GROUP          SIZE           FISHING MORTALITY    NATURAL MORTALITY
     1        0.9649E 07              0.165                 0.20
     2        0.6602E 07              0.305                 0.20
     3        0.4621E 07              0.305                 0.20
     4        0.3327E 07              0.305                 0.20
     5        0.2264E 07              0.305                 0.20
     6        0.1524E 07              0.305                 0.20
     7        0.1035E 07              0.305                 0.20
     8        0.7088E 06              0.305                 0.20
     9        0.5015E 06              0.305                 0.20
    10        0.3604E 06              0.305                 0.20
    11        0.2743E 06              0.305                 0.20
    12        0.2137E 06              0.305                 0.20
    13        0.1621E 06              0.305                 0.20
    14        0.1197E 06              0.305                 0.20
    15        0.8544E 05              0.305                 0.20
    16        0.5859E 05              0.305                 0.20
    17        0.9906E 05              0.305                 0.20
AGE GROUP        TOTAL BIOMASS LOST     CONTRIBUTION TO CATCH
                      (KG)                 (KG)        PERCENT
     1             0.2152E 07          0.5717E 06      0.023
     2             0.3441E 07          0.2078E 07      0.085
     3             0.4156E 07          0.2534E 07      0.103
     4             0.4489E 07          0.2711E 07      0.111
     5             0.4420E 07          0.2669E 07      0.109
     6             0.4059E 07          0.2452E 07      0.100
     7             0.3526E 07          0.2130E 07      0.087
     8             0.2969E 07          0.1793E 07      0.073
     9             0.2476E 07          0.1495E 07      0.061
    10             0.2075E 07          0.1253E 07      0.051
    11             0.1746E 07          0.1055E 07      0.043
    12             0.1455E 07          0.8787E 06      0.036
    13             0.1191E 07          0.7137E 06      0.029
    14             0.9217E 06          0.5566E 06      0.023
    15             0.6877E 06          0.4150E 06      0.017
    16             0.4890E 06          0.2953E 06      0.012
    17             0.8519E 06          0.5145E 06      0.021
THE ANNUAL YIELD IS    24.515 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.2338E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.195E 07


        NUMERICAL PARTICLE TRAJECTORY PROGRAM
     FINITE ELEMENT DATA:

        NUMBER OF NODES =  151        NUMBER OF TRIANGULAR ELEMENTS =  240


     FIELD SIZE:      XMIN =0.2254E 00    YMIN =0.7500E 00    XMAX =0.5223E 01    YMAX =0.5875E 01


  PARAMETER ENTRY
     NUMBER OF TIME STEPS =    1   TIME STEP =   1.00000 DAY                VELOCITY TIME STEP =  1.00000 DAY
     TURT =        10. DAY          TPLT =  2000000. DAY         IPLT =    0          JPLT =    1
     DXY =   0.00100     ISEED =   7850688
     IPCND=  149          IOP=    0          ISTRT=      1000. DAY          ISTOP=     1000. DAY
     INTRT=    1        INTRA=  150                   INTRB=  151
     PLOTTING PARAMETERS
  SPX =   0.10000        SPY =   0.10050          XOFF =  171000.          YOFF =    90000.         ROT =   0.00000
  PARTICLE DATA:
     NP =     0
  NET DRIFT DATA:
     INET=   0                 UNET =   1.00000                         VNET =   1.00000
  TOTAL NUMBER OF ADJACENT ELEMENTS      2580
THIS IS ENTRY NUMBER   1 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER   2 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER   3 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER   4 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER   5 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER   6 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER   7 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER   8 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER   9 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  10 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  11 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  12 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  13 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  14 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  15 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  16 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  17 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  18 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  19 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  20 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  21 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  22 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  23 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  24 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  25 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  26 TO SUBROUTINE ADVDIF.
THIS IS ENTRY NUMBER  27 TO SUBROUTINE ADVDIF.
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THIS IS ENTRY NUMBER  29 TO SUBROUTINE ADVDIF.

THIS IS ENTRY NUMBER  29 TO SUBROUTINE ADVDIF.

THIS IS ENTRY NUMBER  30 TO SUBROUTINE ADVDIF.

THIS IS ENTRY NUMBER  31 TO SUBROUTINE ADVDIF.

NGRPS=   30  XCLOC=    3.[illegible]775  YCLOC=    2.50000 RADIUS=   0.50000

  IT =   1       TIME =          301.000 DAY     PARTICLE BUDGET:    NP =   60      NNOW=   60      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.1268E 12 AND PLARVA ENTRY IS   0.6338E 11  FOR DAY  301

THIS IS ENTRY NUMBER  32 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          302.000 DAY     PARTICLE BUDGET:    NP =   90      NNOW=   90      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.4863E 07 AND PLARVA ENTRY IS   0.2431E 07  FOR DAY  301

THIS IS ENTRY NUMBER  33 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          303.000 DAY     PARTICLE BUDGET:    NP =  120      NNOW=  120      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.2431E 07 AND PLARVA ENTRY IS   0.1215E 07  FOR DAY  301

THIS IS ENTRY NUMBER  34 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          304.000 DAY     PARTICLE BUDGET:    NP =  150      NNOW=  150      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.1620E 07 AND PLARVA ENTRY IS   0.8100E 06  FOR DAY  301

THIS IS ENTRY NUMBER  35 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          305.000 DAY     PARTICLE BUDGET:    NP =  180      NNOW=  180      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.1215E 07 AND PLARVA ENTRY IS   0.6074E 06  FOR DAY  301

THIS IS ENTRY NUMBER  36 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          306.000 DAY     PARTICLE BUDGET:    NP =  210      NNOW=  210      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT

    LRVSUM IS   0.9715E 06 AND PLARVA ENTRY IS   0.4858E 06  FOR DAY  301

THIS IS ENTRY NUMBER  37 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          307.000 DAY     PARTICLE BUDGET:    NP =  240      NNOW=  240      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.8096E 06 AND PLARVA ENTRY IS   0.4047E 06  FOR DAY  301

THIS IS ENTRY NUMBER  38 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          308.000 DAY     PARTICLE BUDGET:    NP =  270      NNOW=  270      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.6936E 06 AND PLARVA ENTRY IS   0.3468E 06  FOR DAY  301

THIS IS ENTRY NUMBER  39 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          309.000 DAY     PARTICLE BUDGET:    NP =  300      NNOW=  300      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.6067E 06 AND PLARVA ENTRY IS   0.3034E 06  FOR DAY  301

THIS IS ENTRY NUMBER  40 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          310.000 DAY     PARTICLE BUDGET:    NP =  330      NNOW=  330      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.5391E 06 AND PLARVA ENTRY IS   0.2694E 06  FOR DAY  301

THIS IS ENTRY NUMBER  41 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          311.000 DAY     PARTICLE BUDGET:    NP =  360      NNOW=  360      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.4851E 06 AND PLARVA ENTRY IS   0.2425E 06  FOR DAY  301

THIS IS ENTRY NUMBER  42 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          312.000 DAY     PARTICLE BUDGET:    NP =  390      NNOW=  390      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.4409E 06 AND PLARVA ENTRY IS   0.2204E 06  FOR DAY  301

THIS IS ENTRY NUMBER  43 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          313.000 DAY     PARTICLE BUDGET:    NP =  420      NNOW=  420      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.4040E 06 AND PLARVA ENTRY IS   0.2020E 06  FOR DAY  301

THIS IS ENTRY NUMBER  44 TO SUBROUTINE ADVDIF.


  IT =   1       TIME =          314.000 DAY     PARTICLE BUDGET:    NP =  450      NNOW=  450      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.3728E 06 AND PLARVA ENTRY IS   0.1864E 06  FOR DAY  301

THIS IS ENTRY NUMBER  45 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          315.000 DAY     PARTICLE BUDGET:    NP =  480      NNOW=  480      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.3461E 06 AND PLARVA ENTRY IS   0.1731E 06  FOR DAY  301

THIS IS ENTRY NUMBER  46 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          316.000 DAY     PARTICLE BUDGET:    NP =  510      NNOW=  510      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.3230E 06 AND PLARVA ENTRY IS   0.1615E 06  FOR DAY  301

THIS IS ENTRY NUMBER  47 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          317.000 DAY     PARTICLE BUDGET:    NP =  540      NNOW=  540      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.3027E 06 AND PLARVA ENTRY IS   0.1513E 06  FOR DAY  301

THIS IS ENTRY NUMBER  48 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          318.000 DAY     PARTICLE BUDGET:    NP =  570      NNOW=  570      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.2848E 06 AND PLARVA ENTRY IS   0.1424E 06  FOR DAY  301

THIS IS ENTRY NUMBER  49 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          319.000 DAY     PARTICLE BUDGET:    NP =  600      NNOW=  600      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.2689E 06 AND PLARVA ENTRY IS   0.1345E 06  FOR DAY  301

THIS IS ENTRY NUMBER  50 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          320.000 DAY     PARTICLE BUDGET:    NP =  630      NNOW=  630      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
    LRVSUM IS   0.2547E 06 AND PLARVA ENTRY IS   0.1273E 06  FOR DAY  301

THIS IS ENTRY NUMBER  51 TO SUBROUTINE ADVDIF.
  IT =   1       TIME =          321.000 DAY     PARTICLE BUDGET:    NP =  660      NNOW=  660      NRCT=    0      NOUT=    0
       IP          XP             YP            IELP      ITMPS      ITMPE     SGMPT
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   LRVSUM IS   0.2419E 06 AND PLARVA ENTRY IS   0.1209E 06  FOR DAY  301
 THIS IS ENTRY NUMBER  52 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          322.000 DAY    PARTICLE BUDGET:   NP =  690      NNOW=  690      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.2303E 06 AND PLARVA ENTRY IS   0.1152E 06  FOR DAY  301
 THIS IS ENTRY NUMBER  53 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          323.000 DAY    PARTICLE BUDGET:   NP =  720      NNOW=  720      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.2198E 06 AND PLARVA ENTRY IS   0.1099E 06  FOR DAY  301
 THIS IS ENTRY NUMBER  54 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          324.000 DAY    PARTICLE BUDGET:   NP =  750      NNOW=  750      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.2102E 06 AND PLARVA ENTRY IS   0.1051E 06  FOR DAY  301
 THIS IS ENTRY NUMBER  55 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          325.000 DAY    PARTICLE BUDGET:   NP =  780      NNOW=  780      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.2013E 06 AND PLARVA ENTRY IS   0.1007E 06  FOR DAY  301
 THIS IS ENTRY NUMBER  56 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          326.000 DAY    PARTICLE BUDGET:   NP =  810      NNOW=  810      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1932E 06 AND PLARVA ENTRY IS   0.9662E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  57 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          327.000 DAY    PARTICLE BUDGET:   NP =  840      NNOW=  840      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1858E 06 AND PLARVA ENTRY IS   0.9288E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  58 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          328.000 DAY    PARTICLE BUDGET:   NP =  870      NNOW=  870      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPS      SGNPT
   LRVSUM IS   0.1788E 06 AND PLARVA ENTRY IS   0.8941E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  59 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          329.000 DAY    PARTICLE BUDGET:   NP =  900      NNOW=  900      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1724E 06 AND PLARVA ENTRY IS   0.8620E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  60 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          330.000 DAY    PARTICLE BUDGET:   NP =  930      NNOW=  930      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1723E 06 AND PLARVA ENTRY IS   0.8615E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  61 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          331.000 DAY    PARTICLE BUDGET:   NP =  960      NNOW=  960      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1722E 06 AND PLARVA ENTRY IS   0.8610E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  62 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          332.000 DAY    PARTICLE BUDGET:   NP =  990      NNOW=  990      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1721E 06 AND PLARVA ENTRY IS   0.8606E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  63 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          333.000 DAY    PARTICLE BUDGET:   NP = 1020      NNOW= 1020      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1720E 06 AND PLARVA ENTRY IS   0.8601E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  64 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          334.000 DAY    PARTICLE BUDGET:   NP = 1050      NNOW= 1050      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1719E 06 AND PLARVA ENTRY IS   0.8596E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  65 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          335.000 DAY    PARTICLE BUDGET:   NP = 1080      NNOW= 1080      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1718E 06 AND PLARVA ENTRY IS   0.8591E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  66 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          336.000 DAY    PARTICLE BUDGET:   NP = 1110      NNOW= 1110      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1717E 06 AND PLARVA ENTRY IS   0.8587E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  67 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          337.000 DAY    PARTICLE BUDGET:   NP = 1140      NNOW= 1140      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1716E 06 AND PLARVA ENTRY IS   0.8582E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  68 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          338.000 DAY    PARTICLE BUDGET:   NP = 1170      NNOW= 1170      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1715E 06 AND PLARVA ENTRY IS   0.8577E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  69 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          339.000 DAY    PARTICLE BUDGET:   NP = 1200      NNOW= 1200      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1715E 06 AND PLARVA ENTRY IS   0.8573E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  70 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          340.000 DAY    PARTICLE BUDGET:   NP = 1230      NNOW= 1230      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1714E 06 AND PLARVA ENTRY IS   0.8568E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  71 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          341.000 DAY    PARTICLE BUDGET:   NP = 1260      NNOW= 1260      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1713E 06 AND PLARVA ENTRY IS   0.8563E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  72 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          342.000 DAY    PARTICLE BUDGET:   NP = 1290      NNOW= 1290      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1712E 06 AND PLARVA ENTRY IS   0.8559E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  73 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =          343.000 DAY    PARTICLE BUDGET:   NP = 1320      NNOW= 1320      NRCT=     0      NOUT=     0
      IP          XP              YP          IELP       ITMPS      ITMPE      SGNPT
   LRVSUM IS   0.1711E 06 AND PLARVA ENTRY IS   0.8554E 05  FOR DAY  301
 THIS IS ENTRY NUMBER  74 TO SUBROUTINE ADVDIF.
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   IT =    1      TIME =        344.000 DAY     PARTICLE BUDGET:    NP = 1350      NNOW= 1350     NACT=    0      NOUT=    0
        IP         XP             YP            IELP      ITMPS      ITMPE      SGNPT
    LRVSUM IS   0.1710E 06 AND PLARVA ENTRY IS   0.8549E 05  FOR DAY  301

  THIS IS ENTRY NUMBER  75 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =        345.000 DAY     PARTICLE BUDGET:    NP = 1380      NNOW= 1380     NACT=    0      NOUT=    0
        IP         XP             YP            IELP      ITMPS      ITMPE      SGNPT
    LRVSUM IS   0.1709E 06 AND PLARVA ENTRY IS   0.8544E 05  FOR DAY  301

  THIS IS ENTRY NUMBER  76 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =        346.000 DAY     PARTICLE BUDGET:    NP = 1410      NNOW= 1410     NACT=    0      NOUT=    0
        IP         XP             YP            IELP      ITMPS      ITMPE      SGNPT
    LRVSUM IS   0.1708E 06 AND PLARVA ENTRY IS   0.8540E 05  FOR DAY  301

  THIS IS ENTRY NUMBER  77 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =        347.000 DAY     PARTICLE BUDGET:    NP = 1440      NNOW= 1440     NACT=    0      NOUT=    0
        IP         XP             YP            IELP      ITMPS      ITMPE      SGNPT
    LRVSUM IS   0.1707E 06 AND PLARVA ENTRY IS   0.8535E 05  FOR DAY  301

  THIS IS ENTRY NUMBER  78 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =        348.000 DAY     PARTICLE BUDGET:    NP = 1470      NNOW= 1470     NACT=    0      NOUT=    0
        IP         XP             YP            IELP      ITMPS      ITMPE      SGNPT
    LRVSUM IS   0.1706E 06 AND PLARVA ENTRY IS   0.8530E 05  FOR DAY  301

  THIS IS ENTRY NUMBER  79 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =        349.000 DAY     PARTICLE BUDGET:    NP = 1500      NNOW= 1500     NACT=    0      NOUT=    0
        IP         XP             YP            IELP      ITMPS      ITMPE      SGNPT
    LRVSUM IS   0.1705E 06 AND PLARVA ENTRY IS   0.8526E 05  FOR DAY  301

  IDAY  IS 350  IT HAS BEEN    0DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS    1


  SPILLET    XLOC     YLOC     RADIUS
     1      3.9400    2.6700    0.0010

  IDAY IS  350 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE    3.981    3.982    2.673    2.675

  THE MAXIMUM SUBSURFACE CONCENTRATION IS ********** PARTS PER BILLION ABOVE BACKGROUND LEVELS.

    THERE ARE  137 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.399E-06 0.665E-06MAP UNITS.

  THIS IS ENTRY NUMBER  80 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =        350.000 DAY     PARTICLE BUDGET:    NP = 1530      NNOW= 1530     NACT=    0      NOUT=    0
        IP         XP             YP            IELP      ITMPS      ITMPE      SGNPT


  HERE IS THE DISTRIBUTION FOR DAY  350

  DAY      350 : LARVAL DISTRIBUTION WRITTEN TO DISC.


  DAY       XLOC        YLOC           NUMBER      DAY SPAWNED  STAGE    ELEMENT
    LRVSUM IS   0.1704E 06 AND PLARVA ENTRY IS   0.8521E 05  FOR DAY  301

  IDAY  IS 351  IT HAS BEEN    1DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS    2


  SPILLET    XLOC     YLOC     RADIUS
     1      3.8321    2.7669    0.0177
     2      3.9400    2.6700    0.0010

  IDAY IS  351 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE    3.907    3.992    2.704    2.672

  THE MAXIMUM SUBSURFACE CONCENTRATION IS  120415.25 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

    THERE ARE   92 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.3100E-02 0.4011E-02MAP UNITS.

  THIS IS ENTRY NUMBER  81 TO SUBROUTINE ADVDIF.
   IT =    1      TIME =        351.000 DAY     PARTICLE BUDGET:    NP = 1560      NNOW= 1560     NACT=    0      NOUT=    0
        IP         XP             YP            IELP      ITMPS      ITMPE      SGNPT
    LRVSUM IS   [illegible] 06 AND PLARVA ENTRY IS   [illegible] 05  FOR DAY  301

  IDAY  IS 352  IT HAS BEEN    2DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS    3


  SPILLET    XLOC     YLOC     RADIUS
     1      3.7632    2.9711    0.0292
     2      3.8321    2.7669    0.0177
     3      3.9400    2.6700    0.0010

  IDAY IS  352 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE    3.741    4.055    2.910    2.781
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THE MAXIMUM SUBSURFACE CONCENTRATION IS   27994.90 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

  THERE ARE   61 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.116E-01 0.100E-01MAP UNITS.

THIS IS ENTRY NUMBER  82 TO SUBROUTINE ADVDIF.
     PARTICLE OUTSIDE    IP=  88            XP=    3.6551        YP=    0.7297
 IT =   1      TIME =          352.000 DAY     PARTICLE BUDGET:    NP = 1590      NNOW= 1590      NACT=    0

     IP           XP              YP             IELP        ITMPS       ITMPE      SGNPT

     88         3.65537         0.72973          17          302          352          F
  OILED: A CLUSTER SPAWNED ON DAY  346 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.1349E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  351 NOW IN STAGE    1 AND IN ELEMENT NUMBER  109 REPRESENTING   0.8104E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  352 NOW IN STAGE    1 AND IN ELEMENT NUMBER  122 REPRESENTING   0.7043E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  352 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.7043E 05ICHTHIOPLANKTON
 LRVSUM IS    0.1702E 06 AND PLARVA ENTRY IS    0.8512E 05  FOR DAY  301

IDAY  IS 353  IT HAS BEEN    3DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS    4


SPILLET    XLOC    YLOC    RADIUS
   1      3.5044  2.6743         0.0391
   2      3.9711  2.7682         0.0292
   3      4.1292  2.6732         0.0177
   4      3.9900  2.6700         0.0018

IDAY IS   353 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE    3.629    4.143    2.573    2.837

THE MAXIMUM SUBSURFACE CONCENTRATION IS   23898.06 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

  THERE ARE   58 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.191E-01 0.977E-02MAP UNITS.

THIS IS ENTRY NUMBER  83 TO SUBROUTINE ADVDIF.
 IT =   1      TIME =          353.000 DAY     PARTICLE BUDGET:    NP = 1619      NNOW= 1619      NACT=    0      NOUT=

     IP           XP              YP             IELP        ITMPS       ITMPE      SGNPT

    1392        3.77120         2.69305          108         346          0          F
    1539        4.04198         2.62275          109         351          0          F
    1568        3.80771         2.77026          122         352          0          F
    1574        3.75233         2.68817          108         352          0          F
  OILED: A CLUSTER SPAWNED ON DAY  343 NOW IN STAGE    1 AND IN ELEMENT NUMBER  122 REPRESENTING   0.8085E 04ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  348 NOW IN STAGE    1 AND IN ELEMENT NUMBER  122 REPRESENTING   0.1619E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  350 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.7703E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  351 NOW IN STAGE    1 AND IN ELEMENT NUMBER  122 REPRESENTING   0.6120E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  352 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.6683E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  353 NOW IN STAGE    1 AND IN ELEMENT NUMBER  122 REPRESENTING   0.7043E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  353 NOW IN STAGE    1 AND IN ELEMENT NUMBER  123 REPRESENTING   0.7043E 05ICHTHIOPLANKTON
 LRVSUM IS    0.1701E 06 AND PLARVA ENTRY IS    0.8507E 05  FOR DAY  301

IDAY  IS 354  IT HAS BEEN    4DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS    5


SPILLET    XLOC    YLOC    RADIUS
   1      4.0787  2.9576         0.0391
   2      4.1637  2.6915         0.0386
   3      4.3018  2.5566         0.0292
   4      4.1624  2.5913         0.0177
   5      3.9900  2.6700         0.0018

IDAY IS   354 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE    3.633    4.301    2.548    2.801

THE MAXIMUM SUBSURFACE CONCENTRATION IS   12098.77 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

  THERE ARE  113 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.249E-01 0.942E-02MAP UNITS.

THIS IS ENTRY NUMBER  84 TO SUBROUTINE ADVDIF.
 IT =   1      TIME =          354.000 DAY     PARTICLE BUDGET:    NP = 1645      NNOW= 1645      NACT=    0      NOUT=    1

     IP           XP              YP             IELP        ITMPS       ITMPE      SGNPT

    1298        3.92403         2.70174          122         343          0          F
    1468        3.87498         2.67237          122         348          0          F
    1510        3.85788         2.58906          108         350          0          F
    1553        3.89981         2.59714          122         351          0          F
    1580        3.87175         2.58143          108         352          0          F
    1592        3.90413         2.64722          122         353          0          F
    1593        3.99967         2.65746          123         353          0          F
  OILED: A CLUSTER SPAWNED ON DAY  353 NOW IN STAGE    1 AND IN ELEMENT NUMBER  122 REPRESENTING   0.[illegible] 05ICHTHIOPLANKTON
 LRVSUM IS    0.1700E 06 AND PLARVA ENTRY IS    0.8502E 05  FOR DAY  301

IDAY  IS 355  IT HAS BEEN    5DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS    6


SPILLET    XLOC    YLOC    RADIUS
   1      4.1690  2.5536         0.0391
   2      4.2359  2.6876         0.0386
   3      4.3541  2.5525         0.0390
   4      4.2547  2.5792         0.0292
   5      4.1623  2.6655         0.0177
   6      3.9900  2.6700         0.0018

IDAY IS   355 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE    3.619    4.408    2.471    2.716

THE MAXIMUM SUBSURFACE CONCENTRATION IS   16837.57 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

  THERE ARE  111 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.293E-01 0.908E-02MAP UNITS.

THIS IS ENTRY NUMBER  85 TO SUBROUTINE ADVDIF.
     PARTICLE OUTSIDE    IP=  84            XP=    3.5683        YP=    0.7180
     PARTICLE OUTSIDE    IP= 212            XP=    3.3118        YP=    0.7182
     PARTICLE OUTSIDE    IP= 224            XP=    3.9011        YP=    0.7397
 IT =   1      TIME =          355.000 DAY     PARTICLE BUDGET:    NP = 1668      NNOW= 1668      NACT=    0      NOUT=    4

     IP           XP              YP             IELP        ITMPS       ITMPE      SGNPT

     84         3.56800         0.71876          15          302          355          F
    212         3.31185         0.71824          17          307          355          F
    224         3.90110         0.73968          16          307          355          F
   1591         3.88710         2.56961          122         353          0           F
  OILED: A CLUSTER SPAWNED ON DAY  351 NOW IN STAGE    1 AND IN ELEMENT NUMBER  137 REPRESENTING   0.2112E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  352 NOW IN STAGE    1 AND IN ELEMENT NUMBER  137 REPRESENTING   0.2965E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  353 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.4419E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  354 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.8104E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  354 NOW IN STAGE    1 AND IN ELEMENT NUMBER  121 REPRESENTING   0.8104E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  354 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.8104E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  354 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.8104E 05ICHTHIOPLANKTON
  OILED: A CLUSTER SPAWNED ON DAY  355 NOW IN STAGE    1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.7043E 05ICHTHIOPLANKTON
 LRVSUM IS    0.1700E 06 AND PLARVA ENTRY IS    0.8498E 05  FOR DAY  301

IDAY  IS 356  IT HAS BEEN    6DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS    7


SPILLET    XLOC    YLOC    RADIUS
   1      4.1236  2.5587         0.0391
   2      4.1906  2.6126         0.0386
   3      4.3468  2.5576         0.0390
   4      4.2053  2.5544         0.0391
   5      4.0365  2.6311         0.0292
   6      3.9442  2.6352         0.0177
   7      3.9900  2.6700         0.0018

IDAY IS   356 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE    3.599    4.604    2.497    2.737

THE MAXIMUM SUBSURFACE CONCENTRATION IS   11026.57 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

  THERE ARE  123 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.299E-01 0.894E-02MAP UNITS.
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THIS IS ENTRY NUMBER  86 TO SUBROUTINE ADVOIF.
        PARTICLE OUTSIDE   IP=   35             XP=     2.5276       YP=    0.7440
  IT =    1      TIME  =        356.000 DAY     PARTICLE BUDGET:     NP = 1694      NNOW= 1694      NRCT=    0      NOUT=    5
        IP          XP              YP             IELP        ITMPS       ITMPE       SGNPT

        35       2.52750         0.76400           33          301         356          F
      1541       3.88600         2.50212          107          351           0          F
      1564       3.85367         2.48664          107          352           0          F
      1613       3.95375         2.57654          108          353           0          F
      1623       3.86706         2.62446          109          354           0          F
      1629       3.69206         2.70178          121          354           0          F
      1630       3.98246         2.38200          108          354           0          F
      1615       3.94556         2.53986          108          354           0          F
      1660       3.90126         2.48712          108          355           0          F
    OILED: A CLUSTER SPAWNED ON DAY  355 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.8383E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  348 NOW IN STAGE   1 AND IN ELEMENT NUMBER  120 REPRESENTING   0.1026E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  350 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.1372E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  352 NOW IN STAGE   1 AND IN ELEMENT NUMBER  120 REPRESENTING   0.2249E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  353 NOW IN STAGE   1 AND IN ELEMENT NUMBER  106 REPRESENTING   0.3000E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  353 NOW IN STAGE   1 AND IN ELEMENT NUMBER  122 REPRESENTING   0.3000E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  355 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.8393E 05ICHTHIOPLANKTON
  LRVSUM IS    0.1670E 06 AND PLARVA ENTRY IS   0.8493E 05  FOR DAY   301

  IDAY  IS 357  IT HAS BEEN    7DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS   8


  SPILLET   XLOC     YLOC    RADIUS
     1     4.0304   2.5575   0.0391
     2     4.1174   2.6517   0.0386
     3     4.2757   2.5568   0.0390
     4     4.1362   2.5536   0.0371
     5     3.9637   2.6303   0.0393
     6     3.8714   2.6344   0.0292
     7     3.9169   2.6692   0.0177
     8     3.5900   2.6700   0.0018

  IDAY IS  357 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE   3.572   4.393   2.470   2.716


  THE MAXIMUM SUBSURFACE CONCENTRATION IS   14880.90 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

    THERE ARE  162 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.309E-01 0.882E-02MAP UNITS.

THIS IS ENTRY NUMBER  87 TO SUBROUTINE ADVOIF.
        PARTICLE OUTSIDE   IP=   49             XP=     2.5440       YP=    0.7078
  IT =    1      TIME  =        357.000 DAY     PARTICLE BUDGET:     NP = 1715      NNOW= 1715      NRCT=    0      NOUT=    6
        IP          XP              YP             IELP        ITMPS       ITMPE       SGNPT

        49       2.54432         0.70779           33          301         357          F
        84       3.85066         2.59150          108          302         355          F
      1462       3.61558         2.64386          120          348           0          F
      1503       3.59564         2.55403          108          350           0          F
      1577       3.61772         2.63119          120          352           0          F
      1596       3.56002         2.63611          106          353           0          F
      1610       3.86357         2.64533          122          353           0          F
      1658       3.84642         2.51870          108          355           0          F
    OILED: A CLUSTER SPAWNED ON DAY  336 NOW IN STAGE   2 AND IN ELEMENT NUMBER  108 REPRESENTING   0.3838E 04ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  338 NOW IN STAGE   3 AND IN ELEMENT NUMBER  107 REPRESENTING   0.4245E 04ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  341 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.5045E 04ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  345 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.6734E 04ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  345 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.6734E 04ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  346 NOW IN STAGE   1 AND IN ELEMENT NUMBER  107 REPRESENTING   0.7401E 04ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  349 NOW IN STAGE   1 AND IN ELEMENT NUMBER  106 REPRESENTING   0.1011E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  350 NOW IN STAGE   1 AND IN ELEMENT NUMBER  107 REPRESENTING   0.8104E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  357 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.7043E 09ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  354 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.2963E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  351 NOW IN STAGE   1 AND IN ELEMENT NUMBER  106 REPRESENTING   0.2114E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  355 NOW IN STAGE   1 AND IN ELEMENT NUMBER  121 REPRESENTING   0.8104E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  354 NOW IN STAGE   1 AND IN ELEMENT NUMBER  106 REPRESENTING   0.2463E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  355 NOW IN STAGE   1 AND IN ELEMENT NUMBER  106 REPRESENTING   0.6340E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  357 NOW IN STAGE   1 AND IN ELEMENT NUMBER  107 REPRESENTING   0.7043E 09ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  357 NOW IN STAGE   1 AND IN ELEMENT NUMBER  106 REPRESENTING   0.7043E 09ICHTHIOPLANKTON
  LRVSUM IS    0.1641E 06 AND PLARVA ENTRY IS   0.8480E 05  FOR DAY   301

  IDAY  IS 358  IT HAS BEEN    8DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS   9


  SPILLET   XLOC     YLOC    RADIUS
     1     4.1314   2.4151   0.0391
     2     4.1589   2.5090   0.0386
     3     4.3571   2.4140   0.0390
     4     4.2173   2.4138   0.0391
     5     4.0445   2.4835   0.0401
     6     3.5520   2.4916   0.0393
     7     3.5576   2.5264   0.0292
     8     4.0709   2.5272   0.0177
     9     3.5500   2.6700   0.0018

  IDAY IS  358 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE   3.542   4.378   2.416   2.746


  THE MAXIMUM SUBSURFACE CONCENTRATION IS    9401.98 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

    THERE ARE  143 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.310E-01 0.132E-01MAP UNITS.

THIS IS ENTRY NUMBER  88 TO SUBROUTINE ADVOIF.
  IT =    1      TIME  =        358.000 DAY     PARTICLE BUDGET:     NP = 1737      NNOW= 1737      NRCT=    0.

        IP          XP              YP             IELP        ITMPS       ITMPE       SGNPT

      1088       3.82738         2.55896          108          336           0          F
      1158       3.85451         2.47427          107          338           0          F
      1247       4.01511         2.58380          108          341           0          F
      1366       4.03242         2.57646          108          345           0          F
      1371       3.89136         2.54014          109          345           0          F
      1383       3.81706         2.48420          107          346           0          F
      1489       3.83775         2.53427          108          349           0          F
      1564       3.81789         2.49637          107          352           0          F
      1577       3.93245         2.55232          108          352           0          F
      1580       3.99755         2.60242          109          353           0          F
      1605       3.57716         2.60424          106          353           0          F
      1632       3.65567         2.65563          121          353           0          F
      1634       3.58764         2.60505          106          354           0          F
      1641       3.92254         2.59809          108          355           0          F
      1658       3.85035         2.58479          107          355           0          F
      1686       3.60075         2.66712          106          357           0          F
    OILED: A CLUSTER SPAWNED ON DAY  356 NOW IN STAGE   1 AND IN ELEMENT NUMBER  108 REPRESENTING   0.8191E 05ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  357 NOW IN STAGE   1 AND IN ELEMENT NUMBER  133 REPRESENTING   0.9004E 08ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  358 NOW IN STAGE   1 AND IN ELEMENT NUMBER  132 REPRESENTING   0.7043E 09ICHTHIOPLANKTON
    OILED: A CLUSTER SPAWNED ON DAY  358 NOW IN STAGE   1 AND IN ELEMENT NUMBER  127 REPRESENTING   0.7043E 09ICHTHIOPLANKTON
  LRVSUM IS    0.1640E 06 AND PLARVA ENTRY IS   0.8484E 05  FOR DAY   301

  IDAY  IS 359  IT HAS BEEN    9DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS  10


  SPILLET   XLOC     YLOC    RADIUS
     1     4.2651   2.4573   0.0391
     2     4.3322   2.5511   0.0386
     3     4.4906   2.4562   0.0390
     4     4.3510   2.4529   0.0391
     5     4.1782   2.5296   0.0401
     6     4.6858   2.5317   0.0377
     7     4.1313   2.5605   0.0393
     8     4.2046   2.5694   0.0292
     9     4.1238   2.7121   0.0177
    10     3.9900   2.6700   0.0018

  IDAY IS  359 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE   3.499   4.254   2.330   2.720


  THE MAXIMUM SUBSURFACE CONCENTRATION IS    7224.63 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

    THERE ARE  129 ELEMENTS OUT THERE, WITH GRID SPACING DX,DY =  0.319E-01 0.196E-01MAP UNITS.

THIS IS ENTRY NUMBER  89 TO SUBROUTINE ADVOIF.
        PARTICLE OUTSIDE   IP=   12             XP=     3.1816       YP=    0.7309
        PARTICLE OUTSIDE   IP=   13             XP=     3.6580       YP=    0.6881
        PARTICLE OUTSIDE   IP=   74             XP=     3.9768       YP=    0.6664
        PARTICLE OUTSIDE   IP=  257             XP=     2.7780       YP=    0.7188
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Note: Days 359 to 467 have been deleted since they follow the same procedure as illustrated herein.

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TODAY IS 104.000 . IT HAS BEEN 104DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS 30

SPILLET   XLOC      YLOC      RADIUS
[illegible]

TODAY IS 104 AND THE VALUES OF XOILMA,XOILMX,YOILMA,YOILMX ARE   2.161   5.346   2.345   3.000
THE MAXIMUM SUBSURFACE CONCENTRATION IS    3226.62 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

  THERE ARE   50 ELEMENTS CUT THERE, WITH GRID SPACING DX,DY =  0.116E OU 0.274E-UTMAP UNITS.

THIS IS ENTRY NUMBER 104 TO SUBROUTINE ADVDIF.
          PARTICLE OUTSIDE   IP=  [illegible]      XP=  [illegible]      YP=  [illegible]
  IT =    1     TIME =    104.000 DAY     PARTICLE BUDGET:     NP = [illegible]     GROUP [illegible]
    IP        XP        YP        XELP     ITAPS     ITAPE     ASAPT
[illegible]

TODAY IS 105.000 . IT HAS BEEN 105DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS 30

SPILLET   XLOC      YLOC      RADIUS
[illegible]

TODAY IS 105 AND THE VALUES OF XOILMA,XOILMX,YOILMA,YOILMX ARE   2.113   5.336   2.354   3.023

THE MAXIMUM SUBSURFACE CONCENTRATION IS    4613.10 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

  THERE ARE   51 ELEMENTS CUT THERE, WITH GRID SPACING DX,DY =  0.120E OU 0.266E-UTMAP UNITS.

THIS IS ENTRY NUMBER 105 TO SUBROUTINE ADVDIF.
          PARTICLE OUTSIDE   IP=  [illegible]      XP=  [illegible]      YP=  [illegible]
  IT =    1     TIME =    105.000 DAY     PARTICLE BUDGET:     NP = [illegible]     GROUP [illegible]
    IP        XP        YP        XELP     ITAPS     ITAPE     ASAPT
[illegible]
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HERE IS THE DISTRIBUTION FOR DAY  105

DAY    105 A LARVAL DISTRIBUTION WRITTEN TO DISC.

DAY       XLOC     YLOC       NUMBER    DAY SPAWNED  STAGE   ELEMENT
   LRVSUM IS   0.2267E 05 AND PLARVA ENTRY IS   0.5305E 05  FOR DAY  341
   LRVSUM IS   0.3253E 05 AND PLARVA ENTRY IS   0.5704E 05  FOR DAY  351

IDAY  IS 470  IT HAS BEEN  120DAYS SINCE THE SPILL. THE NUMBER OF SPILLETS IS  30


SPILLET   XLOC    YLOC    RADIUS
    1    10.3167   -2.0499     0.0373
    2    10.3791   -2.0600     0.0346
    3    10.5473   -2.1005     0.0370
    4    10.3963   -2.1042     0.0391
    5    10.2146   -2.0275     0.0431
    6    10.1160   -2.0234     0.0357
    7    10.1650   -1.9606     0.0344
    8    10.2431   -1.9878     0.0391
    9    10.1582   -1.8450     0.0344
   10    10.0150   -1.8871     0.0396
   11     9.9995   -1.8526     0.0392
   12    10.0374   -1.7261     0.0392
   13     9.9419   -1.6317     0.0390
   14     9.7596   -1.6045     0.0393
   15     9.6595   -1.5183     0.0391
   16     9.5324   -1.5466     0.0391
   17     9.4185   -1.4408     0.0392
   18     9.3503   -1.4065     0.0347
   19     9.2499   -1.3078     0.0346
   20     9.1953   -1.2009     0.0398
   21     9.0481   -1.2105     0.0345
   22     9.0401   -1.1541     0.0349
   23     9.0493   -1.0872     0.0369
   24     9.1718   -1.1009     0.0384
   25     9.0810   -1.0305     0.0391
   26     9.2026   -1.0738     0.0393
   27     9.2956   -0.5725     0.0374
   28     9.3759   -1.0779     0.0394
   29     9.2932   -1.1293     0.0392
   30     9.3049   -1.0493     0.0387

IDAY IS  106 AND THE VALUES OF XOILMN,XOILMX,YOILMN,YOILMX ARE   2.155   5.419   2.376   3.031
 THE MAXIMUM SUBSURFACE CONCENTRATION IS    3193.08 PARTS PER BILLION ABOVE BACKGROUND LEVELS.

   THERE ARE   49 ELEMENTS OUT THERE. WITH GRID SPACING DX,DY =  0.171E 00 0.262E-01MAP UNITS.

THIS IS ENTRY NUMBER 200 TO SUBROUTINE ADVDIF.
          PARTICLE OUTSIDE   IP=  138          XP=   1.2347       YP=   2.2598
          PARTICLE OUTSIDE   IP=  182          XP=   1.0924       YP=   2.3136
          PARTICLE OUTSIDE   IP=  318          XP=   0.9627       YP=   2.2529
          PARTICLE OUTSIDE   IP=  380          XP=   0.5896       YP=   2.2876
          PARTICLE OUTSIDE   IP=  449          XP=   0.8937       YP=   2.2754
          PARTICLE OUTSIDE   IP=  686          XP=   1.1459       YP=   2.2755
          PARTICLE OUTSIDE   IP=  983          XP=   1.0504       YP=   2.2725
   IT =    1      TIME =      106.000 DAY     PARTICLE BUDGET:   NP = 1184     NNOW= 1184     NRCT=    0     NOUT=  720
      IP        XP            YP           IELP        ITMPS      ITMPE      SGNPT
     138     1.23467       2.25979          58         304        106          F
     182     1.09242       2.31356          57         306        106          F
     318     0.96266       2.25292          56         310        106          F
     380     0.58551       2.26701          56         312        105          F
     449     0.89367       2.27542          56         314        106          F
     686     1.14549       2.27549          58         322        106          F
     983     1.05041       2.27254          56         337        106          F
   OILED: A CLUSTER SPAWNED ON DAY   47 NOW IN STAGE   4 AND IN ELEMENT NUMBER   85 REPRESENTING   0.2053E 05ICHTHIOPLANKTON
   LRVSUM IS   0.2266E 05 AND PLARVA ENTRY IS   0.5308E 05  FOR DAY  341
   LRVSUM IS   0.3232E 05 AND PLARVA ENTRY IS   0.5781E 05  FOR DAY  351

  THE OILSPILL BEGAN ON DAY  350, AND ITS DIRECT EFFECTS ON THE FISHERY ENDED ON DAY  107.

THIS IS ENTRY NUMBER 201 TO SUBROUTINE ADVDIF.
          PARTICLE OUTSIDE   IP=  222          XP=   1.3946       YP=   2.2800
          PARTICLE OUTSIDE   IP=  223          XP=   0.5859       YP=   2.3244
          PARTICLE OUTSIDE   IP=  273          XP=   1.0236       YP=   2.2715
          PARTICLE OUTSIDE   IP=  294          XP=   1.3878       YP=   2.3433
          PARTICLE OUTSIDE   IP=  396          XP=   1.0655       YP=   2.3136
          PARTICLE OUTSIDE   IP=  659          XP=   1.3252       YP=   2.3191
          PARTICLE OUTSIDE   IP=  840          XP=   1.0593       YP=   2.3190
          PARTICLE OUTSIDE   IP=  866          XP=   0.8300       YP=   2.3134
   IT =    1      TIME =      107.000 DAY     PARTICLE BUDGET:   NP = 1193     NNOW= 1193     NRCT=    0     NOUT=  728
      IP        XP            YP           IELP        ITMPS      ITMPE      SGNPT
      72     2.30433       2.48527          85         302         47          F
     222     1.39460       2.27997          59         307        107          F
     223     0.98585       2.32993          58         307        107          F
     273     1.02360       2.27151          57         309        107          F
     294     1.38776       2.34303          79         309        107          F
     396     1.06549       2.31358          54         313        107          F
     659     1.32518       2.31910          60         321        107          F
     840     1.07933       2.31400          58         331        107          F
     866     0.82978       2.33136          56         328        107          F
   LRVSUM IS   0.2265E 05 AND PLARVA ENTRY IS   0.5379E 05  FOR DAY  341
   LRVSUM IS   0.3250E 05 AND PLARVA ENTRY IS   0.5770E 05  FOR DAY  351
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.3474E-05

                                   YEAR    1981

   AGE GROUP          SIZE           FISHING MORTALITY    NATURAL MORTALITY
       1          0.8273E 07              0.165                0.20
       2          0.6037E 07              0.305                0.20
       3          0.4345E 07              0.305                0.20
       4          0.2982E 07              0.305                0.20
       5          0.2035E 07              0.305                0.20
       6          0.1397E 07              0.305                0.20
       7          0.9500E 06              0.305                0.20
       8          0.6519E 06              0.305                0.20
       9          0.4457E 06              0.305                0.20
      10          0.3059E 06              0.305                0.20
      11          0.2142E 06              0.305                0.20
      12          0.1537E 06              0.305                0.20
      13          0.1129E 06              0.305                0.20
      14          0.8424E 05              0.305                0.20
      15          0.6258E 05              0.305                0.20
      16          0.4656E 05              0.305                0.20
      17          0.1011E 06              0.305                0.20
   AGE GROUP      TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                      (KG)                     (KG)          PERCENT
       1            0.1835E 07              0.8285E 06        0.039
       2            0.3146E 07              0.1500E 07        0.088
       3            0.3745E 07              0.1786E 07        0.106
       4            0.4024E 07              0.2430E 07        0.113
       5            0.3583E 07              0.2404E 07        0.112
       6            0.3709E 07              0.2240E 07        0.104
       7            0.3264E 07              0.1912E 07        0.092
       8            0.2730E 07              0.1649E 07        0.077
       9            0.2195E 07              0.1320E 07        0.062
      10            0.1723E 07              0.1041E 07        0.048
      11            0.1340E 07              0.8094E 06        0.038
      12            0.1046E 07              0.6318E 06        0.029
      13            0.8227E 06              0.4968E 06        0.023
      14            0.6484E 06              0.3916E 06        0.018
      15            0.5608E 06              0.3061E 06        0.014
      16            0.3883E 06              0.2341E 06        0.011
      17            0.8498E 06              0.2235E 06        0.024
THE ANNUAL YIELD IS     21.471 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.5510E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.191E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.3475E-05
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                                        YEAR   1982

 AGE GROUP            SIZE                FISHING MORTALITY     NATURAL MORTALITY
     1            0.1374E 08                    0.173                   0.20
     2            0.5734E 07                    0.321                   0.20
     3            0.364[illegible]E 07                    0.321                   0.20
     4            0.2675E 07                    0.321                   0.20
     5            0.1803E 07                    0.321                   0.20
     6            0.1230E 07                    0.321                   0.20
     7            0.8433E 06                    0.321                   0.20
     8            0.5764E 06                    0.321                   0.20
     9            0.3934E 06                    0.321                   0.20
    10            0.2684E 06                    0.321                   0.20
    11            0.1844E 06                    0.321                   0.20
    12            0.1292E 06                    0.321                   0.20
    13            0.9271E 05                    0.321                   0.20
    14            0.6814E 05                    0.321                   0.20
    15            0.5C44E 05                    0.321                   0.20
    16            0.3801E 05                    0.321                   0.20
    17            0.[illegible]414E 05                    0.321                   0.20
 AGE GROUP        TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                         (KG)                  (KG)           PERCENT
     1                0.3112E 07           0.1445E 07         0.071
     2                0.3064E 07           0.1888E 07         0.093
     3                0.3249E 07           0.2002E 07         0.098
     4                0.3678E 07           0.2234E 07         0.110
     5                0.360[illegible]E 07           0.2219E 07         0.109
     6                0.3946E 07           0.2067E 07         0.101
     7                0.2550E 07           0.1814E 07         0.089
     8                0.2476E 07           0.1526E 07         0.075
     9                0.1990E 07           0.1226E 07         0.060
    10                0.1547E 07           0.9544E 06         0.047
    11                0.1193E 07           0.7294E 06         0.036
    12                0.9015E 06           0.5556E 06         0.027
    13                0.6572E 06           0.4264E 06         0.021
    14                0.5373E 06           0.3311E 06         0.016
    15                0.4191E 06           0.2583E 06         0.013
    16                0.3250E 06           0.2003E 06         0.010
    17                0.7853E 06           0.4840E 06         0.024
THE ANNUAL YIELD IS    20.363 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4783E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.192E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4233E-05
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                                        YEAR   1983

 AGE GROUP            SIZE                FISHING MORTALITY     NATURAL MORTALITY
     1            0.1374E 08                    0.167                   0.20
     2            0.9460E 07                    0.310                   0.20
     3            0.34[illegible]E 07                    0.310                   0.20
     4            0.2163E 07                    0.310                   0.20
     5            0.1[illegible]E 07                    0.310                   0.20
     6            0.10[illegible]E 07                    0.310                   0.20
     7            0.7[illegible]E 06                    0.310                   0.20
     8            0.5007E 06                    0.310                   0.20
     9            0.34[illegible]E 06                    0.310                   0.20
    10            0.2330E 06                    0.310                   0.20
    11            0.15[illegible]E 06                    0.310                   0.20
    12            0.1076E 06                    0.310                   0.20
    13            0.7[illegible]E 05                    0.310                   0.20
    14            0.5530E 05                    0.310                   0.20
    15            [illegible]                    0.310                   0.20
    16            0.3019E 05                    0.310                   0.20
    17            0.7544E 05                    0.310                   0.20
 AGE GROUP        TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                         (KG)                  (KG)           PERCENT
     1                0.3070E 07           0.1390E 07         0.075
     2                0.4568E 07           0.3020E 07         0.161
     3                0.2498E 07           0.1810E 07         0.097
     4                0.2941E 07           0.1788E 07         0.096
     5                0.3066E 07           0.1864E 07         0.100
     6                0.2858E 07           0.1737E 07         0.093
     7                0.2513E 07           0.15[illegible]E 07         0.082
     8                0.2113E 07           0.1285E 07         0.069
     9                0.1734E 07           0.1036E 07         0.055
    10                0.1326E 07           0.8057E 06         0.043
    11                0.1005E 07           0.6107E 06         0.033
    12                0.7519E 06           0.4571E 06         0.024
    13                0.5634E 06           0.3425E 06         0.018
    14                0.4270E 06           0.2595E 06         0.014
    15                0.3280E 06           0.1994E 06         0.011
    16                0.2533E 06           0.1543E 06         0.008
    17                0.6542E 06           0.3976E 06         0.021
THE ANNUAL YIELD IS    18.656 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4107E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.191E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4930E-05
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                                        YEAR   1984

 AGE GROUP            SIZE                FISHING MORTALITY     NATURAL MORTALITY
     1            0.1374E 08                    0.1[illegible]                   0.20
     2            0.9518E 07                    0.302                   0.20
     3            0.5601E 07                    0.302                   0.20
     4            0.2096E 07                    0.302                   0.20
     5            0.1244E 07                    0.302                   0.20
     6            0.9353E 06                    0.302                   0.20
     7            0.6417E 06                    0.302                   0.20
     8            0.4387E 06                    0.302                   0.20
     9            0.3[illegible]E 06                    0.302                   0.20
    10            0.2057E 06                    0.302                   0.20
    11            0.14[illegible]E 06                    0.302                   0.20
    12            0.9569E 05                    0.302                   0.20
    13            0.6542E 05                    0.302                   0.20
    14            0.4608E 05                    0.302                   0.20
    15            0.33[illegible]E 05                    0.302                   0.20
    16            0.2430E 05                    0.302                   0.20
    17            0.6346E 05                    0.302                   0.20
 AGE GROUP        TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                         (KG)                  (KG)           PERCENT
     1                0.3042E 07           0.1368E 07         0.076
     2                0.4947E 07           0.2975E 07         0.165
     3                0.4926E 07           0.2965E 07         0.165
     4                0.2750E 07           0.1655E 07         0.092
     5                0.2[illegible]27E 07           0.1521E 07         0.084
     6                0.2475E 07           0.1490E 07         0.083
     7                0.2183E 07           0.1314E 07         0.073
     8                0.1830E 07           0.1102E 07         0.061
     9                0.1479E 07           0.8903E 06         0.049
    10                0.1154E 07           0.6947E 06         0.039
    11                0.8[illegible]44E 06           0.5264E 06         0.029
    12                0.6499E 06           0.3957E 06         0.022
    13                0.4778E 06           0.2876E 06         0.016
    14                0.3533E 06           0.2127E 06         0.012
    15                0.2651E 06           0.1596E 06         0.009
    16                0.2020E 06           0.1216E 06         0.007
    17                0.5435E 06           0.3271E 06         0.018
THE ANNUAL YIELD IS    18.001 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3609E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.188E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.9610E-05
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                                  YEAR   1985
   AGE GROUP        SIZE              FISHING MORTALITY    NATURAL MORTALITY
       1        0.1374E 08                 0.167                 0.20
       2        0.9556E 07                 0.310                 0.20
       3        0.5754E 07                 0.310                 0.20
       4        0.3437E 07                 0.310                 0.20
       5        0.1239E 07                 0.310                 0.20
       6        0.7852E 06                 0.310                 0.20
       7        0.5661E 06                 0.310                 0.20
       8        0.3882E 06                 0.310                 0.20
       9        0.2654E 06                 0.310                 0.20
      10        0.1819E 06                 0.310                 0.20
      11        0.1245E 06                 0.310                 0.20
      12        0.8487E 05                 0.310                 0.20
      13        0.5779E 05                 0.310                 0.20
      14        0.3982E 05                 0.310                 0.20
      15        0.2780E 05                 0.310                 0.20
      16        0.2000E 05                 0.310                 0.20
      17        0.5334E 05                 0.310                 0.20
   AGE GROUP     TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                     (KG)                    (KG)       PERCENT
       1             0.3070E 07           0.1399E 07     0.076
       2             0.5014E 07           0.3050E 07     0.165
       3             0.5054E 07           0.3077E 07     0.166
       4             0.4673E 07           0.2840E 07     0.153
       5             0.2435E 07           0.1480E 07     0.080
       6             0.2102E 07           0.1278E 07     0.069
       7             0.1548E 07           0.1184E 07     0.064
       8             0.1639E 07           0.9960E 06     0.054
       9             0.1320E 07           0.8025E 06     0.043
      10             0.1037E 07           0.6275E 06     0.034
      11             0.7847E 06           0.4770E 06     0.026
      12             0.5822E 06           0.3539E 06     0.019
      13             0.4253E 06           0.2584E 06     0.014
      14             0.3088E 06           0.1877E 06     0.010
      15             0.2261E 06           0.1374E 06     0.007
      16             0.1682E 06           0.1022E 06     0.006
      17             0.4621E 06           0.2756E 06     0.015
 THE ANNUAL YIELD IS    18.523 THOUSAND METRIC TONS
 THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3626E 13
 THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.166E 07
 THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5583E-05
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                                  YEAR   1986
   AGE GROUP        SIZE              FISHING MORTALITY    NATURAL MORTALITY
       1        0.1374E 08                 0.171                 0.20
       2        0.9519E 07                 0.320                 0.20
       3        0.5739E 07                 0.320                 0.20
       4        0.3458E 07                 0.320                 0.20
       5        0.2064E 07                 0.320                 0.20
       6        0.7433E 06                 0.320                 0.20
       7        0.4719E 06                 0.320                 0.20
       8        0.3409E 06                 0.320                 0.20
       9        0.2311E 06                 0.320                 0.20
      10        0.1574E 06                 0.320                 0.20
      11        0.1072E 06                 0.320                 0.20
      12        0.7474E 05                 0.320                 0.20
      13        0.5076E 05                 0.320                 0.20
      14        0.3477E 05                 0.320                 0.20
      15        0.2391E 05                 0.320                 0.20
      16        0.1674E 05                 0.320                 0.20
      17        0.4370E 05                 0.320                 0.20
   AGE GROUP     TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                     (KG)                    (KG)       PERCENT
       1             0.3107E 07           0.1449E 07     0.075
       2             0.5073E 07           0.3122E 07     0.167
       3             0.5108E 07           0.3143E 07     0.164
       4             0.4771E 07           0.2936E 07     0.153
       5             0.4171E 07           0.2534E 07     0.132
       6             0.2018E 07           0.1242E 07     0.065
       7             0.1649E 07           0.1014E 07     0.053
       8             0.1456E 07           0.8963E 06     0.047
       9             0.1177E 07           0.7244E 06     0.038
      10             0.9179E 06           0.5649E 06     0.029
      11             0.6970E 06           0.4102E 06     0.022
      12             0.5274E 06           0.3202E 06     0.017
      13             0.3737E 06           0.2331E 06     0.012
      14             0.2736E 06           0.1684E 06     0.009
      15             0.1968E 06           0.1211E 06     0.006
      16             0.1429E 06           0.8794E 05     0.005
      17             0.3860E 06           0.2376E 06     0.012
 THE ANNUAL YIELD IS    19.218 THOUSAND METRIC TONS
 THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3678E 13
 THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
 THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5504E-05
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                                  YEAR   1987
   AGE GROUP        SIZE              FISHING MORTALITY    NATURAL MORTALITY
       1        0.1374E 08                 0.172                 0.20
       2        0.9467E 07                 0.319                 0.20
       3        0.5659E 07                 0.319                 0.20
       4        0.3412E 07                 0.319                 0.20
       5        0.2036E 07                 0.319                 0.20
       6        0.1227E 07                 0.319                 0.20
       7        0.4419E 06                 0.319                 0.20
       8        0.2806E 06                 0.319                 0.20
       9        0.2021E 06                 0.319                 0.20
      10        0.1386E 06                 0.319                 0.20
      11        0.9475E 05                 0.319                 0.20
      12        0.6494E 05                 0.319                 0.20
      13        0.4443E 05                 0.319                 0.20
      14        0.3030E 05                 0.319                 0.20
      15        0.2067E 05                 0.319                 0.20
      16        0.1422E 05                 0.319                 0.20
      17        0.3605E 05                 0.319                 0.20
   AGE GROUP     TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                     (KG)                    (KG)       PERCENT
       1             0.3103E 07           0.1435E 07     0.075
       2             0.5096E 07           0.3095E 07     0.161
       3             0.5028E 07           0.3089E 07     0.161
       4             0.4694E 07           0.2887E 07     0.150
       5             0.4097E 07           0.2519E 07     0.131
       6             0.3329E 07           0.2043E 07     0.106
       7             0.1540E 07           0.9465E 06     0.049
       8             0.1200E 07           0.7372E 06     0.038
       9             0.1015E 07           0.6259E 06     0.033
      10             0.7568E 06           0.4896E 06     0.025
      11             0.6052E 06           0.3714E 06     0.019
      12             0.4513E 06           0.2773E 06     0.014
      13             0.3305E 06           0.2031E 06     0.011
      14             0.2383E 06           0.1463E 06     0.008
      15             0.1698E 06           0.1043E 06     0.005
      16             0.1211E 06           0.7442E 05     0.004
      17             0.3165E 06           0.1944E 06     0.010
 THE ANNUAL YIELD IS    19.238 THOUSAND METRIC TONS
 THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3726E 13
 THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
 THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5433E-05
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                                   YEAR   1988
AGE GROUP         SIZE                FISHING MORTALITY    NATURAL MORTALITY
    1          0.1174E 08                  0.167                 0.20
    2          0.9473E 07                  0.310                 0.20
    3          0.5615E 07                  0.310                 0.20
    4          0.3360E 07                  0.310                 0.20
    5          0.2011E 07                  0.310                 0.20
    6          0.1224E 07                  0.310                 0.20
    7          0.7534E 06                  0.310                 0.20
    8          0.2631E 06                  0.310                 0.20
    9          0.1670E 06                  0.310                 0.20
   10          0.1233E 06                  0.310                 0.20
   11          0.8751E 05                  0.310                 0.20
   12          0.5640E 05                  0.310                 0.20
   13          0.3866E 05                  0.310                 0.20
   14          0.2645E 05                  0.310                 0.20
   15          0.1834E 05                  0.310                 0.20
   16          0.1233E 05                  0.310                 0.20
   17          0.2992E 05                  0.310                 0.20
AGE GROUP       TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                      (KG)                    (KG)          PERCENT
    1              0.3070E 07              0.1399E 07        0.074
    2              0.4975E 07              0.3024E 07        0.160
    3              0.4447E 07              0.3004E 07        0.159
    4              0.4578E 07              0.2783E 07        0.147
    5              0.3545E 07              0.2429E 07        0.128
    6              0.3273E 07              0.1984E 07        0.105
    7              0.2513E 07              0.1528E 07        0.081
    8              0.1110E 07              0.6749E 06        0.036
    9              0.8330E 06              0.5050E 06        0.027
   10              0.6828E 06              0.4150E 06        0.022
   11              0.5227E 06              0.3162E 06        0.017
   12              0.3869E 06              0.2352E 06        0.012
   13              0.2834E 06              0.1725E 06        0.009
   14              0.2051E 06              0.1247E 06        0.007
   15              0.1462E 06              0.8984E 05        0.005
   16              0.1035E 06              0.6289E 05        0.003
   17              0.2593E 06              0.1516E 06        0.008
THE ANNUAL YIELD IS     18.908 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3784E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.154E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5351E-05

                                   YEAR   1989
AGE GROUP         SIZE                FISHING MORTALITY    NATURAL MORTALITY
    1          0.1374E 08                  0.173                 0.20
    2          0.9518E 07                  0.301                 0.20
    3          0.5640E 07                  0.301                 0.20
    4          0.3364E 07                  0.301                 0.20
    5          0.2021E 07                  0.301                 0.20
    6          0.1220E 07                  0.301                 0.20
    7          0.7354E 06                  0.301                 0.20
    8          0.4386E 06                  0.301                 0.20
    9          0.1553E 06                  0.301                 0.20
   10          0.1101E 06                  0.301                 0.20
   11          0.7227E 05                  0.301                 0.20
   12          0.4955E 05                  0.301                 0.20
   13          0.3367E 05                  0.301                 0.20
   14          0.2321E 05                  0.301                 0.20
   15          0.1519E 05                  0.301                 0.20
   16          0.1003E 05                  0.301                 0.20
   17          0.2536E 05                  0.301                 0.20
AGE GROUP       TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                      (KG)                    (KG)          PERCENT
    1              0.3633E 07              0.1362E 07        0.073
    2              0.4532E 07              0.2964E 07        0.159
    3              0.4523E 07              0.2954E 07        0.158
    4              0.4540E 07              0.2728E 07        0.146
    5              0.3427E 07              0.2363E 07        0.126
    6              0.3214E 07              0.1934E 07        0.103
    7              0.2445E 07              0.1455E 07        0.080
    8              0.1827E 07              0.1099E 07        0.059
    9              0.7754E 06              0.4660E 06        0.025
   10              0.5616E 06              0.3375E 06        0.018
   11              0.4495E 06              0.2702E 06        0.014
   12              0.3354E 06              0.2016E 06        0.011
   13              0.2454E 06              0.1475E 06        0.008
   14              0.1777E 06              0.1068E 06        0.006
   15              0.1271E 06              0.7637E 05        0.004
   16              0.8587E 05              0.5401E 05        0.003
   17              0.2160E 06              0.1303E 06        0.007
THE ANNUAL YIELD IS     18.655 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3866E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.154E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5237E-05

                                   YEAR   1990
AGE GROUP         SIZE                FISHING MORTALITY    NATURAL MORTALITY
    1          0.1374E 08                  0.164                 0.20
    2          0.9563E 07                  0.304                 0.20
    3          0.5766E 07                  0.304                 0.20
    4          0.3446E 07                  0.304                 0.20
    5          0.2050E 07                  0.304                 0.20
    6          0.1225E 07                  0.304                 0.20
    7          0.7380E 06                  0.304                 0.20
    8          0.4452E 06                  0.304                 0.20
    9          0.2657E 06                  0.304                 0.20
   10          0.9569E 05                  0.304                 0.20
   11          0.6076E 05                  0.304                 0.20
   12          0.4377E 05                  0.304                 0.20
   13          0.3001E 05                  0.304                 0.20
   14          0.2052E 05                  0.304                 0.20
   15          0.1406E 05                  0.304                 0.20
   16          0.9621E 04                  0.304                 0.20
   17          0.2192E 05                  0.304                 0.20
AGE GROUP       TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                      (KG)                    (KG)          PERCENT
    1              0.3047E 07              0.1371E 07        0.072
    2              0.4575E 07              0.3000E 07        0.156
    3              0.5009E 07              0.3020E 07        0.158
    4              0.4641E 07              0.2798E 07        0.146
    5              0.3595E 07              0.2407E 07        0.126
    6              0.3246E 07              0.1957E 07        0.102
    7              0.2519E 07              0.1518E 07        0.079
    8              0.1861E 07              0.1122E 07        0.059
    9              0.1129E 07              0.6894E 06        0.041
   10              0.5379E 06              0.3243E 06        0.017
   11              0.3794E 06              0.2288E 06        0.012
   12              0.2974E 06              0.1793E 06        0.009
   13              0.2193E 06              0.1316E 06        0.007
   14              0.1576E 06              0.9503E 05        0.005
   15              0.1129E 06              0.6811E 05        0.004
   16              0.8014E 05              0.4832E 05        0.003
   17              0.1882E 06              0.1135E 06        0.006
THE ANNUAL YIELD IS     19.175 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3961E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.155E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5112E-05
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                                  YEAR   1991
AGE GROUP        SIZE              FISHING MORTALITY    NATURAL MORTALITY
    1        0.1375E 08                 0.170                 0.20
    2        0.9552E 07                 0.326                 0.20
    3        0.5778E 07                 0.326                 0.20
    4        0.3984E 07                 0.326                 0.20
    5        0.2682E 07                 0.326                 0.20
    6        0.1219E 07                 0.326                 0.20
    7        0.7434E 06                 0.326                 0.20
    8        0.4464E 06                 0.326                 0.20
    9        0.2713E 06                 0.326                 0.20
   10        0.1635E 06                 0.326                 0.20
   11        0.5782E 05                 0.326                 0.20
   12        0.3671E 05                 0.326                 0.20
   13        0.2645E 05                 0.326                 0.20
   14        0.1814E 05                 0.326                 0.20
   15        0.1243E 05                 0.326                 0.20
   16        0.8498E 04                 0.326                 0.20
   17        0.1936E 05                 0.326                 0.20
AGE GROUP        TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                      (KG)                    (KG)        PERCENT
    1             0.3110E 07             0.1460E 07        0.071
    2             0.5117E 07             0.3108E 07        0.154
    3             0.5121E 07             0.3121E 07        0.156
    4             0.4851E 07             0.3027E 07        0.146
    5             0.4196E 07             0.2601E 07        0.126
    6             0.3359E 07             0.2104E 07        0.102
    7             0.2609E 07             0.1614E 07        0.078
    8             0.1910E 07             0.1196E 07        0.058
    9             0.1370E 07             0.8458E 06        0.041
   10             0.9311E 06             0.5785E 06        0.028
   11             0.3714E 06             0.2115E 06        0.011
   12             0.2979E 06             0.1594E 06        0.008
   13             0.1969E 06             0.1231E 06        0.006
   14             0.1441E 06             0.8911E 05        0.004
   15             0.1013E 06             0.6368E 05        0.003
   16             0.7319E 05             0.4537E 05        0.002
   17             0.1692E 06             0.1044E 06        0.005
THE ANNUAL YIELD IS    20.640 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4305E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.156E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5056E-05

                                  YEAR   1992
AGE GROUP        SIZE              FISHING MORTALITY    NATURAL MORTALITY
    1        0.1379E 08                 0.171                 0.20
    2        0.9435E 07                 0.316                 0.20
    3        0.5642E 07                 0.316                 0.20
    4        0.3414E 07                 0.316                 0.20
    5        0.2054E 07                 0.316                 0.20
    6        0.1230E 07                 0.316                 0.20
    7        0.7316E 06                 0.316                 0.20
    8        0.4374E 06                 0.316                 0.20
    9        0.2637E 06                 0.316                 0.20
   10        0.1599E 06                 0.316                 0.20
   11        0.9695E 05                 0.316                 0.20
   12        0.3416E 05                 0.316                 0.20
   13        0.2167E 05                 0.316                 0.20
   14        0.1563E 05                 0.316                 0.20
   15        0.1157E 05                 0.316                 0.20
   16        0.7324E 04                 0.316                 0.20
   17        0.1172E 05                 0.316                 0.20
AGE GROUP        TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                      (KG)                    (KG)        PERCENT
    1             0.3093E 07             0.1425E 07        0.072
    2             0.5001E 07             0.3064E 07        0.154
    3             0.4995E 07             0.3262E 07        0.154
    4             0.4685E 07             0.2873E 07        0.144
    5             0.4097E 07             0.2504E 07        0.126
    6             0.3321E 07             0.2034E 07        0.102
    7             0.2541E 07             0.1557E 07        0.078
    8             0.1863E 07             0.1142E 07        0.057
    9             0.1324E 07             0.8112E 06        0.041
   10             0.9103E 06             0.5576E 06        0.028
   11             0.4536E 06             0.3698E 06        0.019
   12             0.2769E 06             0.1449E 06        0.007
   13             0.1627E 06             0.9846E 05        0.005
   14             0.1223E 06             0.7493E 05        0.004
   15             0.8769E 05             0.5117E 05        0.003
   16             0.6217E 05             0.3808E 05        0.002
   17             0.1474E 06             0.8773E 05        0.004
THE ANNUAL YIELD IS    19.890 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3989E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.157E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5076E-05

                                  YEAR   1993
AGE GROUP        SIZE              FISHING MORTALITY    NATURAL MORTALITY
    1        0.1374E 08                 0.163                 0.20
    2        0.9468E 07                 0.302                 0.20
    3        0.5610E 07                 0.302                 0.20
    4        0.3367E 07                 0.302                 0.20
    5        0.2017E 07                 0.302                 0.20
    6        0.1224E 07                 0.302                 0.20
    7        0.7541E 06                 0.302                 0.20
    8        0.4367E 06                 0.302                 0.20
    9        0.2613E 06                 0.302                 0.20
   10        0.1574E 06                 0.302                 0.20
   11        0.9457E 05                 0.302                 0.20
   12        0.5600E 05                 0.302                 0.20
   13        0.2074E 05                 0.302                 0.20
   14        0.1274E 05                 0.302                 0.20
   15        0.9325E 04                 0.302                 0.20
   16        0.6394E 04                 0.302                 0.20
   17        0.1409E 05                 0.302                 0.20
AGE GROUP        TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                      (KG)                    (KG)        PERCENT
    1             0.3042E 07             0.1368E 07        0.072
    2             0.4925E 07             0.2965E 07        0.155
    3             0.4932E 07             0.2934E 07        0.153
    4             0.4526E 07             0.2724E 07        0.142
    5             0.3563E 07             0.2385E 07        0.125
    6             0.3248E 07             0.1955E 07        0.102
    7             0.2457E 07             0.1501E 07        0.075
    8             0.1822E 07             0.1057E 07        0.057
    9             0.1286E 07             0.7729E 06        0.040
   10             0.8830E 06             0.5316E 06        0.028
   11             0.5512E 06             0.3559E 06        0.019
   12             0.3839E 06             0.2311E 06        0.012
   13             0.1440E 06             0.8908E 05        0.005
   14             0.9524E 05             0.5574E 05        0.003
   15             0.7475E 05             0.4503E 05        0.002
   16             0.5316E 05             0.3200E 05        0.002
   17             0.1207E 06             0.7265E 05        0.004
THE ANNUAL YIELD IS    19.127 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4001E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.157E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5060E-05
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                                   YEAR    1994
 AGE GROUP         SIZE                FISHING MORTALITY    NATURAL MORTALITY
     1         0.1374E 08                    0.159                 0.20
     2         0.9556E 07                    0.314                 0.20
     3         0.5739E 07                    0.314                 0.20
     4         0.3400E 07                    0.314                 0.20
     5         0.[illegible]E 07             0.314                 0.20
     6         0.1233E 07                    0.314                 0.20
     7         0.7432E 06                    0.314                 0.20
     8         0.4442E 06                    0.314                 0.20
     9         0.2642E 06                    0.314                 0.20
    10         0.1579E 06                    0.314                 0.20
    11         0.9522E 05                    0.314                 0.20
    12         0.5738E 05                    0.314                 0.20
    13         0.34[illegible]E 05           0.314                 0.20
    14         0.1211E 05                    0.314                 0.20
    15         0.7831E 04                    0.314                 0.20
    16         0.5642E 04                    0.314                 0.20
    17         0.1234E 05                    0.314                 0.20
 AGE GROUP       TOTAL BIOMASS LOST        CONTRIBUTION TO CATCH
                     (KG)                       (KG)          PERCENT
     1             0.3084E 07               0.1414E 07         0.071
     2             0.5047E 07               0.3087E 07         0.154
     3             0.506[illegible]E 07     0.3[illegible]E 07 0.155
     4             0.4657E 07               0.2844E 07         0.143
     5             0.4[illegible]E 07       0.2[illegible]E 07 0.1[illegible]
     6             0.331[illegible]E 07     0.202[illegible]E 07 0.101
     7             0.2[illegible]E 07       0.157[illegible]E 07 0.07[illegible]
     8             0.1885E 07               0.11[illegible]E 07 0.058
     9             0.1322E 07               0.8072E 06         0.0[illegible]
    10             0.9012E 06               0.5504E 06         0.0[illegible]8
    11             0.6[illegible]E 06       0.3697E 06         0.01[illegible]
    12             0.3559E 06               0.2417E 06         0.012
    13             0.2529E 06               0.1544E 06         0.005
    14             0.9619E 05               0.5874E 05         0.003
    15             0.6385E 05               0.3902E 05         0.00[illegible]
    16             0.4771E 05               0.2914E 05         0.001
    17             0.1080E 06               0.6[illegible]E 05 0.0[illegible]
THE ANNUAL YIELD IS     19.994 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4028E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS    0.5027E-05

                                   YEAR    1995
 AGE GROUP         SIZE                FISHING MORTALITY    NATURAL MORTALITY
     1         0.1[illegible]E 08            0.1[illegible]        0.20
     2         0.9[illegible]E 07            0.315                 0.20
     3         0.5[illegible]E 07            0.315                 0.20
     4         0.345[illegible]E 07          0.315                 0.20
     5         0.[illegible]E 07             0.315                 0.20
     6         0.121[illegible]E 07          0.315                 0.20
     7         0.7[illegible]E 06            0.315                 0.20
     8         0.4[illegible]E 06            0.315                 0.20
     9         0.2[illegible]E 06            0.315                 0.20
    10         0.1[illegible]E 06            0.315                 0.20
    11         [illegible] 05                0.315                 0.20
    12         0.5[illegible]E 05            0.315                 0.20
    13         0.3[illegible]E 05            0.315                 0.20
    14         0.2[illegible]E 05            0.315                 0.20
    15         0.7[illegible]E 04            0.315                 0.20
    16         0.4605E 04                    0.315                 0.20
    17         0.1079E 05                    0.315                 0.20
 AGE GROUP       TOTAL BIOMASS LOST        CONTRIBUTION TO CATCH
                     (KG)                       (KG)          PERCENT
     1             [illegible] 07           [illegible] 07     0.071
     2             0.50[illegible]E 07      0.[illegible]E 07  0.154
     3             0.5[illegible]E 07       0.3[illegible]E 07 0.154
     4             0.4703E 07               0.2876E 07         0.144
     5             0.40[illegible]E 07      0.2[illegible]E 07 0.133
     6             0.3[illegible]E 07       0.2[illegible]E 07 0.1[illegible]
     7             0.2[illegible]E 07       0.1[illegible]E 07 0.07[illegible]
     8             0.18[illegible]E 07      0.115[illegible]E 07 0.056
     9             0.13[illegible]E 07      0.[illegible]E 06  0.041
    10             0.9[illegible]E 06       0.5[illegible]E 06 0.028
    11             0.6[illegible]E 06       0.3[illegible]E 06 0.018
    12             0.35[illegible]E 06      0.2[illegible]E 06 0.012
    13             0.2[illegible]E 06       0.15[illegible]E 06 0.0[illegible]5
    14             [illegible] 06           0.5791E 05         0.005
    15             0.6[illegible]E 05       0.3[illegible]E 05 0.00[illegible]
    16             0.3969E 05               0.2428E 05         0.001
    17             0.9418E 05               0.5761E 05         0.003
THE ANNUAL YIELD IS     20.[illegible]6 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4030E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS    0.50[illegible]E-05

                                   YEAR    1956
 AGE GROUP         SIZE                FISHING MORTALITY    NATURAL MORTALITY
     1         0.1374E 08                    0.176                 0.20
     2         0.9472E 07                    0.326                 0.20
     3         0.5675E 07                    0.326                 0.20
     4         0.3416E 07                    0.326                 0.20
     5         0.20[illegible]E 07           0.326                 0.20
     6         0.1218E 07                    0.326                 0.20
     7         0.72[illegible]E 06           0.326                 0.20
     8         0.4406E 06                    0.326                 0.20
     9         0.2[illegible]E 06            0.326                 0.20
    10         0.1598E 06                    0.326                 0.20
    11         0.9[illegible]E 05            0.326                 0.20
    12         0.5645E 05                    0.326                 0.20
    13         0.3[illegible]E 05            0.326                 0.20
    14         0.2051E 05                    0.326                 0.20
    15         0.122[illegible]E 05          0.326                 0.20
    16         0.4409E 04                    0.326                 0.20
    17         0.[illegible]E 04             0.326                 0.20
 AGE GROUP       TOTAL BIOMASS LOST        CONTRIBUTION TO CATCH
                     (KG)                       (KG)          PERCENT
     1             0.3130E 07               0.1466E 07         0.071
     2             0.5105E 07               0.3165E 07         0.154
     3             0.50[illegible]E 07      0.3161E 07         0.15[illegible]
     4             0.4756E 07               0.2949E 07         0.143
     5             0.41[illegible]E 07      0.25[illegible]E 07 0.125
     6             0.3335E 07               0.2068E 07         0.101
     7             0.2566E 07               0.1591E 07         0.077
     8             0.190[illegible]E 07     0.1181E 07         0.057
     9             0.13[illegible]E 07      0.8191E 06         0.041
    10             0.9228E 06               0.5721E 06         0.028
    11             0.6[illegible]E 06       0.3[illegible]E 06 0.018
    12             0.3967E 06               0.2459E 06         0.012
    13             0.2559E 06               0.150[illegible]E 06 0.008
    14             0.1629E 06               0.1010E 06         0.005
    15             0.1[illegible]E 06       0.6[illegible]E 05 0.003
    16             0.3[illegible]E 05       0.2[illegible]E 05 0.001
    17             0.8215E 05               0.5[illegible]E 05 0.00[illegible]
THE ANNUAL YIELD IS     20.519 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.430[illegible]E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS    0.50[illegible]1E-05
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                                        YEAR    1997
 AGE GROUP          SIZE                FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                  0.165                  0.20
     2          0.9435E 07                  0.305                  0.20
     3          0.5603E 07                  0.305                  0.20
     4          0.3353E 07                  0.305                  0.20
     5          0.2019E 07                  0.305                  0.20
     6          0.1217E 07                  0.305                  0.20
     7          0.7175E 06                  0.305                  0.20
     8          0.4302E 06                  0.305                  0.20
     9          0.2613E 06                  0.305                  0.20
    10          0.1567E 06                  0.305                  0.20
    11          0.9380E 05                  0.305                  0.20
    12          0.5580E 05                  0.305                  0.20
    13          0.3335E 05                  0.305                  0.20
    14          0.2011E 05                  0.305                  0.20
    15          0.1212E 05                  0.305                  0.20
    16          0.7233E 04                  0.305                  0.20
    17          0.4047E 04                  0.305                  0.20
 AGE GROUP        TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                       (KG)                    (KG)        PERCENT
     1              0.3051E 07             0.1374E 07      0.072
     2              0.4917E 07             0.2971E 07      0.155
     3              0.4949E 07             0.2964E 07      0.155
     4              0.4524E 07             0.2737E 07      0.143
     5              0.3943E 07             0.2348E 07      0.124
     6              0.3217E 07             0.1948E 07      0.101
     7              0.2454E 07             0.1485E 07      0.077
     8              0.1832E 07             0.1088E 07      0.057
     9              0.1245E 07             0.7767E 06      0.040
    10              0.8819E 06             0.5339E 06      0.028
    11              0.5879E 06             0.3555E 06      0.019
    12              0.3773E 06             0.2294E 06      0.012
    13              0.2431E 06             0.1468E 06      0.009
    14              0.1548E 06             0.9144E 05      0.005
    15              0.9751E 05             0.5427E 05      0.003
    16              0.6039E 05             0.3645E 05      0.002
    17              0.6517E 05             0.4173E 05      0.002
THE ANNUAL YIELD IS    19.195 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3984E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5082E-05


                                        YEAR    1998
 AGE GROUP          SIZE                FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                  0.177                  0.20
     2          0.9543E 07                  0.327                  0.20
     3          0.5629E 07                  0.327                  0.20
     4          0.3335E 07                  0.327                  0.20
     5          0.2014E 07                  0.327                  0.20
     6          0.1218E 07                  0.327                  0.20
     7          0.7317E 06                  0.327                  0.20
     8          0.4341E 06                  0.327                  0.20
     9          0.2594E 06                  0.327                  0.20
    10          0.1571E 06                  0.327                  0.20
    11          0.9472E 05                  0.327                  0.20
    12          0.5661E 05                  0.327                  0.20
    13          0.3354E 05                  0.327                  0.20
    14          0.2011E 05                  0.327                  0.20
    15          0.1214E 05                  0.327                  0.20
    16          0.7313E 04                  0.327                  0.20
    17          0.9211E 04                  0.327                  0.20
 AGE GROUP        TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                       (KG)                    (KG)        PERCENT
     1              0.3119E 07             0.1471E 07      0.071
     2              0.5142E 07             0.3193E 07      0.155
     3              0.5124E 07             0.3181E 07      0.155
     4              0.4721E 07             0.2931E 07      0.143
     5              0.4085E 07             0.2535E 07      0.123
     6              0.3341E 07             0.2075E 07      0.101
     7              0.2482E 07             0.1603E 07      0.078
     8              0.1893E 07             0.1167E 07      0.057
     9              0.1375E 07             0.8378E 06      0.042
    10              0.9147E 06             0.5679E 06      0.028
    11              0.6128E 06             0.3804E 06      0.019
    12              0.3995E 06             0.2474E 06      0.012
    13              0.2517E 06             0.1575E 06      0.008
    14              0.1602E 06             0.9944E 05      0.005
    15              0.1010E 06             0.6262E 05      0.003
    16              0.6210E 05             0.3918E 05      0.002
    17              0.8291E 05             0.5357E 05      0.002
THE ANNUAL YIELD IS    20.586 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3980E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.160E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5087E-05


                                        YEAR    1999
 AGE GROUP          SIZE                FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                  0.167                  0.20
     2          0.9429E 07                  0.310                  0.20
     3          0.5631E 07                  0.310                  0.20
     4          0.3360E 07                  0.310                  0.20
     5          0.1997E 07                  0.310                  0.20
     6          0.1194E 07                  0.310                  0.20
     7          0.7187E 06                  0.310                  0.20
     8          0.4316E 06                  0.310                  0.20
     9          0.2562E 06                  0.310                  0.20
    10          0.1512E 06                  0.310                  0.20
    11          0.9227E 05                  0.310                  0.20
    12          0.5589E 05                  0.310                  0.20
    13          0.3340E 05                  0.310                  0.20
    14          0.1987E 05                  0.310                  0.20
    15          0.1188E 05                  0.310                  0.20
    16          0.7161E 04                  0.310                  0.20
    17          0.9766E 04                  0.310                  0.20
 AGE GROUP        TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                       (KG)                    (KG)        PERCENT
     1              0.3070E 07             0.1397E 07      0.072
     2              0.4551E 07             0.3010E 07      0.155
     3              0.4934E 07             0.3002E 07      0.155
     4              0.4569E 07             0.2776E 07      0.143
     5              0.3929E 07             0.2384E 07      0.123
     6              0.3194E 07             0.1941E 07      0.100
     7              0.2473E 07             0.1503E 07      0.077
     8              0.1822E 07             0.1107E 07      0.057
     9              0.1274E 07             0.7745E 06      0.040
    10              0.8694E 06             0.5284E 06      0.027
    11              0.5845E 06             0.3553E 06      0.018
    12              0.3834E 06             0.2331E 06      0.012
    13              0.2452E 06             0.1491E 06      0.008
    14              0.1541E 06             0.9367E 05      0.005
    15              0.5631E 05             0.5856E 05      0.003
    16              0.6022E 05             0.3660E 05      0.002
    17              0.8460E 05             0.5142E 05      0.003
THE ANNUAL YIELD IS    19.407 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3953E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5121E-05
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                                        YEAR   2000
  AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
      1         0.1374E 08                  0.175                  0.20
      2         0.9518E 07                  0.326                  0.20
      3         0.5662E 07                  0.326                  0.20
      4         0.3382E 07                  0.326                  0.20
      5         0.2014E 07                  0.326                  0.20
      6         0.1199E 07                  0.326                  0.20
      7         0.7170E 06                  0.326                  0.20
      8         0.4315E 06                  0.326                  0.20
      9         0.2597E 06                  0.326                  0.20
     10         0.1538E 06                  0.326                  0.20
     11         0.9205E 05                  0.326                  0.20
     12         0.5567E 05                  0.326                  0.20
     13         0.3356E 05                  0.326                  0.20
     14         0.2036E 05                  0.326                  0.20
     15         0.1173E 05                  0.326                  0.20
     16         0.7133E 04                  0.326                  0.20
     17         0.1018E 05                  0.174                  0.20
  AGE GROUP          TOTAL BIOMASS LOST          CONTRIBUTION TO CATCH
                          (KG)                       (KG)         PERCENT
      1               0.3121E 07                0.1454E 07         0.072
      2               0.5101E 07                0.3113E 07         0.156
      3               0.5[illegible]E 07        0.3113E 07         0.155
      4               0.4692E 07                0.2003E 07         0.143
      5               0.4551E 07                0.[illegible]E 07  0.124
      6               0.3773E 07                0.2021E 07         0.103
      7               0.2[illegible]E 07        0.14[illegible]E 07 0.077
      8               0.1849E 07                0.1149E 07         0.057
      9               0.1316E 07                0.8133E 06         0.042
     10               0.8409E 06                0.5507E 06         0.027
     11               0.5470E 06                0.3659E 06         0.018
     12               0.3997E 06                0.2459E 06         0.012
     13               0.2315E 06                0.1[illegible]E 06 0.008
     14               0.1509E 06                0.9011E 05         0.005
     15               0.9[illegible]E 05        0.61[illegible]E 05 0.003
     16               0.6121E 05                0.3785E 05         0.002
     17               0.8547E 05                0.5555E 05         0.003
THE ANNUAL YIELD IS    20.292 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3952E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5123E-05
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                                        YEAR   2001
  AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
      1         0.1374E 08                  0.161                  0.20
      2         0.9447E 07                  0.299                  0.20
      3         0.56[illegible]E 07         0.299                  0.20
      4         0.3351E 07                  0.299                  0.20
      5         0.2[illegible]E 07          0.299                  0.20
      6         0.11[illegible]E 07         0.299                  0.20
      7         0.7[illegible]E 06          0.299                  0.20
      8         0.4267E 06                  0.299                  0.20
      9         0.2[illegible]E 06          0.299                  0.20
     10         0.1535E 06                  0.299                  0.20
     11         0.9[illegible]E 05          0.299                  0.20
     12         0.5447E 05                  0.299                  0.20
     13         0.3[illegible]E 05          0.299                  0.20
     14         0.1900E 05                  0.299                  0.20
     15         0.115[illegible]E 05        0.299                  0.20
     16         0.7[illegible]E 04          0.299                  0.20
     17         0.1074E 05                  0.299                  0.20
  AGE GROUP          TOTAL BIOMASS LOST          CONTRIBUTION TO CATCH
                          (KG)                       (KG)         PERCENT
      1               0.3029E 07                0.1152E 07         0.072
      2               0.4877E 07                0.2421E 07         0.156
      3               0.4[illegible]E 07        0.2911E 07         0.155
      4               0.4481E 07                0.2684E 07         0.143
      5               0.3873E 07                0.2[illegible]E 07 0.124
      6               0.3142E 07                0.1862E 07         0.100
      7               0.2403E 07                0.1414E 07         0.077
      8               0.1762E 07                0.1055E 07         0.056
      9               0.1253E 07                0.7487E 06         0.0[illegible]
     10               0.8563E 06                0.5125E 06         0.027
     11               0.5647E 06                0.3[illegible]E 06 0.018
     12               0.3675E 06                0.2201E 06         0.012
     13               0.2[illegible]E 06        0.1475E 06         0.008
     14               0.1515E 06                0.9077E 05         0.005
     15               0.9[illegible]E 05        0.5[illegible]E 05 0.003
     16               0.5843E 05                0.3499E 05         0.002
     17               0.8726E 05                0.5227E 05         0.003
THE ANNUAL YIELD IS    18.762 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3955E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.157E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5119E-05
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                                        YEAR   2002
  AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
      1         0.1374E 08                  0.175                  0.20
      2         0.9576E 07                  0.321                  0.20
      3         0.5737E 07                  0.321                  0.20
      4         0.3423E 07                  0.321                  0.20
      5         0.2036E 07                  0.321                  0.20
      6         0.1216E 07                  0.321                  0.20
      7         0.7257E 06                  0.321                  0.20
      8         0.4314E 06                  0.321                  0.20
      9         0.257[illegible]E 06        0.321                  0.20
     10         0.1532E 06                  0.321                  0.20
     11         [illegible]E 05             0.321                  0.20
     12         0.5535E 05                  0.321                  0.20
     13         0.3309E 05                  0.321                  0.20
     14         0.2032E 05                  0.321                  0.20
     15         0.1237E 05                  0.321                  0.20
     16         0.7215E 04                  0.321                  0.20
     17         0.1051E 05                  0.321                  0.20
  AGE GROUP          TOTAL BIOMASS LOST          CONTRIBUTION TO CATCH
                          (KG)                       (KG)         PERCENT
      1               0.3112E 07                0.1445E 07         0.071
      2               0.5115E 07                0.3151E 07         0.155
      3               0.5116E 07                0.3151E 07         0.155
      4               0.4732E 07                0.2917E 07         0.144
      5               0.4074E 07                0.2511E 07         0.124
      6               0.3304E 07                0.2039E 07         0.100
      7               0.2[illegible]E 07        0.1565E 07         0.077
      8               0.1851E 07                0.1141E 07         0.056
      9               0.1305E 07                0.8[illegible]E 06 0.042
     10               0.8557E 06                0.5520E 06         0.027
     11               0.5977E 06                0.3683E 06         0.018
     12               0.3860E 06                0.2379E 06         0.012
     13               0.2470E 06                0.1[illegible]E 06 0.008
     14               0.1525E 06                0.9731E 05         0.005
     15               0.9523E 05                0.6136E 05         0.003
     16               0.6169E 05                0.3802E 05         0.002
     17               0.9263E 05                0.5706E 05         0.003
THE ANNUAL YIELD IS    20.290 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.3991E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5073E-05
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                                   YEAR   2003
  AGE GROUP           SIZE              FISHING MORTALITY    NATURAL MORTALITY
       1          0.1374E 08                 0.161                 0.20
       2          0.9460E 07                 0.297                 0.20
       3          0.5695E 07                 0.297                 0.20
       4          0.3437E 07                 0.297                 0.20
       5          0.2033E 07                 0.297                 0.20
       6          0.1209E 07                 0.297                 0.20
       7          0.7222E 06                 0.297                 0.20
       8          0.4307E 06                 0.297                 0.20
       9          0.2561E 06                 0.297                 0.20
      10          0.1531E 06                 0.297                 0.20
      11          0.9218E 05                 0.297                 0.20
      12          0.5536E 05                 0.297                 0.20
      13          0.3246E 05                 0.297                 0.20
      14          0.1905E 05                 0.297                 0.20
      15          0.1149E 05                 0.297                 0.20
      16          0.7168E 04                 0.297                 0.20
      17          0.1053E 05                 0.297                 0.20
  AGE GROUP       TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                      (KG)                     (KG)        PERCENT
       1              0.1023E 07             0.1347E 07     0.071
       2              0.4814E 07             0.2915E 07     0.154
       3              0.4802E 07             0.2926E 07     0.155
       4              0.4564E 07             0.2717E 07     0.144
       5              0.3553E 07             0.2386E 07     0.126
       6              0.3173E 07             0.1997E 07     0.106
       7              0.2438E 07             0.1458E 07     0.077
       8              0.1784E 07             0.1067E 07     0.057
       9              0.1250E 07             0.7475E 06     0.040
      10              0.8526E 06             0.5098E 06     0.027
      11              0.5702E 06             0.3412E 06     0.018
      12              0.3726E 06             0.2229E 06     0.012
      13              0.2367E 06             0.1415E 06     0.007
      14              0.1495E 06             0.8947E 05     0.005
      15              0.9458E 05             0.5654E 05     0.003
      16              0.5914E 05             0.3536E 05     0.002
      17              0.8549E 05             0.5115E 05     0.003
THE ANNUAL YIELD IS     18.870 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4008E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.156E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5052E-05

                                   YEAR   2004
  AGE GROUP           SIZE              FISHING MORTALITY    NATURAL MORTALITY
       1          0.1374E 08                 0.164                 0.20
       2          0.9582E 07                 0.301                 0.20
       3          0.5752E 07                 0.301                 0.20
       4          0.3457E 07                 0.301                 0.20
       5          0.2071E 07                 0.301                 0.20
       6          0.1236E 07                 0.301                 0.20
       7          0.7353E 06                 0.301                 0.20
       8          0.4392E 06                 0.301                 0.20
       9          0.2622E 06                 0.301                 0.20
      10          0.1557E 06                 0.301                 0.20
      11          0.9312E 05                 0.301                 0.20
      12          0.5605E 05                 0.301                 0.20
      13          0.3306E 05                 0.301                 0.20
      14          0.1998E 05                 0.301                 0.20
      15          0.1175E 05                 0.301                 0.20
      16          0.7229E 04                 0.301                 0.20
      17          0.1070E 05                 0.301                 0.20
  AGE GROUP       TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                      (KG)                     (KG)        PERCENT
       1              0.1037E 07             0.1367E 07     0.070
       2              0.4966E 07             0.2994E 07     0.154
       3              0.4578E 07             0.2998E 07     0.155
       4              0.4639E 07             0.2787E 07     0.144
       5              0.4071E 07             0.2417E 07     0.125
       6              0.3262E 07             0.1961E 07     0.101
       7              0.2496E 07             0.1500E 07     0.077
       8              0.1829E 07             0.1099E 07     0.057
       9              0.1286E 07             0.7737E 06     0.040
      10              0.8771E 06             0.5241E 06     0.027
      11              0.5744E 06             0.3482E 06     0.018
      12              0.3794E 06             0.2280E 06     0.012
      13              0.2419E 06             0.1446E 06     0.008
      14              0.1529E 06             0.9188E 05     0.005
      15              0.9559E 05             0.5745E 05     0.003
      16              0.5999E 05             0.3605E 05     0.002
      17              0.9200E 05             0.5521E 05     0.003
THE ANNUAL YIELD IS     19.343 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4075E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.157E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4969E-05

                                   YEAR   2005
  AGE GROUP           SIZE              FISHING MORTALITY    NATURAL MORTALITY
       1          0.1374E 08                 0.169                 0.20
       2          0.9561E 07                 0.314                 0.20
       3          0.5805E 07                 0.314                 0.20
       4          0.3475E 07                 0.314                 0.20
       5          0.2074E 07                 0.314                 0.20
       6          0.1255E 07                 0.314                 0.20
       7          0.7488E 06                 0.314                 0.20
       8          0.4454E 06                 0.314                 0.20
       9          0.2663E 06                 0.314                 0.20
      10          0.1597E 06                 0.314                 0.20
      11          0.9435E 05                 0.314                 0.20
      12          0.5641E 05                 0.314                 0.20
      13          0.3375E 05                 0.314                 0.20
      14          0.2039E 05                 0.314                 0.20
      15          0.1210E 05                 0.314                 0.20
      16          0.7238E 04                 0.314                 0.20
      17          0.1070E 05                 0.314                 0.20
  AGE GROUP       TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                      (KG)                     (KG)        PERCENT
       1              0.3094E 07             0.1414E 07     0.070
       2              0.5050E 07             0.3084E 07     0.152
       3              0.5119E 07             0.3126E 07     0.154
       4              0.4764E 07             0.2909E 07     0.144
       5              0.4143E 07             0.2531E 07     0.125
       6              0.3375E 07             0.2061E 07     0.102
       7              0.2591E 07             0.1582E 07     0.078
       8              0.1879E 07             0.1154E 07     0.057
       9              0.1331E 07             0.8127E 06     0.040
      10              0.9057E 06             0.5531E 06     0.027
      11              0.5582E 06             0.3653E 06     0.018
      12              0.3891E 06             0.2377E 06     0.012
      13              0.2507E 06             0.1531E 06     0.008
      14              0.1590E 06             0.9711E 05     0.005
      15              0.9868E 05             0.6026E 05     0.003
      16              0.6120E 05             0.3739E 05     0.002
      17              0.9455E 05             0.5749E 05     0.003
THE ANNUAL YIELD IS     20.237 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4108E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4929E-05
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                                        YEAR    2006
   AGE GROUP              SIZE               FISHING MORTALITY    NATURAL MORTALITY
       1            0.1374E 08                   0.175                0.20
       2            0.9490E 07                   0.325                0.20
       3            0.5721E 07                   0.325                0.20
       4            0.3473E 07                   0.325                0.20
       5            0.2085E 07                   0.325                0.20
       6            0.1253E 07                   0.325                0.20
       7            0.7507E 06                   0.325                0.20
       8            0.4479E 06                   0.325                0.20
       9            0.2665E 06                   0.325                0.20
      10            0.1572E 06                   0.325                0.20
      11            0.9495E 05                   0.325                0.20
      12            0.5644E 05                   0.325                0.20
      13            0.3375E 05                   0.325                0.20
      14            0.2031E 05                   0.325                0.20
      15            0.1220E 05                   0.325                0.20
      16            0.7240E 04                   0.325                0.20
      17            0.1095E 05                   0.325                0.20
   AGE GROUP        TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                         (KG)                     (KG)       PERCENT
       1              0.3126E 07              0.1461E 07      0.070
       2              0.5100E 07              0.3157E 07      0.152
       3              0.5130E 07              0.3175E 07      0.153
       4              0.4827E 07              0.2989E 07      0.144
       5              0.4193E 07              0.2596E 07      0.125
       6              0.3426E 07              0.2121E 07      0.102
       7              0.2641E 07              0.1635E 07      0.079
       8              0.1933E 07              0.1197E 07      0.058
       9              0.1355E 07              0.8384E 06      0.041
      10              0.9233E 06              0.5716E 06      0.028
      11              0.6121E 06              0.3787E 06      0.018
      12              0.3559E 06              0.2451E 06      0.012
      13              0.2533E 06              0.1569E 06      0.008
      14              0.1610E 06              0.9977E 05      0.005
      15              0.1011E 06              0.6260E 05      0.003
      16              0.6224E 05              0.3853E 05      0.002
      17              0.9611E 05              0.5950E 05      0.003
THE ANNUAL YIELD IS    20.780 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4087E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4954E-05

                                        YEAR    2007
   AGE GROUP              SIZE               FISHING MORTALITY    NATURAL MORTALITY
       1            0.1374E 08                   0.188                0.20
       2            0.9441E 07                   0.311                0.20
       3            0.5619E 07                   0.311                0.20
       4            0.3384E 07                   0.311                0.20
       5            0.2054E 07                   0.311                0.20
       6            0.1233E 07                   0.311                0.20
       7            0.7412E 06                   0.311                0.20
       8            0.4441E 06                   0.311                0.20
       9            0.2650E 06                   0.311                0.20
      10            0.1576E 06                   0.311                0.20
      11            0.9415E 05                   0.311                0.20
      12            0.5617E 05                   0.311                0.20
      13            0.3319E 05                   0.311                0.20
      14            0.1996E 05                   0.311                0.20
      15            0.1202E 05                   0.311                0.20
      16            0.7216E 04                   0.311                0.20
      17            0.1070E 05                   0.311                0.20
   AGE GROUP        TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                         (KG)                     (KG)       PERCENT
       1              0.3075E 07              0.1434E 07      0.071
       2              0.4967E 07              0.3024E 07      0.153
       3              0.4971E 07              0.3030E 07      0.153
       4              0.4610E 07              0.2806E 07      0.142
       5              0.4049E 07              0.2465E 07      0.125
       6              0.3304E 07              0.2012E 07      0.102
       7              0.2555E 07              0.1555E 07      0.079
       8              0.1875E 07              0.1143E 07      0.058
       9              0.1321E 07              0.8043E 06      0.041
      10              0.8561E 06              0.5456E 06      0.028
      11              0.5547E 06              0.3621E 06      0.018
      12              0.3561E 06              0.2350E 06      0.012
      13              0.2456E 06              0.1495E 06      0.009
      14              0.1551E 06              0.9443E 05      0.005
      15              0.9761E 05              0.5942E 05      0.003
      16              0.6579E 05              0.3701E 05      0.002
      17              0.9289E 05              0.5655E 05      0.003
THE ANNUAL YIELD IS    19.759 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4046E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5005E-05

                                        YEAR    2008
   AGE GROUP              SIZE               FISHING MORTALITY    NATURAL MORTALITY
       1            0.1374E 08                   0.171                0.20
       2            0.9511E 07                   0.316                0.20
       3            0.5667E 07                   0.316                0.20
       4            0.3370E 07                   0.316                0.20
       5            0.2034E 07                   0.316                0.20
       6            0.1212E 07                   0.316                0.20
       7            0.7396E 06                   0.316                0.20
       8            0.4445E 06                   0.316                0.20
       9            0.2665E 06                   0.316                0.20
      10            0.1589E 06                   0.316                0.20
      11            0.9453E 05                   0.316                0.20
      12            0.5646E 05                   0.316                0.20
      13            0.3367E 05                   0.316                0.20
      14            0.2002E 05                   0.316                0.20
      15            0.1197E 05                   0.316                0.20
      16            0.7206E 04                   0.316                0.20
      17            0.1075E 05                   0.316                0.20
   AGE GROUP        TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                         (KG)                     (KG)       PERCENT
       1              0.3093E 07              0.1425E 07      0.071
       2              0.5042E 07              0.3088E 07      0.154
       3              0.5012E 07              0.3071E 07      0.153
       4              0.4624E 07              0.2833E 07      0.141
       5              0.4030E 07              0.2465E 07      0.123
       6              0.3326E 07              0.2037E 07      0.102
       7              0.2568E 07              0.1573E 07      0.078
       8              0.1894E 07              0.1160E 07      0.058
       9              0.1331E 07              0.8192E 06      0.041
      10              0.9103E 06              0.5576E 06      0.028
      11              0.6016E 06              0.3685E 06      0.018
      12              0.3910E 06              0.2395E 06      0.012
      13              0.2446E 06              0.1572E 06      0.008
      14              0.1567E 06              0.9602E 05      0.005
      15              0.9759E 05              0.6003E 05      0.003
      16              0.6117E 05              0.3747E 05      0.002
      17              0.9398E 05              0.5757E 05      0.003
THE ANNUAL YIELD IS    20.049 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4029E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5027E-05
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                                             YEAR   2009
  AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
      1         0.1374E 08                   0.167                 0.20
      2         0.9686E 07                   0.309                 0.20
      3         0.5676E 07                   0.309                 0.20
      4         0.3379E 07                   0.309                 0.20
      5         0.2011E 07                   0.309                 0.20
      6         0.1211E 07                   0.309                 0.20
      7         0.7352E 06                   0.309                 0.20
      8         0.4414E 06                   0.309                 0.20
      9         0.2654E 06                   0.309                 0.20
     10         0.1599E 06                   0.309                 0.20
     11         0.9684E 05                   0.309                 0.20
     12         0.5641E 05                   0.309                 0.20
     13         0.3370E 05                   0.309                 0.20
     14         0.2010E 05                   0.309                 0.20
     15         0.1195E 05                   0.309                 0.20
     16         0.7145E 04                   0.309                 0.20
     17         0.1071E 05                   0.309                 0.20
  AGE GROUP         TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                         (KG)                    (KG)       PERCENT
      1             0.3069E 07              0.1394E 07      0.071
      2             0.4972E 07              0.3017E 07      0.156
      3             0.4569E 07              0.3018E 07      0.154
      4             0.4595E 07              0.2784E 07      0.142
      5             [illegible]             [illegible]     0.122
      6             0.3723E 07              0.1562E 07      0.100
      7             0.2525E 07              0.1533E 07      0.078
      8             0.1659E 07              0.1128E 07      0.058
      9             0.1117E 07              0.7551E 06      0.041
     10             0.9032E 06              0.5463E 06      0.028
     11             0.5969E 06              0.3622E 06      0.019
     12             0.3883E 06              0.2344E 06      0.012
     13             0.2467E 06              0.1459E 06      0.008
     14             0.1556E 06              0.9444E 05      0.005
     15             0.9671E 05              0.5864E 05      0.003
     16             0.5597E 05              0.3639E 05      0.002
     17             0.9745E 05              0.5623E 05      0.003
THE ANNUAL YIELD IS     19.566 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4016E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5041E-05


                                             YEAR   2010
  AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
      1         0.1374E 08                   0.169                 0.20
      2         0.9524E 07                   0.311                 0.20
      3         [illegible]                  0.311                 0.20
      4         0.3413E 07                   0.311                 0.20
      5         0.2032E 07                   0.311                 0.20
      6         0.1209E 07                   0.311                 0.20
      7         0.7212E 06                   0.311                 0.20
      8         0.4420E 06                   0.311                 0.20
      9         [illegible]                  0.311                 0.20
     10         0.1595E 06                   0.311                 0.20
     11         [illegible]                  0.311                 0.20
     12         0.5722E 05                   0.311                 0.20
     13         [illegible]                  0.311                 0.20
     14         0.2026E 05                   0.311                 0.20
     15         [illegible]                  0.311                 0.20
     16         0.7145E 04                   0.311                 0.20
     17         0.1074E 05                   0.311                 0.20
  AGE GROUP         TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                         (KG)                    (KG)       PERCENT
      1             0.3075E 07              0.1404E 07      0.071
      2             0.5011E 07              0.3051E 07      0.156
      3             0.5011E 07              [illegible]     0.156
      4             0.4649E 07              0.2830E 07      0.143
      5             [illegible]             [illegible]     0.123
      6             0.3743E 07              0.1932E 07      0.100
      7             [illegible]             [illegible]     0.077
      8             0.1669E 07              0.1138E 07      0.058
      9             [illegible]             0.8051E 06      0.041
     10             0.9067E 06              0.5723E 06      0.028
     11             0.6016E 06              0.3675E 06      0.019
     12             0.3919E 06              0.2386E 06      0.012
     13             0.2455E 06              0.1519E 06      0.008
     14             0.1574E 06              0.9584E 05      0.005
     15             0.9816E 05              0.5974E 05      0.003
     16             0.6551E 05              0.3609E 05      0.002
     17             0.9321E 05              0.5675E 05      0.003
THE ANNUAL YIELD IS     19.776 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4028E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5027E-05


                                             YEAR   2011
  AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
      1         0.1374E 08                   0.167                 0.20
      2         0.9511E 07                   0.310                 0.20
      3         0.5712E 07                   0.310                 0.20
      4         0.3423E 07                   0.310                 0.20
      5         0.2047E 07                   0.310                 0.20
      6         0.1218E 07                   0.310                 0.20
      7         0.7252E 06                   0.310                 0.20
      8         0.4368E 06                   0.310                 0.20
      9         0.2651E 06                   0.310                 0.20
     10         0.1571E 06                   0.310                 0.20
     11         0.9505E 05                   0.310                 0.20
     12         0.5731E 05                   0.310                 0.20
     13         0.3420E 05                   0.310                 0.20
     14         0.2034E 05                   0.310                 0.20
     15         0.1215E 05                   0.310                 0.20
     16         0.7249E 04                   0.310                 0.20
     17         0.1075E 05                   0.310                 0.20
  AGE GROUP         TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                         (KG)                    (KG)       PERCENT
      1             0.3670E 07              0.1149E 07      0.071
      2             0.4995E 07              0.3010E 07      0.156
      3             0.5010E 07              0.3045E 07      0.155
      4             0.4650E 07              0.2427E 07      0.143
      5             0.4526E 07              0.2447E 07      0.126
      6             0.3759E 07              0.1981E 07      0.100
      7             0.2495E 07              0.1517E 07      0.077
      8             0.1645E 07              0.1124E 07      0.057
      9             0.1317E 07              0.8016E 06      0.041
     10             0.9031E 06              0.5489E 06      0.028
     11             0.6031E 06              0.3666E 06      0.019
     12             0.3931E 06              0.2372E 06      0.012
     13             0.2511E 06              0.1476E 06      0.008
     14             0.1578E 06              0.9989E 05      0.005
     15             0.9852E 05              0.5988E 05      0.003
     16             0.6196E 05              0.3705E 05      0.002
     17             0.9311E 05              0.5661E 05      0.003
THE ANNUAL YIELD IS     19.730 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4037E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5016E-05
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                                         YEAR   2012
 AGE GROUP          SIZE               FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                 0.149                  0.20
     2          0.9518E 07                 0.312                  0.20
     3          0.5712E 07                 0.312                  0.20
     4          0.3430E 07                 0.312                  0.20
     5          0.2054E 07                 0.312                  0.20
     6          0.1229E 07                 0.312                  0.20
     7          0.7317E 06                 0.312                  0.20
     8          0.4395E 06                 0.312                  0.20
     9          0.2623E 06                 0.312                  0.20
    10          0.1592E 06                 0.312                  0.20
    11          0.9557E 05                 0.312                  0.20
    12          0.5744E 05                 0.312                  0.20
    13          0.3441E 05                 0.312                  0.20
    14          0.2054E 05                 0.312                  0.20
    15          0.1222E 05                 0.312                  0.20
    16          0.7296E 04                 0.312                  0.20
    17          0.1081E 05                 0.312                  0.20
 AGE GROUP      TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                     (KG)                    (KG)          PERCENT
     1              0.3079E 07             0.1402E 07       0.071
     2              0.5017E 07             0.3059E 07       0.154
     3              0.5028E 07             0.3066E 07       0.154
     4              0.4681E 07             0.2854E 07       0.143
     5              0.4056E 07             0.2473E 07       0.124
     6              0.3279E 07             0.2012E 07       0.101
     7              0.2527E 07             0.1541E 07       0.077
     8              0.1845E 07             0.1129E 07       0.057
     9              0.1312E 07             0.7985E 06       0.040
    10              0.9068E 06             0.5529E 06       0.028
    11              0.6048E 06             0.3689E 06       0.019
    12              0.3955E 06             0.2412E 06       0.012
    13              0.2536E 06             0.1546E 06       0.008
    14              0.1579E 06             0.9747E 05       0.005
    15              0.9947E 05             0.6062E 05       0.003
    16              0.6158E 05             0.3735E 05       0.002
    17              0.9430E 05             0.5717E 05       0.003
THE ANNUAL YIELD IS    19.908 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4046E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.198E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5004E-05


                                         YEAR   2013
 AGE GROUP          SIZE               FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                 0.149                  0.20
     2          0.9505E 07                 0.312                  0.20
     3          0.5721E 07                 0.312                  0.20
     4          0.3421E 07                 0.312                  0.20
     5          0.2055E 07                 0.312                  0.20
     6          0.1230E 07                 0.312                  0.20
     7          0.7361E 06                 0.312                  0.20
     8          0.4391E 06                 0.312                  0.20
     9          0.2630E 06                 0.312                  0.20
    10          0.1571E 06                 0.312                  0.20
    11          0.9536E 05                 0.312                  0.20
    12          0.5724E 05                 0.312                  0.20
    13          0.3441E 05                 0.312                  0.20
    14          0.2061E 05                 0.312                  0.20
    15          0.1230E 05                 0.312                  0.20
    16          0.7317E 04                 0.312                  0.20
    17          0.1094E 05                 0.312                  0.20
 AGE GROUP      TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                     (KG)                    (KG)          PERCENT
     1              0.3079E 07             0.1404E 07       0.071
     2              0.5010E 07             0.3055E 07       0.154
     3              0.5019E 07             0.3067E 07       0.154
     4              0.4669E 07             0.2847E 07       0.143
     5              0.4057E 07             0.2474E 07       0.124
     6              0.3303E 07             0.2014E 07       0.101
     7              0.2542E 07             0.1550E 07       0.078
     8              0.1857E 07             0.1112E 07       0.057
     9              0.1302E 07             0.7941E 06       0.040
    10              0.8548E 06             0.5456E 06       0.027
    11              0.6035E 06             0.3680E 06       0.018
    12              0.3947E 06             0.2403E 06       0.012
    13              0.2535E 06             0.1546E 06       0.008
    14              0.1605E 06             0.9784E 05       0.005
    15              0.1001E 06             0.6104E 05       0.003
    16              0.6176E 05             0.3766E 05       0.002
    17              0.9432E 05             0.5751E 05       0.003
THE ANNUAL YIELD IS    19.890 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4046E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.9004E-05


                                         YEAR   2014
 AGE GROUP          SIZE               FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                 0.165                  0.20
     2          0.9505E 07                 0.305                  0.20
     3          0.5691E 07                 0.305                  0.20
     4          0.3415E 07                 0.305                  0.20
     5          0.2044E 07                 0.305                  0.20
     6          0.1231E 07                 0.305                  0.20
     7          0.7370E 06                 0.305                  0.20
     8          0.4410E 06                 0.305                  0.20
     9          0.2625E 06                 0.305                  0.20
    10          0.1562E 06                 0.305                  0.20
    11          0.9413E 05                 0.305                  0.20
    12          0.5712E 05                 0.305                  0.20
    13          0.3425E 05                 0.305                  0.20
    14          0.2061E 05                 0.305                  0.20
    15          0.1235E 05                 0.305                  0.20
    16          0.7368E 04                 0.305                  0.20
    17          0.1034E 05                 0.305                  0.20
 AGE GROUP      TOTAL BIOMASS LOST      CONTRIBUTION TO CATCH
                     (KG)                    (KG)          PERCENT
     1              0.3051E 07             0.1378E 07       0.071
     2              0.4559E 07             0.2992E 07       0.154
     3              0.4956E 07             0.2993E 07       0.154
     4              0.4609E 07             0.2793E 07       0.143
     5              0.4001E 07             0.2417E 07       0.124
     6              0.3267E 07             0.1573E 07       0.101
     7              0.2517E 07             0.1520E 07       0.078
     8              0.1847E 07             0.1116E 07       0.057
     9              0.1245E 07             0.7821E 06       0.040
    10              0.8799E 06             0.5314E 06       0.027
    11              0.5984E 06             0.3556E 06       0.018
    12              0.3889E 06             0.2349E 06       0.012
    13              0.2479E 06             0.1509E 06       0.008
    14              0.1586E 06             0.9580E 05       0.005
    15              0.9937E 05             0.6001E 05       0.003
    16              0.6149E 05             0.3714E 05       0.002
    17              0.9155E 05             0.5650E 05       0.003
THE ANNUAL YIELD IS    19.476 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4055E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.198E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4993E-05
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                                     YEAR   2015.
      AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
          1          0.1374E 08                 0.170                  0.20
          2          0.9543E 07                 0.315                  0.20
          3          0.5730E 07                 0.315                  0.20
          4          0.3436E 07                 0.315                  0.20
          5          0.2061E 07                 0.315                  0.20
          6          0.1237E 07                 0.315                  0.20
          7          0.7427E 06                 0.315                  0.20
          8          0.4458E 06                 0.315                  0.20
          9          0.2676E 06                 0.315                  0.20
         10          0.1606E 06                 0.315                  0.20
         11          0.9640E 05                 0.315                  0.20
         12          0.5787E 05                 0.315                  0.20
         13          0.3447E 05                 0.315                  0.20
         14          0.2069E 05                 0.315                  0.20
         15          0.1242E 05                 0.315                  0.20
         16          0.7452E 04                 0.315                  0.20
         17          0.1101E 05                 0.315                  0.20
      AGE GROUP      TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                           (KG)                    (KG)          PERCENT
          1             0.3049E 07             0.1472E 07         0.070
          2             0.5049E 07             0.3389E 07         0.153
          3             0.5065E 07             0.3103E 07         0.156
          4             0.4706E 07             0.2879E 07         0.143
          5             0.4049E 07             0.2492E 07         0.124
          6             0.3331E 07             0.2038E 07         0.101
          7             0.2575E 07             0.1575E 07         0.078
          8             0.1891E 07             0.1157E 07         0.057
          9             0.1334E 07             0.8158E 06         0.040
         10             0.9059E 06             0.5540E 06         0.028
         11             0.5994E 06             0.3663E 06         0.018
         12             0.3925E 06             0.2401E 06         0.012
         13             0.2553E 06             0.1560E 06         0.008
         14             0.1617E 06             0.9990E 05         0.005
         15             0.1010E 06             0.6215E 05         0.003
         16             0.6313E 05             0.3862E 05         0.002
         17             0.9613E 05             0.5880E 05         0.003
THE ANNUAL YIELD IS    20.146 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4068E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4577E-05

                                     YEAR   2016
      AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
          1          0.1374E 08                 0.165                  0.20
          2          0.9492E 07                 0.305                  0.20
          3          0.5732E 07                 0.305                  0.20
          4          0.3421E 07                 0.305                  0.20
          5          0.2053E 07                 0.305                  0.20
          6          0.1231E 07                 0.305                  0.20
          7          0.7390E 06                 0.305                  0.20
          8          0.4438E 06                 0.305                  0.20
          9          0.2657E 06                 0.305                  0.20
         10          0.1590E 06                 0.305                  0.20
         11          0.9461E 05                 0.305                  0.20
         12          0.5674E 05                 0.305                  0.20
         13          0.3373E 05                 0.305                  0.20
         14          0.2006E 05                 0.305                  0.20
         15          0.1239E 05                 0.305                  0.20
         16          0.7433E 04                 0.305                  0.20
         17          0.1131E 05                 0.305                  0.20
      AGE GROUP      TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                           (KG)                    (KG)          PERCENT
          1             0.3051E 07             0.1374E 07         0.071
          2             0.4997E 07             0.2908E 07         0.153
          3             0.4983E 07             0.2956E 07         0.154
          4             0.4624E 07             0.2751E 07         0.143
          5             0.4000E 07             0.2421E 07         0.124
          6             0.3269E 07             0.1974E 07         0.101
          7             0.2523E 07             0.1524E 07         0.078
          8             0.1859E 07             0.1123E 07         0.058
          9             0.1311E 07             0.7932E 06         0.041
         10             0.8955E 06             0.5405E 06         0.028
         11             0.5923E 06             0.3577E 06         0.018
         12             0.3856E 06             0.2317E 06         0.012
         13             0.2472E 06             0.1493E 06         0.008
         14             0.1583E 06             0.9375E 05         0.005
         15             0.9530E 05             0.6004E 05         0.003
         16             0.6207E 05             0.3764E 05         0.002
         17             0.9609E 05             0.5730E 05         0.003
THE ANNUAL YIELD IS    19.521 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4070E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4574E-05

                                     YEAR   2017
      AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
          1          0.1374E 08                 0.171                  0.20
          2          0.9543E 07                 0.321                  0.20
          3          0.5729E 07                 0.321                  0.20
          4          0.3441E 07                 0.321                  0.20
          5          0.2068E 07                 0.321                  0.20
          6          0.1239E 07                 0.321                  0.20
          7          0.7432E 06                 0.321                  0.20
          8          0.4460E 06                 0.321                  0.20
          9          0.2678E 06                 0.321                  0.20
         10          0.1604E 06                 0.321                  0.20
         11          0.9597E 05                 0.321                  0.20
         12          0.5715E 05                 0.321                  0.20
         13          0.3430E 05                 0.321                  0.20
         14          0.2068E 05                 0.321                  0.20
         15          0.1243E 05                 0.321                  0.20
         16          0.7462E 04                 0.321                  0.20
         17          0.1114E 05                 0.321                  0.20
      AGE GROUP      TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                           (KG)                    (KG)          PERCENT
          1             0.3112E 07             0.1465E 07         0.070
          2             0.5096E 07             0.3141E 07         0.153
          3             0.5108E 07             0.3149E 07         0.153
          4             0.4757E 07             0.2937E 07         0.143
          5             0.4138E 07             0.2550E 07         0.124
          6             0.3370E 07             0.2077E 07         0.101
          7             0.2602E 07             0.1602E 07         0.078
          8             0.1914E 07             0.1179E 07         0.057
          9             0.1355E 07             0.8349E 06         0.041
         10             0.9254E 06             0.5703E 06         0.028
         11             0.6132E 06             0.3793E 06         0.018
         12             0.3995E 06             0.2456E 06         0.012
         13             0.2518E 06             0.1564E 06         0.008
         14             0.1615E 06             0.9952E 05         0.005
         15             0.1023E 06             0.6310E 05         0.003
         16             0.6380E 05             0.3933E 05         0.002
         17             0.9818E 05             0.6051E 05         0.003
THE ANNUAL YIELD IS    20.524 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4071E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.159E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4574E-05
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                                      YEAR   2018
 AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                 0.167                 0.20
     2          0.9460E 07                 0.310                 0.20
     3          0.5667E 07                 0.310                 0.20
     4          0.3401E 07                 0.310                 0.20
     5          0.2043E 07                 0.310                 0.20
     6          0.1229E 07                 0.310                 0.20
     7          0.7357E 06                 0.310                 0.20
     8          0.4413E 06                 0.310                 0.20
     9          0.2649E 06                 0.310                 0.20
    10          0.1590E 06                 0.310                 0.20
    11          0.9521E 05                 0.310                 0.20
    12          0.5699E 05                 0.310                 0.20
    13          0.3392E 05                 0.310                 0.20
    14          0.2019E 05                 0.310                 0.20
    15          0.1210E 05                 0.310                 0.20
    16          0.7381E 04                 0.310                 0.20
    17          0.1105E 05                 0.310                 0.20
 AGE GROUP      TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                     (KG)                    (KG)        PERCENT
     1              0.3070E 07           0.1399E 07       0.071
     2              0.4969E 07           0.3022E 07       0.153
     3              0.4973E 07           0.3021E 07       0.153
     4              0.4624E 07           0.2811E 07       0.143
     5              0.4020E 07           0.2444E 07       0.124
     6              0.3285E 07           0.1957E 07       0.101
     7              0.2531E 07           0.1539E 07       0.078
     8              0.1852E 07           0.1132E 07       0.057
     9              0.1317E 07           0.8007E 06       0.041
    10              0.9024E 06           0.5485E 06       0.028
    11              0.6034E 06           0.3657E 06       0.019
    12              0.3909E 06           0.2376E 06       0.012
    13              0.2490E 06           0.1514E 06       0.008
    14              0.1546E 06           0.9517E 05       0.005
    15              0.9854E 05           0.5991E 05       0.003
    16              0.6207E 05           0.3773E 05       0.002
    17              0.9572E 05           0.5819E 05       0.003
THE ANNUAL YIELD IS    19.715 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4045E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.5005E-05


                                      YEAR   2019
 AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                 0.163                 0.20
     2          0.9518E 07                 0.302                 0.20
     3          0.5681E 07                 0.302                 0.20
     4          0.3403E 07                 0.302                 0.20
     5          0.2043E 07                 0.302                 0.20
     6          0.1227E 07                 0.302                 0.20
     7          0.7375E 06                 0.302                 0.20
     8          0.4418E 06                 0.302                 0.20
     9          0.2650E 06                 0.302                 0.20
    10          0.1597E 06                 0.302                 0.20
    11          0.9552E 05                 0.302                 0.20
    12          0.5718E 05                 0.302                 0.20
    13          0.3422E 05                 0.302                 0.20
    14          0.2037E 05                 0.302                 0.20
    15          0.1212E 05                 0.302                 0.20
    16          0.7352E 04                 0.302                 0.20
    17          0.1112E 05                 0.302                 0.20
 AGE GROUP      TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                     (KG)                    (KG)        PERCENT
     1              0.3042E 07           0.1369E 07       0.071
     2              0.4942E 07           0.2975E 07       0.154
     3              0.4526E 07           0.2965E 07       0.153
     4              0.4574E 07           0.2755E 07       0.142
     5              0.3973E 07           0.2393E 07       0.124
     6              0.3245E 07           0.1953E 07       0.101
     7              0.2509E 07           0.1511E 07       0.078
     8              0.1843E 07           0.1110E 07       0.057
     9              0.1303E 07           0.7845E 06       0.041
    10              0.8921E 06           0.5370E 06       0.028
    11              0.5943E 06           0.3594E 06       0.019
    12              0.3874E 06           0.2335E 06       0.012
    13              0.2484E 06           0.1495E 06       0.008
    14              0.1562E 06           0.9407E 05       0.005
    15              0.9719E 05           0.5851E 05       0.003
    16              0.6071E 05           0.3654E 05       0.002
    17              0.9480E 05           0.5707E 05       0.003
THE ANNUAL YIELD IS    19.335 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4059E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4988E-05


                                      YEAR   2020
 AGE GROUP          SIZE              FISHING MORTALITY     NATURAL MORTALITY
     1          0.1374E 08                 0.167                 0.20
     2          0.9556E 07                 0.310                 0.20
     3          0.5759E 07                 0.310                 0.20
     4          0.3437E 07                 0.310                 0.20
     5          0.2059E 07                 0.310                 0.20
     6          0.1236E 07                 0.310                 0.20
     7          0.7424E 06                 0.310                 0.20
     8          0.4462E 06                 0.310                 0.20
     9          0.2673E 06                 0.310                 0.20
    10          0.1603E 06                 0.310                 0.20
    11          0.9621E 05                 0.310                 0.20
    12          0.5778E 05                 0.310                 0.20
    13          0.3460E 05                 0.310                 0.20
    14          0.2070E 05                 0.310                 0.20
    15          0.1232E 05                 0.310                 0.20
    16          0.7335E 04                 0.310                 0.20
    17          0.1111E 05                 0.310                 0.20
 AGE GROUP      TOTAL BIOMASS LOST       CONTRIBUTION TO CATCH
                     (KG)                    (KG)        PERCENT
     1              0.3070E 07           0.1397E 07       0.070
     2              0.5018E 07           0.3050E 07       0.153
     3              0.5053E 07           0.3070E 07       0.154
     4              0.4673E 07           0.2840E 07       0.143
     5              0.4050E 07           0.2462E 07       0.124
     6              0.3305E 07           0.2009E 07       0.101
     7              0.2574E 07           0.1553E 07       0.078
     8              0.1883E 07           0.1145E 07       0.058
     9              0.1333E 07           0.8082E 06       0.041
    10              0.9057E 06           0.5530E 06       0.028
    11              0.6066E 06           0.3687E 06       0.019
    12              0.3963E 06           0.2409E 06       0.012
    13              0.2540E 06           0.1544E 06       0.008
    14              0.1605E 06           0.9759E 05       0.005
    15              0.9993E 05           0.6074E 05       0.003
    16              0.6168E 05           0.3749E 05       0.002
    17              0.9624E 05           0.5853E 05       0.003
THE ANNUAL YIELD IS    19.907 THOUSAND METRIC TONS
THE TOTAL NUMBER OF SPAWN FOR THE YEAR IS  0.4082E 13
THE AVERAGE NUMBER OF EGGS PER FEMALE IS 0.158E 07
THE RATIO OF EGGS HATCHING TO EGGS SPAWNED IS   0.4560E-05

  THE MAXIMUM NUMBER OF PARTICLES IN THE SYSTEM AT ANY ONE TIME WAS  1794
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THESE ARE THE LOSS RATES IN 10 ELEMENTS DUE TO TRANSPORT AND MORTALITY ON DAY 365, YEAR 1979

ELEMENT      INITIAL NUMBER     PERCENT TRANSPORTED OUT      PERCENT DIED     RATIO
   63          0.0                   0.0                       0.0             0.0
   64          0.0                   0.0                       0.0             0.0
   67          0.1312E 06           -4.36673                  -3.08838         1.3160
   69          0.1959E 06          -11.35016                 -29.41174         1.1237
   91          0.5234E 06          -31.16451                 -10.97850         1.0802
   93          0.2618E 10          -45.97723                  99.54456        -0.5505
  107          0.4227E 10           45.94494                  99.98457         0.5301
  108          0.2817E 10           45.95785                  99.99104         0.5500
  122          0.7067E 09            0.04182                  99.97656         0.3004
  123          0.0                   0.0                       0.0             0.0
  DAY  SPAWNED:     1     NUMBER  OILED:     0.3277E  10
  DAY  SPAWNED:     2     NUMBER  OILED:     0.2622E  10
  DAY  SPAWNED:     3     NUMBER  OILED:     0.3277E  10
  DAY  SPAWNED:     4     NUMBER  OILED:     0.4915E  10
  DAY  SPAWNED:     5     NUMBER  OILED:     0.4260E  10
  DAY  SPAWNED:     6     NUMBER  OILED:     0.4587E  10
  DAY  SPAWNED:     7     NUMBER  OILED:     0.2255E  10
  DAY  SPAWNED:     8     NUMBER  OILED:     0.2457E  10
  DAY  SPAWNED:     9     NUMBER  OILED:     0.2623E  10
  DAY  SPAWNED:    10     NUMBER  OILED:     0.3933E  10
  DAY  SPAWNED:    11     NUMBER  OILED:     0.2295E  10
  DAY  SPAWNED:    12     NUMBER  OILED:     0.5571E  10
  DAY  SPAWNED:    13     NUMBER  OILED:     0.6226E  10
  DAY  SPAWNED:    14     NUMBER  OILED:     0.6553E  10
  DAY  SPAWNED:    15     NUMBER  OILED:     0.5570E  10
  DAY  SPAWNED:    16     NUMBER  OILED:     0.5898E  10
  DAY  SPAWNED:    17     NUMBER  OILED:     0.6553E  10
  DAY  SPAWNED:    18     NUMBER  OILED:     0.6881E  10
  DAY  SPAWNED:    19     NUMBER  OILED:     0.6226E  10
  DAY  SPAWNED:    20     NUMBER  OILED:     0.4915E  10
  DAY  SPAWNED:    21     NUMBER  OILED:     0.6847E  10
  DAY  SPAWNED:    22     NUMBER  OILED:     0.6841E  10
  DAY  SPAWNED:    23     NUMBER  OILED:     0.8523E  10
  DAY  SPAWNED:    24     NUMBER  OILED:     0.8192E  10
  DAY  SPAWNED:    25     NUMBER  OILED:     0.8192E  10
  DAY  SPAWNED:    26     NUMBER  OILED:     0.8191E  10
  DAY  SPAWNED:    27     NUMBER  OILED:     0.6226E  10
  DAY  SPAWNED:    28     NUMBER  OILED:     0.7209E  10
  DAY  SPAWNED:    29     NUMBER  OILED:     0.5898E  10
  DAY  SPAWNED:    30     NUMBER  OILED:     0.5243E  10
  DAY  SPAWNED:    31     NUMBER  OILED:     0.5898E  10
  DAY  SPAWNED:    32     NUMBER  OILED:     0.7209E  10
  DAY  SPAWNED:    33     NUMBER  OILED:     0.7536E  10
  DAY  SPAWNED:    34     NUMBER  OILED:     0.5571E  10
  DAY  SPAWNED:    35     NUMBER  OILED:     0.6882E  10
  DAY  SPAWNED:    36     NUMBER  OILED:     0.5898E  10
  DAY  SPAWNED:    37     NUMBER  OILED:     0.7537E  10
  DAY  SPAWNED:    38     NUMBER  OILED:     0.4588E  10
  DAY  SPAWNED:    39     NUMBER  OILED:     0.6882E  10
  DAY  SPAWNED:    40     NUMBER  OILED:     0.1933E  10
  DAY  SPAWNED:    41     NUMBER  OILED:     0.4916E  10
  DAY  SPAWNED:    42     NUMBER  OILED:     0.5244E  10
  DAY  SPAWNED:    43     NUMBER  OILED:     0.7865E  10
  DAY  SPAWNED:    44     NUMBER  OILED:     0.2950E  10
  DAY  SPAWNED:    45     NUMBER  OILED:     0.5247E  10
  DAY  SPAWNED:    46     NUMBER  OILED:     0.3605E  10
  DAY  SPAWNED:    47     NUMBER  OILED:     0.7208E  10
  DAY  SPAWNED:    48     NUMBER  OILED:     0.4915E  10
  DAY  SPAWNED:    49     NUMBER  OILED:     0.4261E  10
  DAY  SPAWNED:    50     NUMBER  OILED:     0.4260E  10
  DAY  SPAWNED:    51     NUMBER  OILED:     0.5570E  10
  DAY  SPAWNED:    52     NUMBER  OILED:     0.6553E  10
  DAY  SPAWNED:    53     NUMBER  OILED:     0.3277E  10
  DAY  SPAWNED:    54     NUMBER  OILED:     0.2949E  10
  DAY  SPAWNED:    55     NUMBER  OILED:     0.5570E  10
  DAY  SPAWNED:    56     NUMBER  OILED:     0.5243E  10
  DAY  SPAWNED:    57     NUMBER  OILED:     0.4915E  10
  DAY  SPAWNED:    58     NUMBER  OILED:     0.2294E  10
  DAY  SPAWNED:    59     NUMBER  OILED:     0.4588E  10
  DAY  SPAWNED:    60     NUMBER  OILED:     0.2950E  11
  DAY  SPAWNED:    61     NUMBER  OILED:     0.3145E  11
  DAY  SPAWNED:    62     NUMBER  OILED:     0.3931E  11
  DAY  SPAWNED:    63     NUMBER  OILED:     0.1311E  11
  DAY  SPAWNED:    64     NUMBER  OILED:     0.2359E  11
  DAY  SPAWNED:    65     NUMBER  OILED:     0.2359E  11
  DAY  SPAWNED:    66     NUMBER  OILED:     0.2621E  11
  DAY  SPAWNED:    67     NUMBER  OILED:     0.1310E  11
  DAY  SPAWNED:    68     NUMBER  OILED:     0.1049E  11
  DAY  SPAWNED:    69     NUMBER  OILED:     0.1835E  11
  DAY  SPAWNED:    70     NUMBER  OILED:     0.1573E  11
  DAY  SPAWNED:    71     NUMBER  OILED:     0.1049E  11
  DAY  SPAWNED:    72     NUMBER  OILED:     0.1049E  11
  DAY  SPAWNED:    73     NUMBER  OILED:     0.1049E  11
  DAY  SPAWNED:    74     NUMBER  OILED:     0.7864E  10
  DAY  SPAWNED:    75     NUMBER  OILED:     0.2621E  10
  DAY  SPAWNED:    76     NUMBER  OILED:     0.1573E  11
  DAY  SPAWNED:    77     NUMBER  OILED:     0.2621E  10
  DAY  SPAWNED:    78     NUMBER  OILED:     0.2621E  10
  DAY  SPAWNED:    79     NUMBER  OILED:     0.2621E  10
  DAY  SPAWNED:    80     NUMBER  OILED:     0.2621E  10
  DAY  SPAWNED:    81     NUMBER  OILED:     0.7863E  10
  DAY  SPAWNED:    82     NUMBER  OILED:     0.1587E  06
  DAY  SPAWNED:    83     NUMBER  OILED:     0.5242E  10
  DAY  SPAWNED:    84     NUMBER  OILED:     0.2621E  10
  DAY  SPAWNED:    85     NUMBER  OILED:     0.5242E  10
  DAY  SPAWNED:    86     NUMBER  OILED:     0.2127E  05
  DAY  SPAWNED:    87     NUMBER  OILED:     0.2371E  06
  DAY  SPAWNED:    88     NUMBER  OILED:     0.7863E  10
  DAY  SPAWNED:    89     NUMBER  OILED:     0.1589E  06
  DAY  SPAWNED:    90     NUMBER  OILED:     0.1237E  05
  DAY  SPAWNED:    91     NUMBER  OILED:     0.9242E  05
  DAY  SPAWNED:    92     NUMBER  OILED:     0.2473E  06
  DAY  SPAWNED:    93     NUMBER  OILED:     0.6553E  09
  DAY  SPAWNED:    94     NUMBER  OILED:     0.6552E  09
  DAY  SPAWNED:    95     NUMBER  OILED:     0.8986E  09
  DAY  SPAWNED:    96     NUMBER  OILED:     0.1347E  05
  DAY  SPAWNED:    97     NUMBER  OILED:     0.1966E  10
  DAY  SPAWNED:   305     NUMBER  OILED:     0.2817E  04
  DAY  SPAWNED:   309     NUMBER  OILED:     0.2823E  04
  DAY  SPAWNED:   314     NUMBER  OILED:     0.2820E  04
  DAY  SPAWNED:   315     NUMBER  OILED:     0.2835E  04
  DAY  SPAWNED:   316     NUMBER  OILED:     0.2837E  04
  DAY  SPAWNED:   317     NUMBER  OILED:     0.3477E  04
  DAY  SPAWNED:   318     NUMBER  OILED:     0.7128E  04
  DAY  SPAWNED:   319     NUMBER  OILED:     0.8501E  04
  DAY  SPAWNED:   321     NUMBER  OILED:     0.3636E  04
  DAY  SPAWNED:   323     NUMBER  OILED:     0.3819E  04
  DAY  SPAWNED:   324     NUMBER  OILED:     0.2837E  04
  DAY  SPAWNED:   325     NUMBER  OILED:     0.5684E  04
  DAY  SPAWNED:   326     NUMBER  OILED:     0.9564E  04
  DAY  SPAWNED:   327     NUMBER  OILED:     0.5709E  04
  DAY  SPAWNED:   328     NUMBER  OILED:     0.1420E  05
  DAY  SPAWNED:   329     NUMBER  OILED:     0.2851E  04
  DAY  SPAWNED:   330     NUMBER  OILED:     0.7841E  04
  DAY  SPAWNED:   331     NUMBER  OILED:     0.1139E  05
  DAY  SPAWNED:   332     NUMBER  OILED:     0.1138E  05
  DAY  SPAWNED:   333     NUMBER  OILED:     0.1711E  05
  DAY  SPAWNED:   334     NUMBER  OILED:     0.8559E  04
  DAY  SPAWNED:   335     NUMBER  OILED:     0.1997E  05
  DAY  SPAWNED:   336     NUMBER  OILED:     0.2116E  05
  DAY  SPAWNED:   337     NUMBER  OILED:     0.3032E  05
  DAY  SPAWNED:   338     NUMBER  OILED:     0.2157E  05
  DAY  SPAWNED:   339     NUMBER  OILED:     0.2836E  05
  DAY  SPAWNED:   340     NUMBER  OILED:     0.3326E  05
  DAY  SPAWNED:   341     NUMBER  OILED:     0.3731E  05
  DAY  SPAWNED:   342     NUMBER  OILED:     0.2408E  05
  DAY  SPAWNED:   343     NUMBER  OILED:     0.5117E  05
  DAY  SPAWNED:   344     NUMBER  OILED:     0.4534E  05
  DAY  SPAWNED:   345     NUMBER  OILED:     0.5017E  05
  DAY  SPAWNED:   346     NUMBER  OILED:     0.8064E  05
  DAY  SPAWNED:   347     NUMBER  OILED:     0.4953E  05
  DAY  SPAWNED:   348     NUMBER  OILED:     0.7753E  05
  DAY  SPAWNED:   349     NUMBER  OILED:     0.6340E  05
  DAY  SPAWNED:   350     NUMBER  OILED:     0.1261E  06
  DAY  SPAWNED:   351     NUMBER  OILED:     0.2155E  06
  DAY  SPAWNED:   352     NUMBER  OILED:     0.1409E  10
  DAY  SPAWNED:   353     NUMBER  OILED:     0.1409E  10
  DAY  SPAWNED:   354     NUMBER  OILED:     0.5626E  06
  DAY  SPAWNED:   355     NUMBER  OILED:     0.7047E  09
  DAY  SPAWNED:   356     NUMBER  OILED:     0.4473E  06
  DAY  SPAWNED:   357     NUMBER  OILED:     0.1113E  10
  DAY  SPAWNED:   358     NUMBER  OILED:     0.1409E  10
  DAY  SPAWNED:   359     NUMBER  OILED:     0.3522E  10
  DAY  SPAWNED:   360     NUMBER  OILED:     0.1409E  10
  DAY  SPAWNED:   361     NUMBER  OILED:     0.4930E  10
  DAY  SPAWNED:   362     NUMBER  OILED:     0.2114E  10
  DAY  SPAWNED:   363     NUMBER  OILED:     0.4930E  10
  DAY  SPAWNED:   364     NUMBER  OILED:     0.4931E  10

****NORMAL TERMINATION****
```

12.5 Section 7 Appendix

12.5.1 Description of Computer Software

Computer Software for Qualitative/Quantitative IR Analysis

The laboratory is equipped with a Nova 3/12 Mini computer. The computer has 64K core memory, hard disk (10m byte) dual floppy disks (.3M byte each), 8 channel D/A board, 16 channel digital I/O board, A/D converter, foreground/background management system, two terminals and a digital plotter. It is interfaced to the Hewlett Packard GC/MS system and the Beckman 4260 Infrared Spectrometer. In addition, there is a Micro Nova, equipped with 28K core memory, dual floppy disks (.3M byte each) 8 channel D/A board, 16 channel digital I/O board, A/D converter, graphics terminal. It is interfaced to the P.E. gas chromatograph.

Extensive software was written for data collection and massage and is described in the following section.

1. Infrared Software

a) Program Descriptions:

i) IRBECK - this program collects the data from the Beckman 4260 Infrared spectrometer in 1 cm^{-1} increments and stores the data on file.

ii) SCALESUB - this program "separates" components from a mixture by subtracting the infrared spectrum of a particular component from the infrared spectrum of the mixture containing the component.

iii) ADDSPEC - this program adds two or more infrared spectra.

iv) ELASTASPEC - this program scales (expands or contracts) an infrared spectrum (in absorbance units).

v) HOW MUCH - this program determines the amount of a designated component in a sample.

Flow charts of the above programs are shown in Figures I-E-1 through 5.

b) Development of Data Acquisition Techniques

i) Determination of instrumental settings for measurement and computer storage of accurate spectra.

Although the measurement of high quality infrared spectra has always been essential for accurate sample analysis, it becomes even more critical for digitized infrared spectra. This requires the selection of instrumental conditions such that accurate data is transmitted to the computer during a scan. To choose these conditions, it is necessary to consider the magnitude of the signal reaching the detector. This is governed by the energy throughput of the sample.

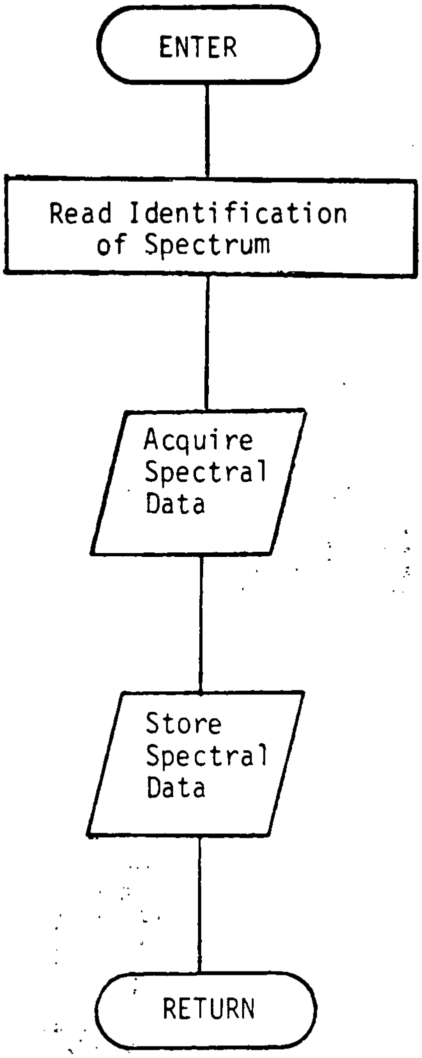

ENTER
Read Identification of Spectrum
Acquire Spectral Data
Store Spectral Data
RETURN

Figure I-E-1

SCALESUB

Figure 1-E-2.

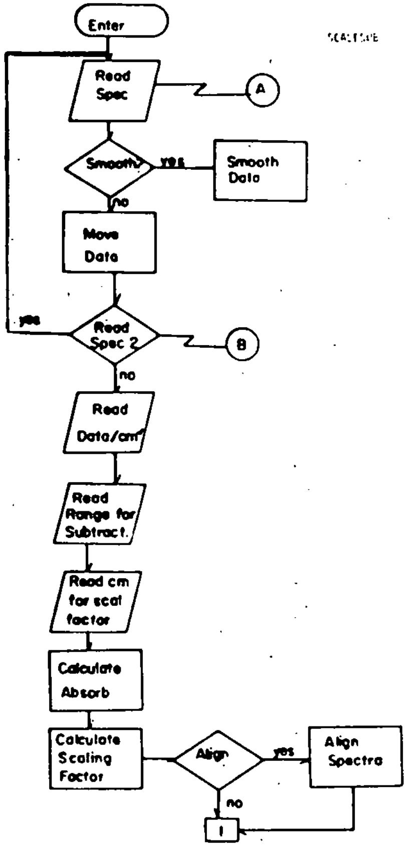


FIGURE 2b
SCALESUB

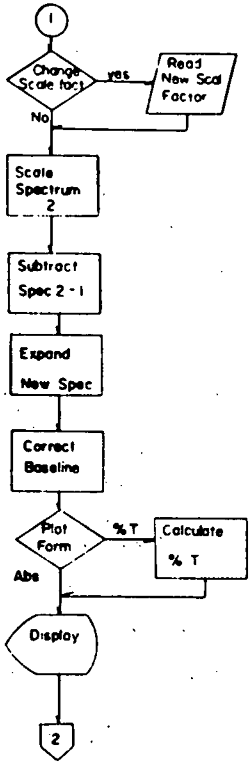
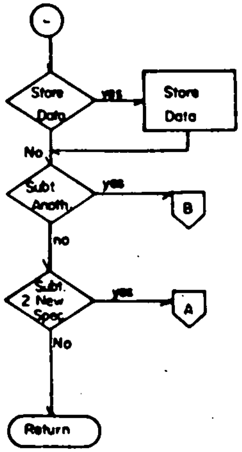


FIGURE 2c
SCALESUB



ADDSPEC

FIGURE 3a

ADDSPEC

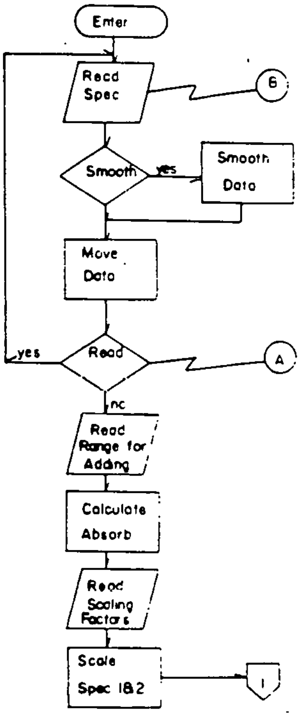


FIGURE 3b

ADDSPEC

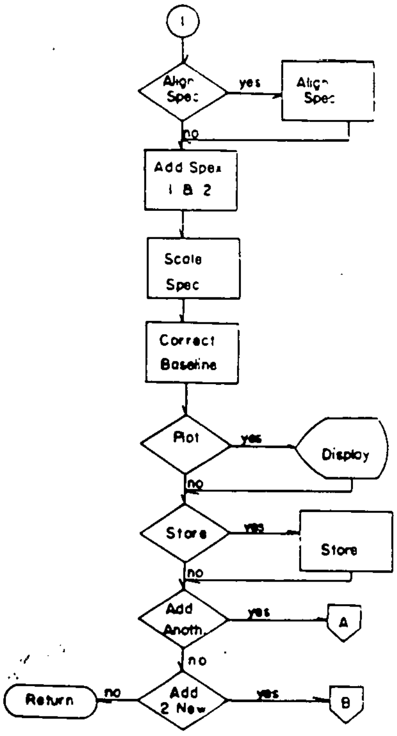


FIGURE 4a

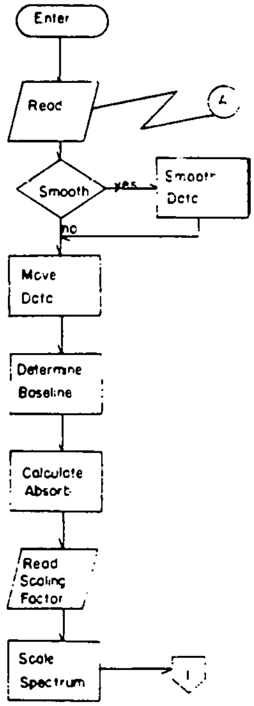
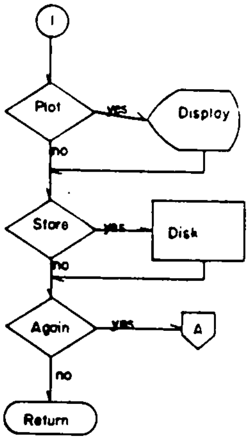


FIGURE 4b



HOWMUCH

FIGURE 5a
HOWMUCH

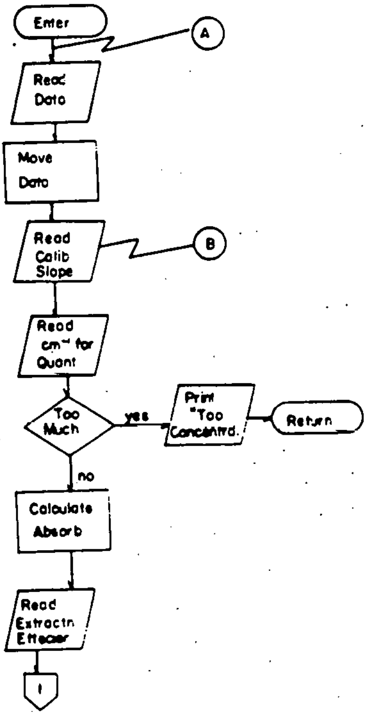
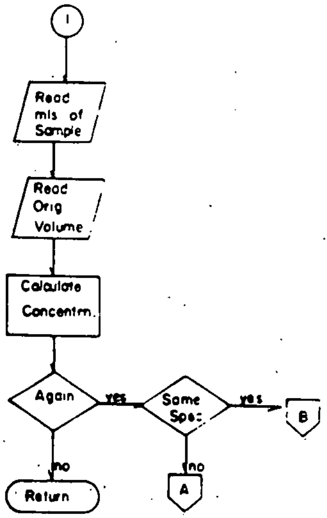


FIGURE 5b
HOWMUCH



For infrared analysis of the meso-tank samples, we are extracting water samples with CS_2 and transferring an aliquot of the sample to a sealed cell of 6 mm pathlength. To eliminate the absorptions due to the CS_2 in a spectrum, a second cell (also 6 mm pathlength) with pure CS_2 was placed in the reference beam of the instrument. The CS_2 then absorbs infrared energy from the sample and reference beams at its characteristic frequencies. The resultant spectrum was due to the absorption bands of the sample (solute). The absorption of energy from both beams by CS_2 greatly reduced the energy throughput of the sample.

To determine the proper instrumental parameters for measuring accurate spectra of samples in CS_2, a simple mixture of benzene-chloroform (1:1) was initially tested. In the region of interest between 1355 and 655 cm^{-1}, chloroform has two absorption bands (1210 and 755 cm^{-1}) and benzene has two absorption bands (1030 and 670 cm^{-1}).

The infrared spectrum of the benzene-chloroform mixture in CS_2 is shown in Figure I-E-6 (top). It shows the absorption bands of the mixture and the CS_2, because a compensating cell was not used in the reference beam.

The CS_2 absorbs totally between 880 and 830 cm^{-1}, resulting in a 50 cm^{-1} region in which no energy reaches the detector. This divides the spectrum between 1355 and 655 cm^{-1} into two "windows," wherein the absorptions due to the sample can be measured. The first window (1300-890 cm^{-1}) contains a CS_2 doublet centered at 1040 cm^{-1}. The second window (825-655 cm^{-1}) contains four relatively stronger bands due to the CS_2 (805, 785, 755, and 655 cm-1).

The first optical window provides for a higher energy throughput because it contains the least intense CS_2 bands. Considering this window first, instrument settings were chosen for this available energy. Instrument gain was chosen for this region according to instrument specifications. Slits were set at .3 mm at 3000 cm-1. The third important parameter, scan speed, was chosen by repeated scans of this sample at varying speeds and speed suppressions and by storing these data on the computer.

Tracking error is introduced into the measurement if the scan is not slow enough. To determine at which speed the tracking error was eliminated in the measurement, it was assumed that a spectrum measured accurately at, e.g., 300 cm^{-1}/min. with a speed suppression of 2, would be identical to a spectrum of the same sample measured accurately at 300 cm^{-1}/min. with a speed suppression of 1. Subtraction of these two spectra should give a horizontal (straight) line. Any deviation from a straight line is a gauge of the inaccuracy of spectral measurement in either or both spectra.

Figure I-E-6 (bottom) shows the compensated infrared spectrum of the mixture of CS_2. This spectrum was scanned in the 1300-1000 cm region at speeds of 1000, 600, 300, and 150 cm^{-1}/min. At each speed, the speed

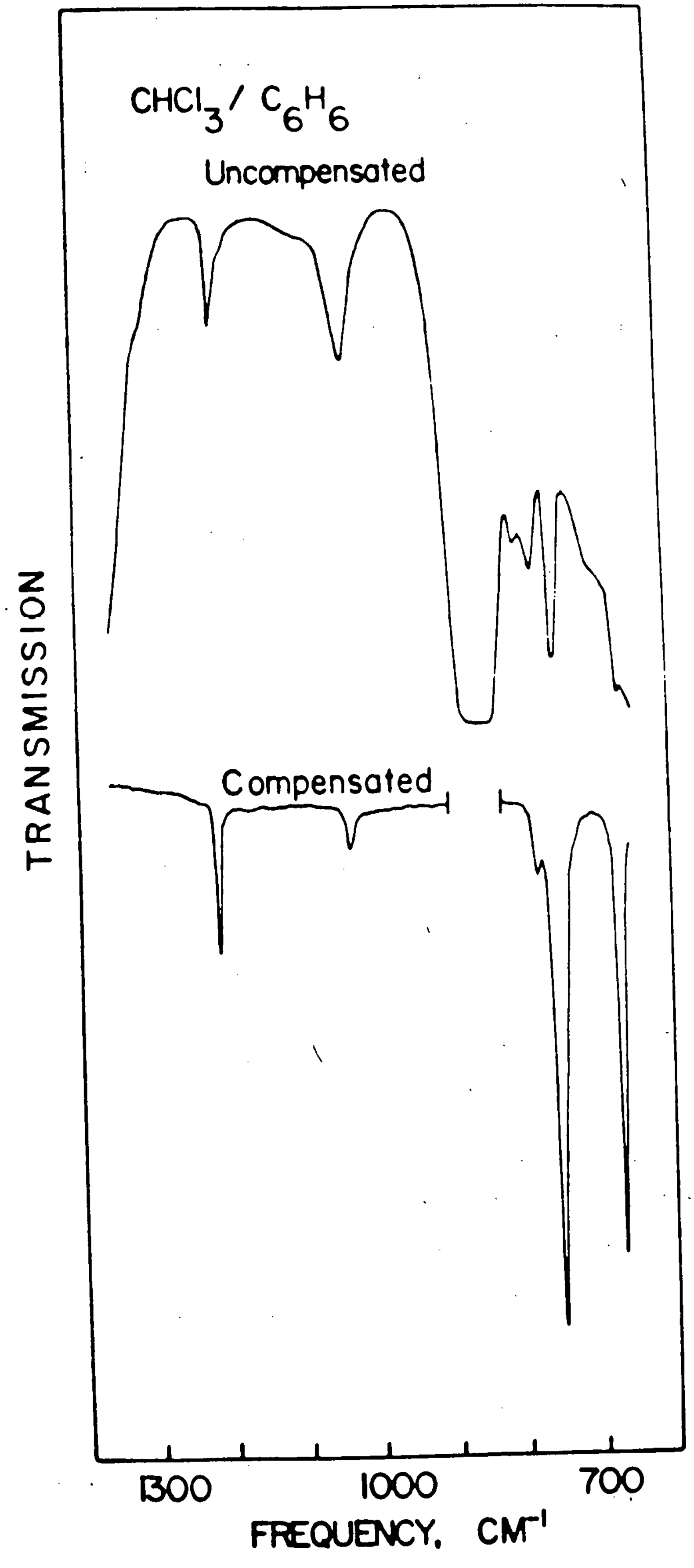

$CHCl_3$ / C_6H_6
Uncompensated
Compensated
TRANSMISSION
1300
1000
700
FREQUENCY, CM^{-1}

Figure I-E-6.

suppression was also varied from 3 to 0, yielding three spectra at each speed for a total of 12 spectra. At each speed, subtractions were performed between the spectra measured at the various speed suppressions.

Figure I-E-7 shows the results of these subtractions. It can be seen that at slower speeds and higher speed suppressions, deviation from a straight line plot is minimized. There is still some difference evidenced at 150 cm^{-1}/min., speed suppression 3-2; thus, it was decided to measure additional spectra at 150 cm-1/min with a speed suppression of 4 and at 50 cm^{-1}/min with a speed suppression 1 and 0. Figure I-E-8 shows the results of subtractions of these additional spectra. It can be seen that by the subtraction of the spectrum measured at 150 cm^{-1}/min. with a speed suppression of 3 from speed suppression of 4, there is a slight deviation. By slowing the scan down to 50 cm^{-1}/min. and subtracting speed suppression 0 from speed suppression 1, a straight line was obtained.

To determine whether or not the spectrum measured at 150 cm^{-1}/min. with a speed suppression of 4 was measured with acceptable accuracy, it was then subtracted from the spectrum measured at 50 cm-1 with a speed suppression of 1. As can be seen in Figure I-E-8, a relatively straight line was also obtained, indicating that within this "window," a spectrum would be accurately measured at a speed 150 cm^{-1}/min. with a speed suppression of 4.

Moving to the second "window" (825-655 cm^{-1}), we find a different energy situation. CS_2 has more intense bands here, resulting in a lower energy throughput than in the first situation. This requires a slight increase in instrument gain and the determination of proper scan speed. From the results already obtained, we know that it is not possible to scan faster than 150 cm^{-1}/min. Therefore, spectra of the mixture were measured at 150 cm^{-1}/min. with speed suppression varying from 4 to 1, yielding 4 spectra.

Subtractions of these spectra from one another are shown in Figure I-E-9. The subtraction of a spectrum at speed suppression 3 from the one measured at speed suppression 4 gives slight deviations. The spectrum of the mixture between 1355 and 655 cm^{-1} was, therefore, measured at 150 cm-1/min. with a speed suppression of 4.

The infrared spectra of the components were individually measured in the same region, under the same conditions. Figure I-E-10 shows the spectra of the benzene and chloroform. Beneath the benzene is the spectrum resulting from the subtraction of chloroform from the mixture, yielding benzene. Beneath the spectrum of the chloroform is the spectrum resulting from the subtraction of benzene from the mixture, yielding chloroform.

It can be seen that both spectra resulting from these subtractions vary slightly from the spectra of the corresponding pure compound in the 825-655 cm^{-1} region. To determine the stability of the sample in the infrared beam for this region, five repetitive infrared scans of the mixture were made. In each case, the sample remained in the infrared beam for 20 minutes.

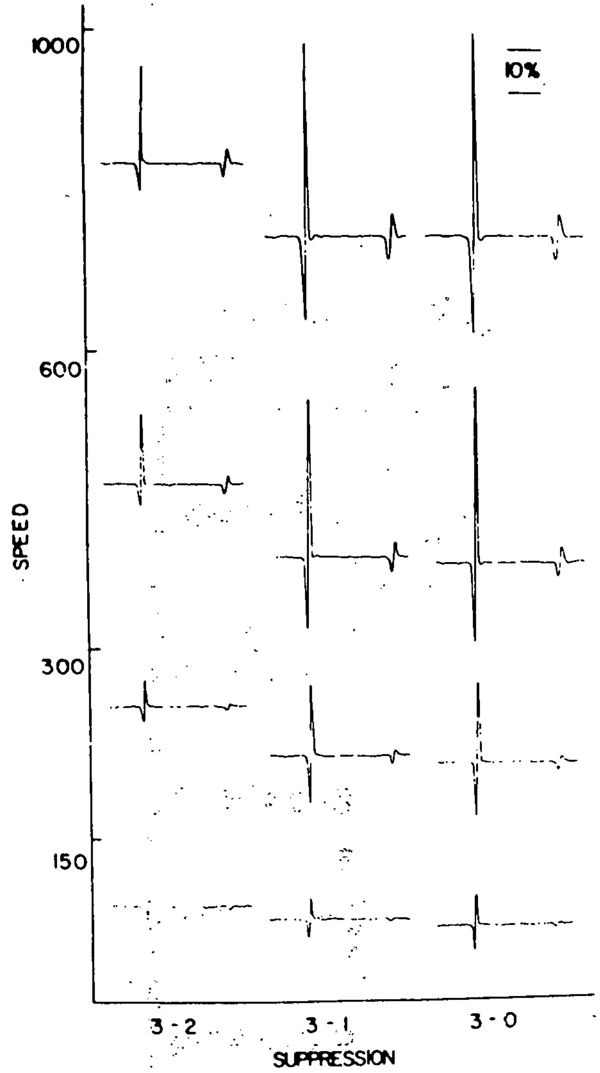


Figure 1-E-7.

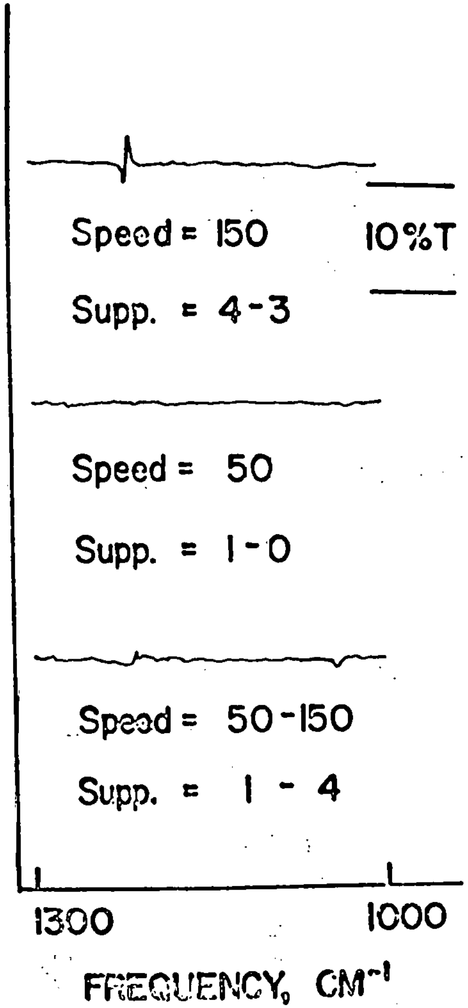


Figure 1-E-8.

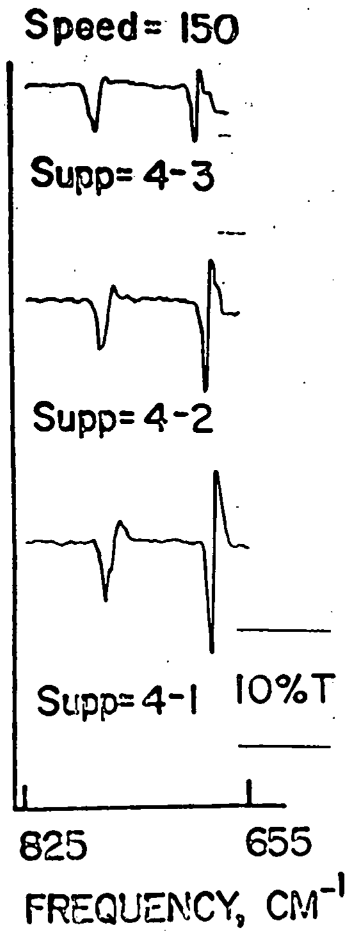


Figure I-E-9.

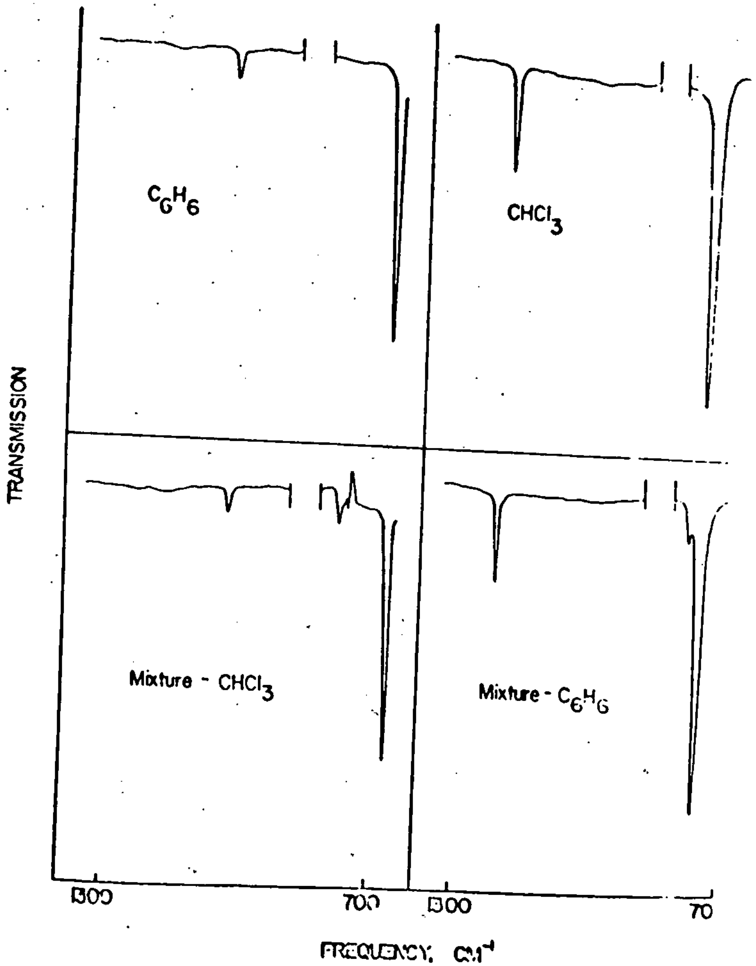


Figure I-E-10.

Figure I-E-11 shows the results of subtracting the fifth scan from the first scan. As can be seen, neither the mixture nor either of the individual components yield a straight line, indicating an instability in the infrared spectrum of each sample with time. This accounts for the poor subtractions in the 825-655 cm-1 region.

Considering the instability of this mixture in the fingerprint region, it was decided to move to another sample type. A mixture of dibutyl, diisobutyl, and dioctyl phthalate were placed into CS_2 solution. Phthalates are a common contaminant in organic extracts from sea water and the sources of phthalates are numerous. They can occur from leaching of PVC pipes in the tanks. We have detected phthalates in some "pure" lots of CS_2. Certain phthalates are also naturally present in sea water. It is necessary to separate these contaminants from the hydrocarbon extracts before sample analysis. Several infrared scans of the phthalate mixture were, therefore, measured and the sample was found to be relatively stable in the infrared beam.

Figure I-E-12 shows the uncompensated and compensated infrared spectrum of the phthalate mixture in CS_2. As can be seen, this sample has many more absorption bands in this infrared region than did the previous mixture. Therefore, it would be expected that the rate of scan necessary for measurement of an accurate spectrum would be 150 cm^{-1}/min. with speed suppression of 4, or possibly slower. It would be very desirable to be able to increase the scan rate, and one way to allow for a faster scan without sacrificing spectral accuracy might be to increase the slit-width. This would increase energy throughput to the detector. There is, however, a loss of spectral resolution with increase in slit-width.

Figure I-E-13 shows the infrared spectra of the phthalate mixture measured with the slit-width set for .3mm and for .45 mm at 3000 cm^{-1}. The spectra show that with a 50% increase in slit-width, resolution is not sacrificed to any appreciable degree.

Infrared spectra of the mixture were then measured at 150 cm^{-1}/min., varying the speed suppression from 4 to 0, yielding five spectra. Subtraction of the spectrum measured at speed suppression 0 from that measured at speed suppression 4 yielding the straight line in Figure I-E-13. Thus by opening the slits to .45 mm at 3000 cm-1, we are able to scan approximately twice as fast as a slit-width of .3mm.

The computer programs were next tested on separation of phthalates from hydrocarbon samples. The top spectrum of Figure I-E-14 is that of a mixture of Kuwait oil and phthalates in CS_2. The middle spectrum is the result of subtracting a spectrum of the phthalate spectrum from the top spectrum, yielding a spectrum of oil. The bottom spectrum is of the pure oil in CS_2.

The two lower spectra are almost identical indicating a successful separation of phthalates from the mixture.

The subtraction program is also directly applicable to the separation of dispersant from a mixture of oil and dispersant. The meso-tank experiments were designed so that the fate of oil in water and that of oil carried into the water column by a dispersant were monitored under

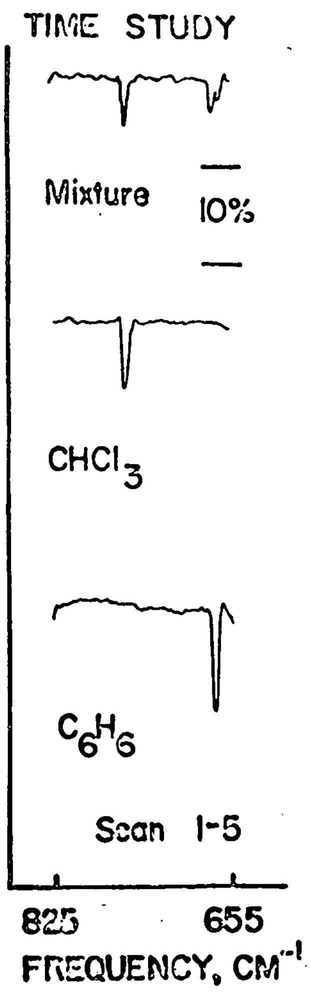


Figure I-E-11.

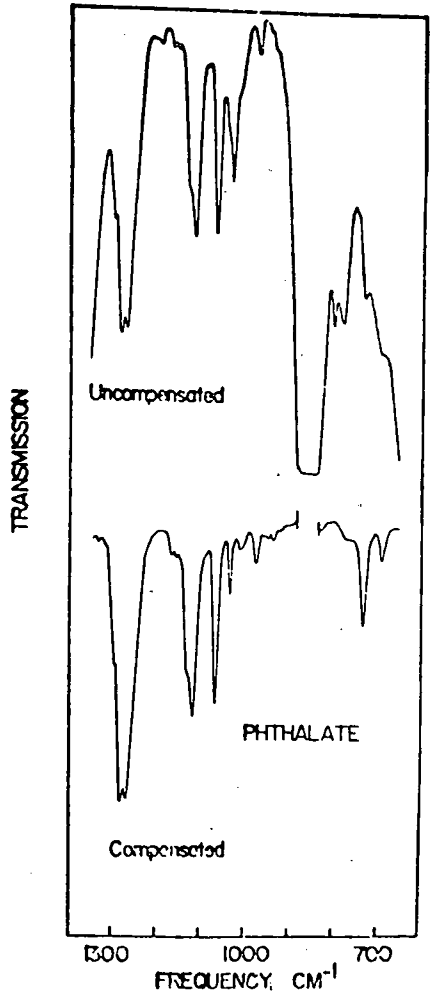


Figure I-E-12.

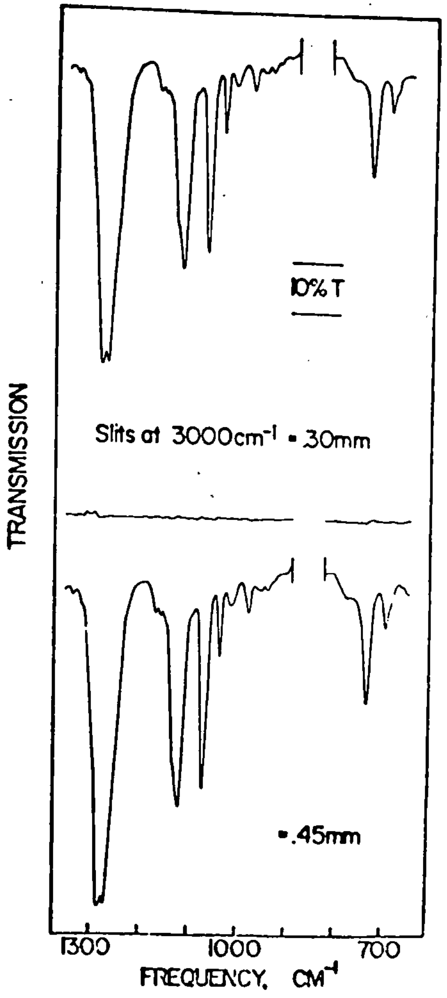


Figure I-E-13.

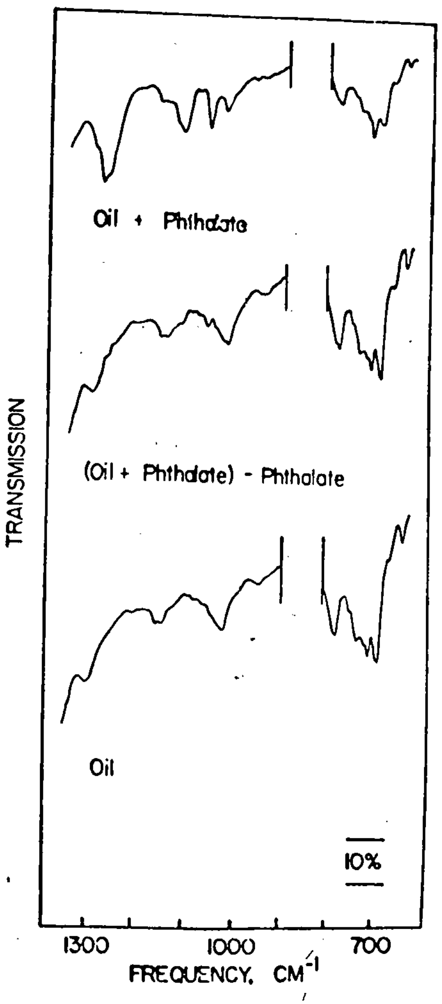


Figure I-E-14.

identical conditions. Oil was "spilled" into one tank while oil and dispersant were spilled into the other tank. Water samples of both tanks were collected at varying depths and the hydrocarbons were then extracted with CS_2.

To determine the types and amounts of petroleum hydrocarbons present in the oil/dispersant tank samples, it is necessary to separate the oil from the dispersant. Like the oil, the dispersant is also a complex mixture of hydrocarbons which has a very strong and complex infrared spectrum.

Figure I-E-15 shows the infrared spectra of oil on CS_2 as well as dispersant in CS_2 in the 4000-650 cm^{-1} region. As can be seen, the dispersant has hydrocarbon bands between 3000 and 2900 cm^{-1} which overlap with the hydrocarbon bands due to the Kuwait oil. The 2930 cm^{-1} band is used for quantitative analysis of petroleum hydrocarbons. Therefore, it is necessary to eliminate the overlapping dispersant band in this region. Looking at the fingerprint region (1355-655 cm^{-1}), it can be seen that the dispersant also has relatively intense bands which overlap with the bands of the oil. To perform qualitative analysis of the petroleum, the absorption bands due to the dispersant must be eliminated as well.

Since dispersants and petroleum are both complex mixtures of hydrocarbons, chemical separation of these two mixtures is extremely difficult, if not altogether impossible.

To determine the feasibility of separating these two mixtures spectrally, a mixture of Kuwait oil and dispersant was placed in CS_2. The top spectrum in Figure I-E-16 is of the mixture. The concentration of the oil and the dispersant were both known. A CS_2 solution of a known amount of dispersant was also prepared.

The middle spectrum is the result of the subtraction of the spectrum of the dispersant from that of the oil/dispersant mixture. The bottom spectrum is of Kuwait oil. Comparison of the lower two spectra shows them to be almost identical, indicating a successful separation of oil and dispersant. The fingerprint of the oil is free from interfering dispersant bands and can be used for qualitative analysis.

When subtracting the dispersant from the mixture, a factor is calculated and this factor is used to scale the spectrum of the pure dispersant so that the intensity of the dispersant bands in the pure solution match that of the dispersant bands in the mixture. The scaling factor should provide a means to determine the amount of a component in a mixture.

The concentration of dispersant in CS_2 was known. By multiplying the scaling factor obtained from the subtraction in Figure I-E-16 by the known concentration, a concentration of 540-545 ppm was obtained. The concentration of the dispersant in the mixture was known to be 542 ppm. Knowing the concentration of dispersant in the mixture, we can now determine the amount of hydrocarbon due to petroleum.

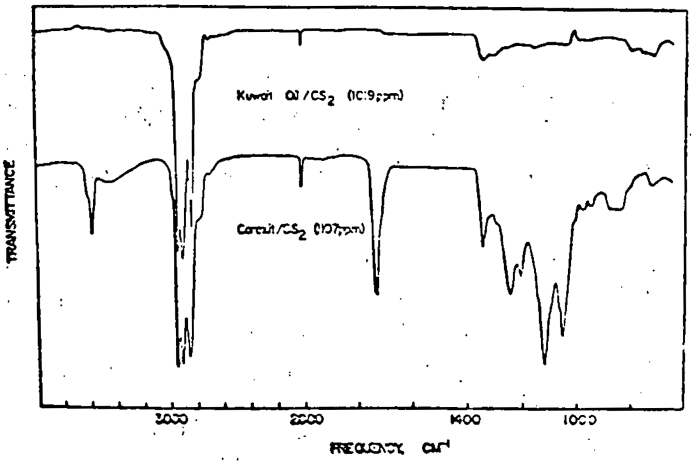


Figure I-E-15. Infrared Spectra of a Known Concentration of Kuwait Oil in CS_2 and a Known Concentration of Corexit in CS_2

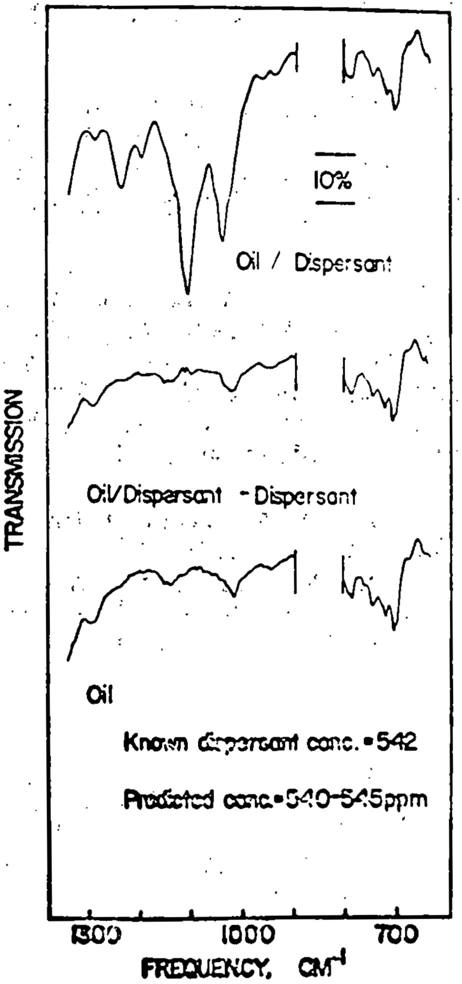


Figure I-E-16.

Solutions of pure compounds in CS_2 were used for this series of tests of the computer programs. However, samples from the tank experiments are CS_2 extracts of the oil, oil/dispersant and dispersant from sea water. To determine how these samples differ from CS_2 solutions of the neat compounds, laboratory experiments were conducted in which oil, oil/dispersant and dispersant were "spilled" into large containers of sea water. One liter samples of these "spills" were then extracted with CS_2, along with a control.

The top spectrum in Figure I-E-17 is of the neat oil in CS_2. The spectrum of the control was subtracted from that of the CS_2 extract of the oil from the water. Differences in the relative intensities of the bands can be seen between corresponding bands in each spectrum.

The top spectrum in Figure I-E-18 is that of the CS_2 extract of the oil/dispersant mixture from water, minus its control. The middle spectrum is of the CS_2 extract of the dispersant from water minus control. The bottom spectrum is the result of the subtraction of the middle spectrum from the top spectrum, yielding a spectrum of the oil carried into the water by the dispersant.

In Figure I-E-19, the top spectrum is the result of the subtraction shown in Figure I-E-18, i.e., the oil carried into the water by the dispersant. The middle spectrum is the result of the subtraction in Figure I-E-17, i.e, the oil in water. The bottom spectrum is of neat oil in CS_2. The three spectra are obviously different in contours and relative intensities, indicating a difference in chemical composition between samples.

2) GC Software and GC/MS Software

Computer programs for massage of the GC data were developed by this laboratory.

a) Program Descriptions

i) GCPE - can acquire GC data for any length of time. From the user input information, initial temperature, final temperature, rate and number of minutes, the program determines how many times to acquire 3600 consecutive data points in a 'do-loop.' The data acquisition rate is three points per second so a forty-five minute run will have 8100 data points or will need to cycle the 'do-loop' twice (2x3600=7200) and acquire the last 900 points (remainder) outside of the 'do-loop.' Along with storing the data and data name, the initial temperature, rate and number of minutes are also stored (Figure I-E-20).

ii) SMOTH9 - this 9 point smoothing routine will open any data file created by GCPE and display the smoothed chromatogram on a Houston Instrument Complot. This program is really the reverse of GCPE in that it generates the smoothed data in 3600 data point arrays and then generates the remainder of the data points. A graphical example of the smoothing is shown in Figure I-E-21. 1 through I-4 cannot be calculated due to the nature of the general smoothing formula.

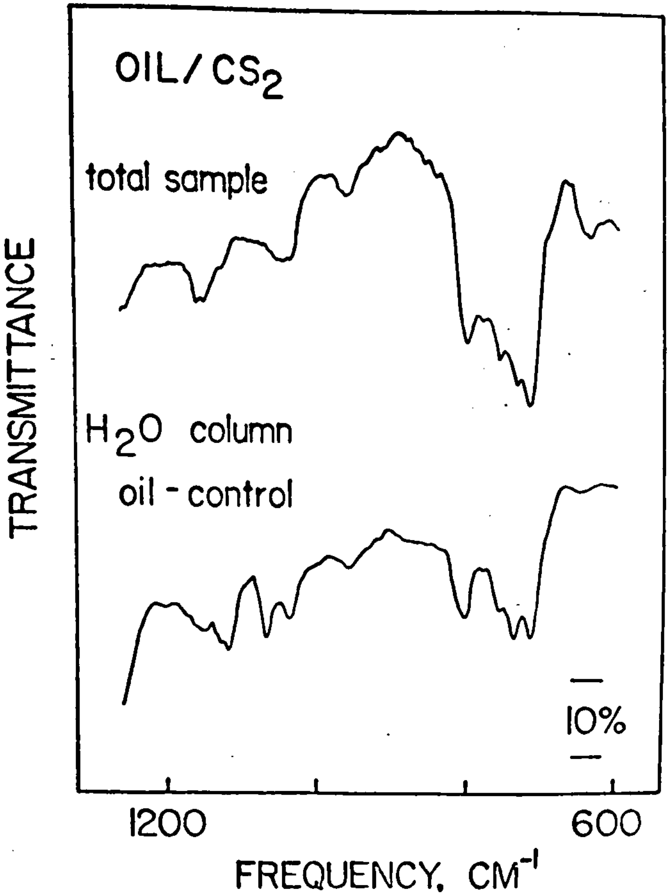


Figure I-E-17.

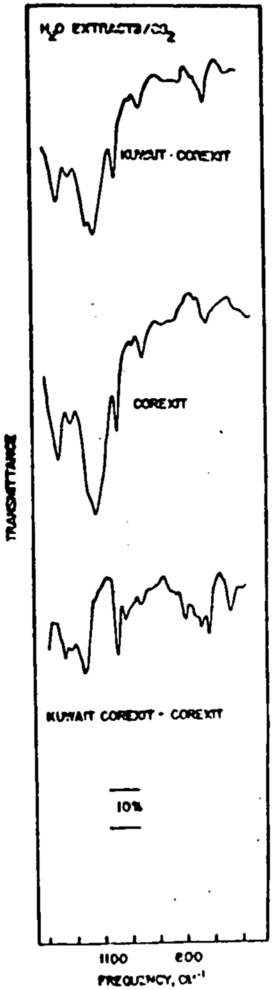


Figure I-E-18.

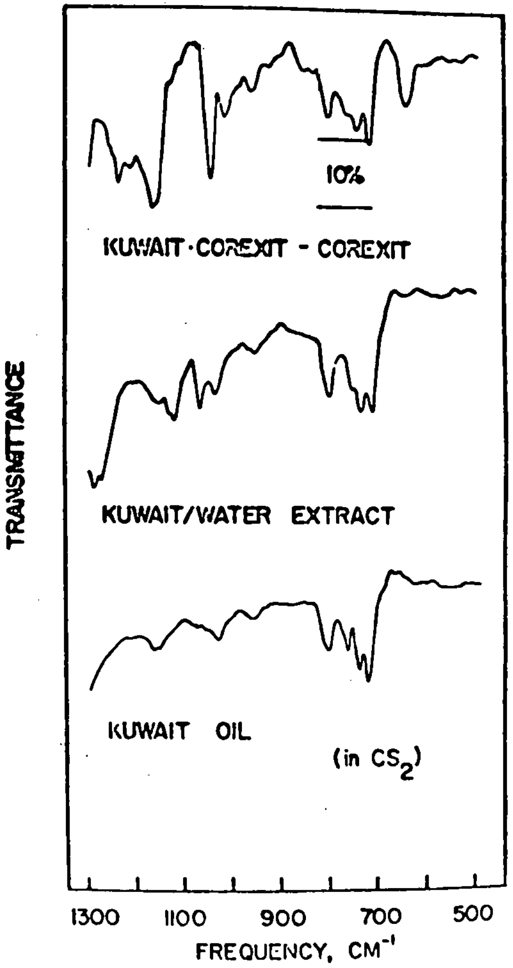
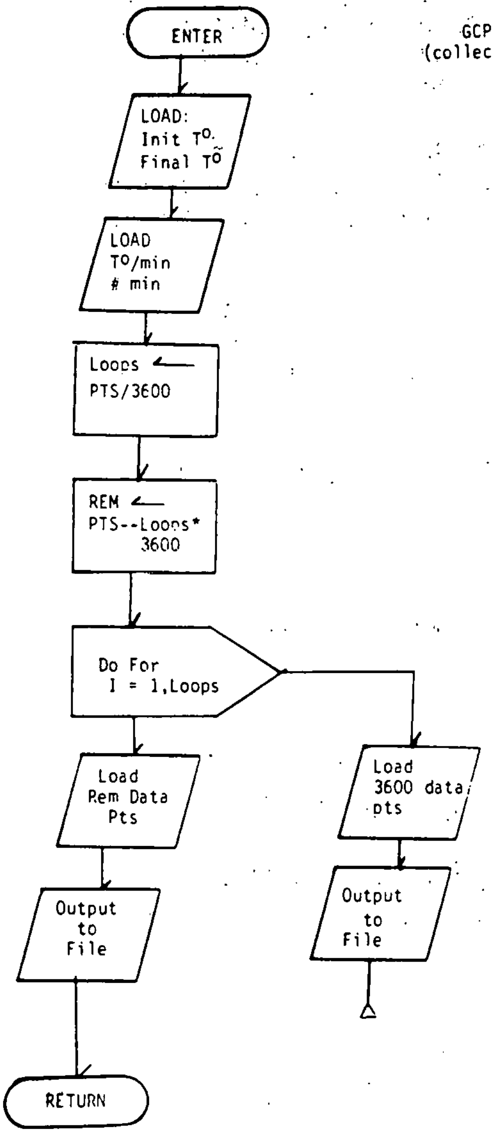
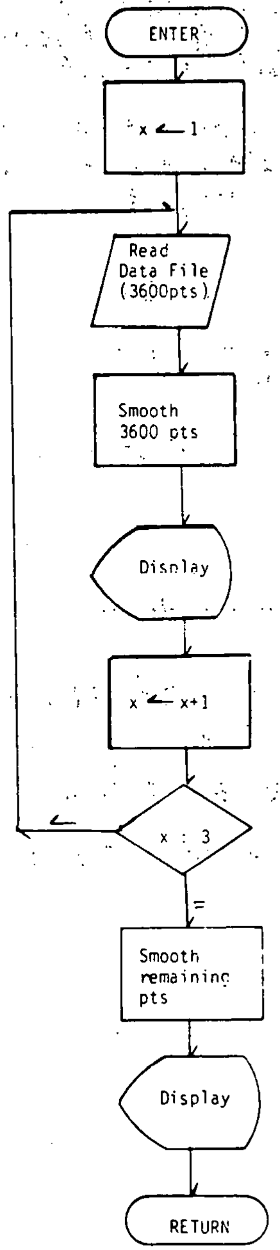


Figure I-E-19.



GCPE
(collects data)

Figure I-E-20



SMOTH 9
(Plots Data)

Figure I-E-21

(iii) MSPEC.FR - scans and acquires data from the GC/MS system. Stores data on disk for subsequent data processing and display. Uses subroutine GCMS.SR. Outputs a 0 to -10 VDC staircase voltage ramp in 400 steps. At every step (corresponding to one amu, 400 amu full scan) a signal is taken off the electron multiplier via the Nova ADC.

TOTION.FR - plots out on the plotter a reconstructed gas chromatogram for the entire analysis. This is called a total ion plot. For each reconstructed GC peak, a mass spectrum may be displayed via program MSPLT.FR or MASSPLOT.FR.

MSPLT.FR - plot out individual mass spectra on CRT.

MASSPLOT.FR - plot out individual mass spectra on plotter, same as flow diagram for MSPLT.FR.

MSSERCH.FR - determines if a particular mass is present in an analysis.

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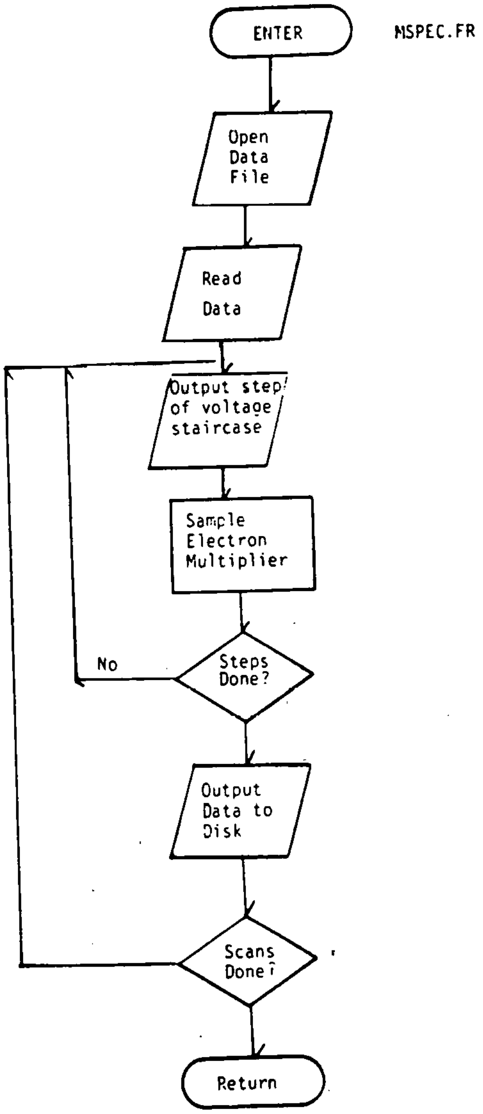

Figure 1-E-22.

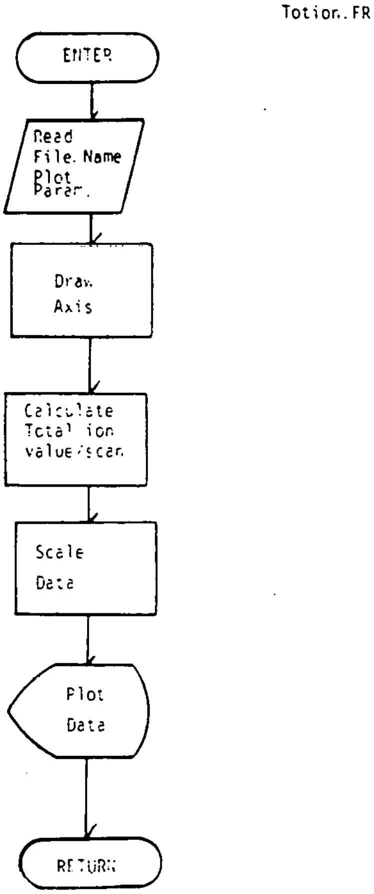

Figure 1-E-23

MSPLT.FR

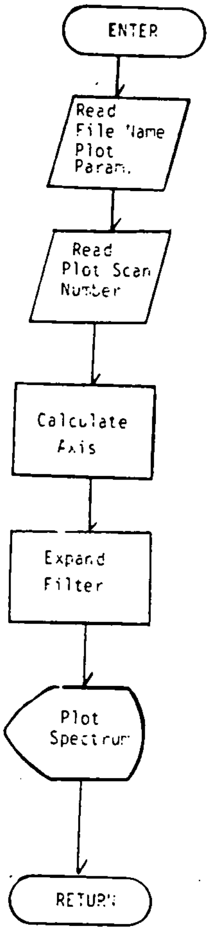

Figure I-E-24

MSSEARCH.FR

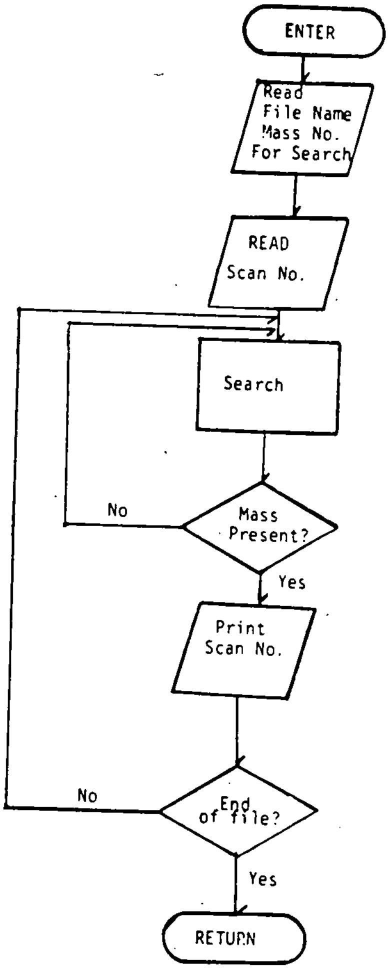

Figure I-E-25

12.6 Section 8 Appendices

12.6.1 Appendix 1 Colony Types of Bacterial Isolates from the Laboratory Experiment

12.6.2 Appendix 2 Replica Plating

APPENDIX 1

Colony Types of Bacterial Isolates from the Laboratory Experiment

The criteria for the colony description are given in the following order: size, color, reaction to light, granular or smooth, elevation and border. Size was categorized as small (2 mm or less), medium (2-5 mm), and large (greater than 5 mm). Reaction to light was designated as transparent, translucent, or opaque. The appearance of each colony type was described as rough or smooth and if the colony glistened this was noted. Colony elevation was described as flat, raised, convex, umbonate, or drop-like. The border of the colonies were described as entire (circular with no irregularities), undulating, scalloped, or irregular. The symbols used are numbers 1 though 35 (number of colony isolated), K (growth on Kuwait crude agar), N (growth on naphthalene agar), H (growth on n-hexadecane agar), and OZR (growth on OZR medium). Bacteria that metabolized a hydrocarbon or Kuwait crude oil substrate were Gram stained and were reported as Gram positive, Gram negative, or Gram variable, and were classified as either a rod or coccus.

1 H: Medium, yellow-green, opaque, smooth, convex, entire, Gram negative rod.

2 N: Medium, yellow-orange, opaque, smooth, umbonate, slightly irregular border, Gram positive rod with some filaments present.

3 K: Medium, grey-brown, opaque-translucent in rings, smooth, flat, entire, Gram negative rod.

4 H: Medium, white, opaque, smooth, raised, entire, Gram positive rod.

5 N: Medium-large, white, translucent-opaque, smooth, flat, scalloped-hazy border, Gram negative rod.

6 N: Medium, buff, opaque, smooth, convex, entire, no Gram stain, bacterium was lost.

7 K: Medium, yellow-green, opaque, smooth, convex, entire, Gram positive rod.

8 K: Medium, white, opaque center with translucent border, smooth border with granular center, wrinkled and umbonate, older colonies are starred in center, scalloped border, Gram variable rod.

9 N: Medium-large, white, opaque, smooth, raised, starred in center when old, entire, Gram negative rod.

10 N: Medium, white, translucent-opaque, smooth and granular center, umbonate, entire, gram negative rod.

11 K: Medium-large, white, translucent to opaque, smooth, slightly umbonate, entire, Gram negative rod.

12 N: Medium, yellow, opaque, smooth, glistening, raised, umbonate when old, entire, Gram positive rod.

13 HNK: Medium, white, opaque, smooth, umbonate, slightly undulating border, Gram positive coccoid-rod.

14 N: Medium, green-yellow, opaque, rough, flat and below the surface of the agar, irregular, Gram positive rod.

15 N: Medium, white with brown center, opaque, smooth, flat, scalloped border, Gram variable rod.

16 H: Medium, white, opaque, smooth, convex, entire, Gram variable rod.

17 H: Medium-large, yellow with buff border, opaque, smooth, and glisting, convex, entire, Gram negative, coccoid to rod shaped.

18 N: Medium to large, white, translucent to opaque, smooth, umbonate, undulating, Gram positive rod.

19 K:. Medium, white, opaque, smooth, slightly raised, entire, Gram negative coccoid to rod shaped.

20 N: Medium, yellow-green, opaque, smooth, convex center with diffuse entire border, Gram positive rod.

21 N: Medium, alternating rings of brown, grey, and white, translucent and opaque, smooth, flat, entire, Gram negative rod.

22 N: Small to medium, white, opaque, granular, rough, raised, slightly irregular border, Gram positive rod.

23 HK: Small to medium, white, translucent to opaque, smooth raised, entire, Gram positive rod.

24 NH: Medium, yellow, opaque, smooth, raised, entire, gram positive coccoid to rod shaped.

25 K: Small, white-yellow, opaque, smooth, raised, entire, Gram positive rod.

26 OZR: Small, white, opaque, smooth, convex, entire.

27 OZR: Small, white, opaque, smooth, flat, entire.

28 OZR: Small, white, opaque, smooth, flat, entire.

29 OZR: Large, green-yellow, translucent to opaque, rough, agarolytic, irregular.

30 OZR: Large, brown and white rings, translucent to opaque, smooth, agarolytic, entire.

31 OZR: Large, yellow, opaque, smooth, mucoid, convex, entire.

32 OZR: Small, yellow, opaque, smooth, convex, entire.

33 OZR: Medium, white, translucent to opaque, smooth, droplike, entire.

34 OZR: Medium, yellow, opaque, smooth, flat, entire.

APPENDIX 2

Replica Plating: Heterotrophic Bacterial Population diversity and Hydrocarbon Degraders in the Heterotrophic Bacterial Population During the Laboratory Experiment Bacterial colonies on OZR master plates were enumerated by colony type (colony types are given in Appendix 1). Colonies that grew on hydrocarbon replica plates but not on the basal medium control plate are designated by the hydrocarbon plate they grew on. OZR master plates were made from surface, water column, and sediment samples from four aquaria with Narragansett Bay water plus: (1) control, (2) Kuwait crude oil 15 ppm (v/v), (3) Kuwait crude oil 15 ppm (v/v) and 3 ppm (v/v) Corexit 9527, and (4) Corexit 9527 3 ppm (v/v).
Symbols:

(1) Numbers 1-36: Bacterial isolates as determined by colony morphology (see appendix 1)

(2) OZR: Master plates with OZR medium

(3) B: Number of bacteria growing on the basal medium

(4) N: Naphthalene utilizers

(5) H: *n*-Hexadecane utilizers

(6) K: Kuwait crude utilizers

A. Water Column Samples from oil aquarium.

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
0	100	29	24	5	
		32	23	8	
		30	11	7	
		33	3		
		35	3		
		31	17	14	
		28	8		
		27	2		
		34	1		
		14	7		N
		11	2		K
1	66	31	2	2	
		30	11	5	
		32	5	3	
		35	1		
		29	5	4	
		28	32		
		27	5		
		11	4		K
		9	1		N
2	107	30	15	3	
		31	6	2	
		29	15	7	
		32	7	6	
		35	6		
		34	2		
		28	40		
		27	8		
		22	8		K
7	no data				
10	61	30	1		
		31	5		
		29	10		
		34	9		
		27	3		
		28	33		
14	56	29	51		
		3	1		K
		34	2	2	
		28	2		

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
18	85	31	2		
		19	2		
		29	11	3	
		28	66		
		27	4		
21	84	31	6		
		29	15		
		30	4		
		32	4		
		27	8		
		33	2		
		28	31		
		34	14		

B. Water Column samples from oil and dispersant aquarium.

0	no data				
1	65	31	7	5	
		30	5		
		32	6	5	
		35	4		
		29	18	6	
		27	4		
		28	10		
		12	3		N
		19	8		K
2	121	31	32	24	
		29	44	7	
		32	2	2	
		35	6		
		30	13		
		28	19		
		27	2		
		1	1		H
		11	2		K
7	no data				
10	65	31	1		
		29	34		
		32	1		
		38	23		
		19	6		K

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
14	89	31	4	2	
		34	1		
		30	2		
		35	1		
		29	78	3	
		28	2		
		19	1		K
18	139	31	8		
		35	5		
		34	1		
		29	21		
		27	3		
		28	102		
		22	1		K
21	58	35	8		
		30	1		
		34	4		
		29	12		
		27	6		
		28	22	3	
		17	2		H
		19	1		K
		25	2		K

C. Water column samples from dispersant aquarium.

0	52	31	4	3	
		30	13	8	
		32	7		
		29	8	4	
		27	1		
		28	11		
		34	1		
		19	1		K
		21	1		N
		15	3		N
		20	2		N
1	61	31	6	4	
		30	6	3	
		29	23	7	
		32	3	3	
		35	1		
		33	1		
		28	13		
		27	2		

day	total # colonies OZR masters	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
		34	2		
		6	1		N
		11	2		K
		3	1		K
2	37	30	1		
		31	2		
		32	1		
		29	16		
		34	6	1	
		27	2	3	
		28	5		
		24	4		N
7	99	31	8	1	
		30	6		
		35	2	1	
		34	4		
		29	50	6	
		28	18		
		27	5		
		19	5		K
		22	1		K
10	71	31	5		
		32	3		
		29	39	5	
		28	17		
		27	1		
		19	3		K
		22	3		K
14	40	29	28		
		28	6		
		27	3		
		21	1		N
		16	1		H
		19	1		K
18	57	29	4		
		31	2		
		35	2		
		27	8		
		28	40		
		32	1		

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
21	69	31	3		
		29	4	2	
		34	22		
		28	21		
		27	18		
		24	1		N

D. Water column samples from control aquarium.

0	66	31	4	2	
		29	13	9	
		32	5	2	
		30	9		
		28	26		
		27	1		
		35	2		
		21	4		N
		15	1		N
		19	1		K
1	80	31	6	3	
		30	12	4	
		29	20	5	
		27	8		
		28	21		
		34	3		
		32	7		
		33	1		
		16	1		H
		19	1		K
2	36	31	9		
		29	6	1	
		32	4		
		33	1		
		30	1		
		28	9		
		35	3		
		24	1		N
		22	2		K
7	126	31	19		
		29	25		
		30	4		
		35	6		
		34	10		
		27	7		
		28	5		

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
10	79	31	10	2	
		32	3		
		30	5		
		35	1		
		29	14		
		33	1		
		34	3		
		28	37		
		27	5		
14	56	31	2		
		32	3		
		30	2		
		29	6	2	
		27	4		
		28	28		
		34	11		
18	59	31	6		
		35	1		
		29	2		
		28	35		
		27	10		
		34	4		
		17	1		H
21	53	31	5		
		29	6		
		30	2		
		32	6		
		27	10		
		28	19	1	
		34	5		

E. Sediment samples from oil aquarium.

0	65	32	22	6	
		30	4	2	
		35	4		
		33	2		
		29	10	5	
		28	6		
		27	6		
		31	2		
		15	2		N
		16	2		H
		23	1		H
		19	4		K

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
1	87	30	3		
		32	24	5	
		29	35	9	
		28	6		
		27	5		
		34	3		
		33	5		
		31	2		
		19	1		K
		3	1		K
		11	2		K
2	57	30	6	1	
		32	13	5	
		33	4		
		35	4		
		29	16	4	
		27	9		
		28	2		
		34	1		
		19	1		K
		25	1		K
7	70	31	6		
		30	5		
		29	30	10	
		32	5	5	
		35	2		
		28	15		
		27	3		
		4	4		H
10	101	30	5		
		29	30		
		32	15		
		35	4		
		31	2		
		27	24		
		28	21		
14	64	29	32		
		30	3	7	
		32	4		
		35	5		
		27	6		
		28	11		
		33	1	1	
		34	1		
		19	1		K

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
18	46	29	19	7	
		30	1		
		32	5		
		35	3		
		33	7		
		27	5		
		28	6		
21	61	30	5		
		32	4		
		33	3		
		29	17	3	
		34	7		
		28	13		
		27	4		
		15	2		N
		4	1		H
		19	3		K
		3	2		K
F. Sediment samples oil and dispersant aquarium.					
0	82	30	6		
		32	25	20	
		29	7	4	
		35	21		
		33	7		
		34	4		
		27	3		
		28	5		
		18	1		N
		19	3		K
1	70	30	8		
		31	7	3	
		29	22	7	
		32	8	8	
		35	4		
		33	2		
		34	2		
		27	5		
		28	8		
		23	1		K,H
		19	2		K
		25	1		K

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
2	83	29	28	12	
		30	6		
		32	11	6	
		33	3		
		35	14		
		28	11		
		27	1		
		34	3		
		19	4		K
		7	2		K
7	126	31	23	23	
		30	1		
		35	3	2	
		32	1	1	
		29	69	15	
		28	16		
		27	2		
		34	2		
		8	9		K
10	85	31	12	3	
		30	3		
		29	47	7	
		32	8	7	
		35	2		
		27	5		
		28	5		
		33	1		
		24	1		H,N
14	105	31	12		
		30	2		
		35	2		
		32	2		
		29	64		
		28	13		
		27	2		
		24	2		
		22	6		
18	115	31	7	2	
		32	4		
		29	89	13	
		28	12		
		27	1		
		17	1		H
		22	1		K

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
21	62	29	34	3	
		32	1		
		34	3		
		28	7		
		27	17		

G. Sediment samples dispersant aquarium.

0	61	30	7		
		32	14	2	
		35	6		
		34	2		
		29	5		
		27	6		
		28	7		
		12	1		N
		19	7		K
1	63	30	7		
		31	2		
		29	14	6	
		32	15	12	
		35	12		
		33	3		
		34	3		
		28	3		
		27	4		
2	no data				
7	217	31	35	27	
		35	3	3	
		29	124	26	
		34	5		
		27	2		
		28	41		
		10	1		N
		4	4		H
		19	6		K
10	238	31	40	26	
		32	4	1	
		30	1		
		29	146	7	
		27	6		
		28	27		
		34	5		

day	total # colonies OZR master	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
		24	1		N,H
		15	1		N
		23	3		
		22	4		
14	76	31	3	3	
		32	4		
		35	1		
		30	3		
		29	54	4	
		27	2		
		28	9		
18	120	31	1		
		29	110	7	
		28	15		
		27	3		
		16	1		H
21	128	31	7	4	
		32	2	2	
		35	4	4	
		29	87	9	
		27	9		
		28	20		

H. Sediment samples control aquarium.

0	36	33	7		
		32	14	5	
		30	1		
		29	7	1	
		27	3		
		13	1		N,H,K
		19	3		K
1	65	31	7		
		30	7	3	
		32	22	11	
		29	8	3	
		27	11		
		33	4		
		28	5		
		13	1		K

day	total # colonies OZR medium	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
2	60	31	15		
		29	11	3	
		32	17	7	
		33	3		
		30	2		
		28	6	3	
		27	4		
		19	2		K
7	217	31	30	2	
		29	104	24	
		34	19	8	
		27	39		
		28	5	3	
		33	1		
		35	8	5	
		5	1		N
		2	2		N
		9	4		N
		14	3		H
		19	1		K
10	231	31	9	2	
		30	7	1	
		29	117	12	
		32	27	3	
		28	33	1	
		27	5		
		33	2		
		34	11		
		35	9		
		14	9		N
		19	2		K
14	121	31	5	1	
		29	65	7	
		32	4	1	
		30	3		
		34	2		
		35	9		
		28	16		
		17	4		H
		27	7		
		22	5		K
18	no data				
21	no data				

I. Surface samples from oil aquarium.

day	total # colonies OZR medium	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
1	95	30	12	8	
		29	15	4	
		27	15		
		28	41		
		32	8	8	
		15	1		N
		12	2		N
		19	1		K
2	153	31	13	13	
		30	7	7	
		29	18	7	
		27	8		
		28	86		
		32	19	8	
		19	2		K
10	110	32	12		
		29	2		
		27	37		
		28	59		
14	35	30	1		
		29	2		
		28	27		
		27	5		
21	73	32	2		
		29	1		
		27	29		
		28	41		

J. Surface samples from oil and dispersant aquarium.

1	50	31	6	2	
		29	11	2	
		30	5	2	
		32	3		
		27	15	2	
		28	8		
		19	2		K

day	total # colonies OZR medium	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
2	149	31	55	40	
		29	35	7	
		30	6	3	
		32	3		
		27	9		
		28	37		
		15	2		N
		24	1		N
		13	1		H
10	75	31	9	3	
		30	1	1	
		29	10	2	
		27	28		
		28	10	8	
		18	3		N
		22	14		K
14	44	31	1		
		29	6	2	
		27	14		
		28	23	7	
21	no data				

K. Surface samples from dispersant aquarium.

day	total # colonies OZR medium	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
1	92	31	10	10	
		29	25	7	
		27	16	4	
		28	15		
		32	6	3	
		30	5		
		2	3		N
		16	4		H
		19	8		K
2	36	31	2		
		32	2		
		30	1		
		29	3		
		27	24		
		28	4		
10	89	31	12		
		29	11		
		27	33	1	
		28	28	1	
		32	3		
		22	2		K

day	total # colonies OZR medium	colony type	# of each colony type	# colonies growing on basal medium	growth on hydrocarbon substrate
14	30	29	2		
		27	9		
		28	19		
21	93	33	5		
		27+28(a)	88		

(a) Too difficult to distinguish between colony type 27 and 29 on this plate; therefore combined the totals.

L. Surface samples from control aquarium.

1	98	27	13	4	
		16	11		H
		28	11		
		29	22	8	
		30	6		
		31	14	14	
		32	14	4	
		24	2		N
		7	1		K
		19	4		K
2	56	31	18	2	
		29	8	4	
		27	19	3	
		28	8		
		30	1		
		32	1	1	
		13	1		H
10	87	29	30		
		31	2		
		28	37		
		27	10		
		32	6		
		12	2		N
14	28	29	5	1	
		27	2	1	
		28	20		
		24	1		N
21	71	29	3		
		27	21	1	
		28	46	1	
		31	2		

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TITL OPEN OCEAN BARRIER NEAR COMPLETION
PUBL OIL AND GAS JOURNAL
CODE 0305R

AUTH ABRAHAMS R.N., MILLER E.R.
TITL OIL SPILL CONTAINMENT SYSTEM DEVELOPMENT AND TESTING PROGRAM
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST A BRIEF REVIEW OF THE CONTAINMENT BARRIER DESIGN FEATURES AND DEVELOPMENT PROGRAM ARE PRESENTED IN THIS PAPER.
KEYW CONTAINMENT, BARRIERS, AIR DELIVERY SYSTEM
CODE 6050F

AUTH ACTON R.
TITL EFFECTS OF OIL POLLUTION AND DISPERSANT USAGE OF THE MARINE ENVIRONMENT WITH REFERENCE TO PACIFIC NORTHWEST AREAS
PUBL CITATION NO. 1/2 - 360-6358
CODE 1105R

AUTH ADAIR J.C.
TITL REDUCES 5000,000 GPD REFINER WASTES TO WATER TO MAXIMUM, OIL CONTENT 15 PPM

PUBL CHEMICAL PROCESSING, CHICAGO
CODE 0475R

AUTH ADAMO L.C., LOVE C.M.
TITL SEASONAL MEAN TRANSPORT OF HYPOTHETICAL OIL SLICKS IN SOUTHERN CALIFORNIA WATERS
PUBL INSTITUTE OF ENVIRONMENTAL SCIENCES
ABST THIS STUDY IS TO INTERPRET AVAILABLE KNOWLEDGE OF THE BEHAVIOR OF OIL SPILLED AT SEA IN TERMS OF THE POTENTIAL TRAJECTORIES OF OIL ACCIDENTALLY RELEASED IN THE AREA NOMINATED FOR THE FEDERAL LEASE-SALE PROGRAM OFFSHORE SOUTHERN CALIFORNIA.
KEYW MEAN WIND AND CURRENT DATA, OIL SLICK MOVEMENT, ALTERATIONS OF A SPILL
CODE 2997F

AUTH ADAMS C.E.
TITL A METHOD FOR THE SEPARATION OF OIL FROM AQUEOUS OIL DETERGENT SOLUTIONS PRIOR TO IR ANALYSIS
PUBL NAVAL ORDINANCE LAB. 8/1974
ABST A PROCEDURE WAS DEVISED TO PERMIT THE ANALYSIS OF OIL IN WATER SOLUTIONS IN THE PRESENCE OF DISSOLVED DETERGENTS USING THE CCL4 EXTRACTION, IR SPECTROPHOTOMETRIC METHOD. THIS PROCEDURE EFFECTIVELY REMOVED ALL THE DETERGENT AND ALLOWED AN INTERFACIAL ANALYSIS OF THE CCL4 - OIL SOLUTION.
KEYW DISSOLVED DETERGENTS, ANALYSIS OF OIL IN WATER, IR SPECTROPHOTOMETRIC METHOD
CODE 2361F

AUTH AGNEW R.
TITL A FREE FLOATING ENDLESS BELT OIL SKIMMER
PUBL EPA, OFFICE OF RESEARCH AND MONITORING, AUG. 1972, EPA-R-72-006
ABST THIS PAPER DISCUSSES RESULTS OF A FREE FLOATING ENDLESS BELT OIL SKIMMER TEST EXPERIMENTS.
KEYW RECOVERY, SKIMMER, OIL PICKUP RATES
CODE 0571F

AUTH AGRAWAL R., HALE L.A.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO.1933, MAY 6-8, 1974
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KEYW BARRIERS, ENTRAINMENT, HEADWAVE
CODE 0534F

AUTH AGRAWAL R.K.
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PUBL PHD DISSERTATION TEXAS A+M UNIV. AUG. 1973
ABST EXPERIMENTAL OBSERVATION CONCERNING THE EFFECTS OF CURRENTS ON AN OIL SLICK RETAINED BY A PHYSICAL BARRIER ARE PRESENTED.
CODE 0456R

AUTH AGRAWAL S., LIN S.P.
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PUBL AICHE JOURNAL, VOL. 21, NO. 3, MAY 1975
ABST IN THIS NOTE THE EIGENVALUE PROBLEM IS SOLVED FOR SPATIALLY GROWING LONG WAVES IN A FILM.
KEYW EIGENVALUE, SPATIALLY GROWING, GROWING DISTURBANCES
CODE 6301F

AUTH AHEARN D.G., MEYERS S.P.
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PUBL WORKSHOP, GEORGIA STATE UNIVERSITY, DEC. 1972
ABST RESEARCH FOR MICROBIAL UTILIZATION OF HYDROCARBONS IS DISCUSSED.
KEYW MICROORGANISMS, BIODEGRADATION, HYDROCARBONS
CODE 2998F

AUTH AHMADJIAN M., BAER C., LYNCH P., BROWN C.
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PUBL ENVIRONMENTAL SCIENCE AND TECH., VOL. 10, NO. 8, AUG. 1976
ABST THE FEASIBILITY OF WEATHERING PETROLEUM IN CONFINED AREAS AND UNDER SIMULATED CONDITIONS WAS EXPLORED.
KEYW WEATHERING PETROLEUM, INFRARED SPECTRA, COMPUTER MATIC METHOD
CODE 2554F

AUTH ALBERTS D.A.
TITL AN ORGANIZATION PLAN FOR MINIMIZING THE DAMAGING EFFECTS OF A MAJOR OIL SPILL
PUBL TEXACO INC. EPA CONFERENCE 1975
ABST INCLUDED IS A TYPICAL LINE DIAGRAM ORGANIZATIONAL CHART BUT STRESSED ARE BASIC CONCEPTS WITH SPECIFIC IMPLEMENTATION DEPENDENT UPON THE ACTUAL SITUATION.
KEYW ORGANIZATION, DAMAGING EFFECTS, ACTUAL SITUATION
CODE 0106R

AUTH ALEXANDER J.E., ALEXANDER E.C.

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PUBL MESA NEW YORK BIGHT ATLAS MONOGRAPH 2, N.Y. SEA GRANT INSTITUTE, MARCH 1977 PB 272 326
ABST THIS PAPER DISCUSSES THE LIMITED KNOWLEDGE OF THE CHEMICAL PROPERTIES OF N.Y. BIGHT DUE TO LACK OF RESEARCH.
KEYW TEMPERATURE-SALINITY RELATIONSHIPS, TWO-LAYERED SYSTEM, VERTICALLY HOMOGENOUS SYSTEM
CODE 7608B

AUTH ALEXANDER L.M.
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PUBL URI, DEPT. OF OCEANOGRAPHY, JUNE 1966
ABST THIS STUDY ATTEMPTS TO PROVIDE SOME CRITERIA FOR ANALYZING THE NATURE OF MARINE RESOURCE USE IN ONE COASTAL AREA.
KEYW MARINE USE, RESOURCES, NARRAGANSETT BAY
CODE 0064R

AUTH ALLAN D.
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PUBL DOT/OST, REPORT NO C-76571, CONTRACT NO. DOT 40171
CODE 4032F

AUTH ALLEN A.A.
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PUBL MARCONSULT, INC., SANTA MONICA, CA, SSIE NO. GKP 1251
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AUTH ALLEN A.A., SCHLUETER R.S., FARSAL L.E.
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PUBL PROCEEDINGS OF THE SYMPOSIUM ON TECHNOLOGY FOR THE FUTURE TO CONTROL INDUSTRIAL AND URBAN WASTES.
CODE 2053R

AUTH ALPINE GEOPHYSICAL ASSOCIATES INC.
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PUBL EPA WATER QUALITY OFFICE MAY 1971, PROJECT NO. 15080 FTU, CONTRACT NO. 14-12-860
ABST THIS PAPER DESCRIBES THE RESULTS AND PROGRESS IN THE CONTROL AND ABATEMENT OF POLLUTION IN OUR NATIONS WATERS.
KEYW CASUALTY REPORT, MOVEMENT, CONTROL, CHEMICAL, SURVEILLANCE
CODE 0544F

AUTH ALTMANN R.
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PUBL AIAA/SNAME, ADVANCE MARINE VEHICLES MEETING, NORFOLK, VA., MAY 22-24, 1967, PAPER NO. 67-354
ABST A REPORT ON THE DEVELOPMENT OF THE HYDROFOIL SLED
KEYW DIHEDRAL LADDER HYDROFOILS, SPEEDS AND DISPLACEMENTS, SUBCAVITATING, BASE VENTED, FULLY-VENTILATED
CODE 0512F

AUTH ALYAKUNSAYA I.O.
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PUBL ZOOL VOL. 95, BIO ABSTRACTS VOL. 48
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AUTH AMPAYA J.P., MIKOLAJ P.G.
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PUBL MARINE TECHNOLOGY SOCIETY JOURNAL
CODE 0349R

AUTH AMUNDSEN P.A.
TITL WHO SHOULD OPERATE THE OFFSHORE TERMINALS: WHAT ARE THE OPTIONS?
PUBL UNKNOWN
ABST THIS PAPER DISCUSSES DEEPWATER TERMINAL OPERATIONS AND THE VARIOUS OPTIONS.
KEYW DEEPWATER TERMINALS, DEEP-DRAFT SHIPS, , INDUSTRY/TRADE
CODE 7204F

AUTH ANDERSON C.M.
TITL COST-EFFECTIVENESS ANALYSIS OF LUBRICANT RECLAMATION BY THE NAVY
PUBL NAVAL FACILITIES ENGINEERING COMMAND, CIVIL ENGINEERING LABORATORY, TN NO. N-1481, MAY 1977
ABST THIS REPORT INCLUDES A FORMAT FOR MONETARY, ENERGY, ENVIRONMENTAL ITEMS TO AID PUBLIC WORKS ENGINEERS AND PLANNERS IN DETERMINING THE MOST COST-EFFECTIVE USED OIL DISPOSITION.
KEYW POL, RECYCLING, COST EFFECTIVENESS
CODE 6574F

AUTH ANDERSON E.V.
TITL US SUPERPORT PLANS ADVANCING
PUBL CHEMICAL AND ENGINEERING NEWS
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AUTH ANDERSON J.
TITL LAB STUDIES ON THE EFFECTS OF OIL ON MARINE ORGANISMS - AN OVERVIEW
PUBL TEXAS A AND M UNIV., BIOLOGY DEPT., API NO. 4249, MARCH 1975
ABST THIS REPORT DISCUSSES THE LAB STUDIES AND TESTS.
KEYW OIL WATER MIXTURES, TOXICITY, UPTAKE AND RELEASE OF HYDROCARBONS
CODE 2572F

AUTH ANDERSON J.W., RILEY R.G., BEAN R.M.
TITL RECRUITMENT OF BENTHIC ANIMALS AS A FUNCTION OF PETROLEUM HYDROCARBON CONCENTRATIONS IN THE SEDIMENT
PUBL JOURNAL OF THE FISHERIES, VOL. 35, MAY 1978
ABST THREE FIELD INSTALLATIONS, CONSISTING OF CLEAN AND OILED SEDIMENT IN FIBERGLASS TRAYS, WERE PLACED IN THE INTERTIDAL ZONE OF SEQUIM BAY, WASHINGTON, D.C.
KEYW BENTHIC ORGANISMS, GAS CHROMATOGRAPHY, HYDROCARBONS, SEDIMENT, SPECTROSCOPIC TECHNIQUES
CODE 2669F

AUTH ANDERSON J.W., DIXIT D.B., WARD G.S., FOSTER R.S.
TITL EFFECTS OF PETROLEUM HYDROCARBONS ON THE RATE OF HEART AND HATCHING SUCCESS OF ESTUARINE FISH EMBRYOS
PUBL PHYSIOLOGICAL RESPONSES OF MARINE BIOTA TO POLLUTANTS, ACADEMIC PRESS, 1977
ABST CONTAINS MANY REPORTS ON THE EFFECT OF SALINITY AND TEMPERATURE, SINGLY OR IN COMBINATION ON HATCHING SUCCESS AND ON THE RATE OF EMBRYONIC DEVELOPMENT OF FISH.
KEYW SALINITY, TEMPERATURE, HATCHING SUCCESS
CODE 7601F

AUTH ANDERSON J.W., MALINS D.C.
TITL PHYSIOLOGICAL STRESSES AND RESPONSE IN CHRONICALLY OILED ORGANISMS
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST MICROBIAL DEGRADATION OF OIL, EFFECTS OF OIL SEDIMENTS ON FIELD POPULATIONS, BIOAVAILABILITY OF SEDIMENT-BOUND HYDROCARBONS, TISSUE RETENTION OF HYDROCARBONS, MEANS OF DETERMINING EFFECTS ON BIOTA, RECOMMENDATIONS ARE DISCUSSED.
KEYW MICROBIAL DEGRADATION, OIL SEDIMENTS, FIELD POPULATIONS, BIOAVAILABILITY
CODE 2669F

AUTH ANDERSON J.W., MOORE L.J., BLAYLOCK J.W., WOODRUFF D.L., KIESSER S.L.
TITL BIOAVAILABILITY OF SEDIMENT-SORBED NAPTHALENES TO THE SIPUNCULID WORM, PHASCOLOSOMA AGASSIZII
PUBL ENERGY RESEARCH AND DEVELOPMENT, REPORT NO. BNWL-SA-5864, OCT. 1976
ABST THE SUBJECT OF THIS PAPER CONCERNS BIOAVAILABILITY OF SEDIMENT BOUND NAPTHALENES.
KEYW HYDROCARBONS, MARINE ORGANISMS, DEVELOPMENT OF SENSITIVE ANALYTICAL TECHNIQUES
CODE 2683F

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TITL CHARACTERISTICS OF DISPERSIONS AND WATER-SOLUBLE EXTRACTS OF CRUDE AND REFINED OILS AND THEIR TOXICITY ESTUARINE CRUSTACEANS AND FISH
PUBL MAR. BIOL.
CODE 5054R

AUTH ANDERSON J.W., NEFF J.M.
TITL ACCUMULATION AND RELEASE OF PETROLEUM HYDROCARBONS BY EDIBLE MARINE ANIMALS
PUBL WORLD HEALTH ORGANIZATION AND THE COMMISSION OF THE EUROPEAN COMMUNITIES, JUNE 1974
ABST SUBMITTED TO A SYMPOSIUM: RECENT ADVANCES IN THE ASSESSMENT OF THE HEALTH EFFECTS OF ENVIRONMENTAL POLLUTION, SPONSORED BY THE USEPA.
CODE 5000R

AUTH ANDERSON R.D.
TITL PETROLEUM HYDROCARBONS AND OYSTER RESOURCES OF GALVESTON BAY, TX
PUBL VIRGINIA INSTITUTE OF MARINE SCIENCE, FOR EPA CONFERENCE 1975
ABST FIELD AND LAB STUDIES OF PETROLEUM HYDROCARBONS IN THE TISSUE OF THE AMERICAN OYSTER ARE DISCUSSED.
KEYW HYDROCARBONS, OYSTER RESOURCES, GALVESTON BAY (TEX.)
CODE 0146R

AUTH ANDRIAU A.
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PUBL HAZARDS OF MARITIME TRANSIT, BALLINGER PUBLISHING CO., 1973
ABST DISCUSSES SUCH THINGS AS IMCO, FEDERAL REGULATIONS FOR TANKER SAFETY, AND INCLUDES A TABLE OF INTERNATIONAL MEASURES FOR PREVENTING POLLUTION OF THE SEA.
CODE 3106H

AUTH ANONYMOUS
TITL A.P.O.A. REVIEW
PUBL A PUBLICATION OF THE ARCTIC PETROLEUM OPERATORS ASSOCIATION, PUBLIC INFORMATION COMMITTEE, CALGARY, ALASKA
ABST VARIOUS ARTICLES - MONTHLY PUBLICATION
KEYW ARCTIC
CODE 7690F

AUTH ANONYMOUS
TITL ACTA OCEANOGRAPHICA TAIWANICA - SCIENCE REPORTS OF THE NATIONAL TAIWAN UNIV. DECEMBER 1978
PUBL INSTITUTE OF OCEANOGRAPHY, COLLEGE OF SCIENCE, NATIONAL TAIWAN UNIVERSITY, TAIPEI, TAIWAN, REP. OF CHINA
ABST COLLOQUIUM ON RESEARCH AND DEVELOPMENT OF MARINE RESOURCES IN AREAS ADJACENT TO TAIWAN HELD AT THE INSTITUTE OF OCEANOGRAPHY, NATIONAL TAIWAN UNIVERSITY JULY 3-5, 1978. PAPERS INCLUDE, "HYDROCARBONS IN THE SURFACE SEDIMENTS OF NORTH TAIWAN STRAIT" BY WEI-LIN JENG, "A NEW METHOD FOR TIDAL CURRENT PREDICTION" BY FUH YIN AND "THE OCCURRENCE AND CHARACTERISTICS OF MICROBIAL INDICATORS IN THE ESTUARINE ECOSYSTEM OF TA-TU CHI OF TAIWAN" BY L. P. LIN, H. P. LIN AND Y. C. CHENG.
KEYW TIDAL CURRENT PREDICTION, ECOSYSTEM, TAIWAN, HYDROCARBONS, SURFACE SEDIMENTS
CODE 7750F

AUTH ANONYMOUS
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PUBL INSTITUTE OF OCEANOGRAPHY, COLLEGE OF SCIENCE, NATIONAL TAIWAN UNIVERSITY, TAIPEI, TAIWAN, REP. OF CHINA
ABST VOLUME NO. 9, FEBRUARY 1979, INCLUDES PAPER "ON UPWELLING OFF THE PENG-HU ISLAND" BY KUANG-LUNG FAN.
KEYW MAGNETIC MEASUREMENTS, MICROBIOLOGICAL STUDIES, TAIWAN, CIRCULATION
CODE 7751F

AUTH ANONYMOUS
TITL AEROSOL MEASUREMENTS
PUBL ANALYTICAL CHEMISTRY DIVISION INSTITUTE FOR MATERIALS RESEARCH, NATIONAL BUREAU OF STANDARDS
ABST PAPERS FOLLOWED BY VERBAL DISCUSSIONS WERE GIVEN

IN A SEMINAR & WORKSHOP SPONSORED BY THE NATIONAL BUREAU OF STANDARDS & THE FOOD AND DRUG ADMINISTRATION TO DEFINE THE STATE OF DEVELOPMENT OF AEROSOL MEASURING INSTRUMENTS. THE INSTRUMENTS DISCUSSED WERE BASED UPON A VARIETY OF OPERATING PRINCIPLES INCLUDING LASER LIGHT SCATTERING OPTICAL IMAGING, DOPPLER SHIFT, ELECTROMOBILITY, PIEZOELECTRIC EFFECT, AND BETA-RAY ABSORPTION.
KEYW AEROSOL INSTRUMENT PERFORMANCE, AEROSOL MEASURING INSTRUMENTS, BETA-RAY ABSORPTION
CODE 7736F

AUTH ANONYMOUS
TITL THE AMOCO CADIZ OIL SPILL
PUBL NOAA/EPA SPECIAL REPORT
ABST THIS REPORT IS A PRELIMINARY US CONTRIBUTION TO THE STUDY OF THE AMOCO CADIZ OIL SPILL.
KEYW TANKERS, ACCIDENTS, AMOCO CADIZ
CODE 7606D

AUTH ANONYMOUS
TITL ANALYSIS AND REDESIGN OF TOWPOINT OF THE ADAPTS NO. 2 PROTOTYPE OIL STORAGE CONTAINER
PUBL UNIROYAL INC.
CODE 0162A

AUTH ANONYMOUS
TITL ANALYSIS OF INLAND WATER WAYS OIL TRANSPORT TRAFFIC DENSITY PATTERNS
PUBL BATTELLE COLUMBUS, SEPT. 1973
KEYW INLAND WATERWAYS, OIL TRANSPORT, TRAFFIC DENSITY
CODE 0201A

AUTH ANONYMOUS
TITL ANALYSIS OF LIGHTWEIGHT OIL CONTAINMENT SYSTEM SEA TRIALS
PUBL HYDRONAUTICS INC., 10/73, AD 770 344
CODE 0176A

AUTH ANONYMOUS
TITL ANALYSIS OF OIL DAMAGE COMPENSATION ACT
PUBL 92ND CONGRESS, SEPT. 21, 1972
ABST SECTION BY SECTION ANALYSIS OF PROPOSED ACT CONCERNING COMPENSATION FOR OIL POLLUTION DAMAGE.
CODE 6065F

AUTH ANONYMOUS
TITL ANALYSIS REDESIGN OF TOWPOINT OF THE ADAPTS NO. 2 PROTOTYPE OIL STORAGE CONTAINER
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 714101/009
CODE 0746A

AUTH ANONYMOUS
TITL ANALYTICAL INSTRUMENT CORP. - EQUIPMENT SPECS.
PUBL ANALYTICAL INSTRUMENT CORP. HOUSTON, TX
ABST DESIGN FEATURES AND SPECIFICATIONS
KEYW PROCESS CHROMATOGRAPHS, AUTOMATIC SAMPLING SYSTEM, ON-STREAM ANALYZERS
CODE 4009D

AUTH ANONYMOUS
TITL ANOTHER VIEW OF OFFSHORE OIL AND GAS OPERATIONS
PUBL NATIONAL ACADEMY OF SCIENCES, MARINE TECHNOLOGY SOCIETY JOURNAL
CODE 0336A

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TITL APPENDICES TO SURVEY STUDY TO SELECT A LIMITED NUMBER OF HAZARDOUS MATERIALS TO DEFINE AMELIORATION REQUIREMENTS, VOL. II
PUBL USCG, MARCH 1974, ADA 004312
CODE 0257A

AUTH ANONYMOUS
TITL APPLICABILITY OF REMOTE SENSOR TECHNIQUES FOR OIL SLICK DETECTION
PUBL USCG, FEB. 1971, AD 720 622
CODE 0216A

AUTH ANONYMOUS
TITL ARGO MERCHANT SPILL
PUBL UNKNOWN
ABST VARIOUS NEWSPAPER ARTICLES
KEYW NEWSPAPER ARTICLES, ARGO MERCHANT, OIL SPILL
CODE 6182B

AUTH ANONYMOUS
TITL AT-SEA TESTING OF A HIGH SEAS OIL RECOVERY SYSTEM
PUBL USCG
KEYW TESTING, HIGH SEAS, RECOVERY
CODE 0236A

AUTH ANONYMOUS
TITL BACKGROUND PAPERS FOR A WORKSHOP ON INPUTS, FATES AND EFFECTS OF PETROLEUM IN THE MARINE ENVIRONMENT
PUBL NATIONAL ACADEMY OF SCIENCES, MAY 1973, AD 783989
ABST INPUTS, CHEMICAL TECH, BIO. TECH., PHYSICAL CHEMICAL AND BIOLOGICAL FATES
CODE 6105A

AUTH ANONYMOUS
TITL BACTERIA HELP CLEAN UP OIL SPILL
PUBL OCEAN INDUSTRY, APRIL 1978
ABST THIS PAPER DISCUSSES THE CLEAN UP OF OIL SPILLS WITH MOSCUR.
KEYW OIL EATING BACTERIA, NUTRIENTS, CLEANUP
CODE 2655F

AUTH ANONYMOUS
TITL BARGE SLIP RETAINER BOOM ELIMINATES OIL SPILLS
PUBL ELECTRIC WORLD, 181(11):47
CODE 2001A

AUTH ANONYMOUS
TITL BATTELLE WATER SPRAY BOOM
PUBL OIL SPILL CONTAINMENT AND REMOVAL SYSTEMS - A FEASIBILITY STUDY, APPENDIX D AIRESEARCH MANUFACTURING CO. 1970
KEYW OIL SPILL CONTAINMENT, REMOVAL
CODE 2023H

AUTH ANONYMOUS
TITL THE BATTLE AGAINST OIL POLLUTION AT SEA
PUBL TRADE AND INDUSTRY, JULY 1973
ABST DESCRIBES THE CAUSES AND EFFECTS OF OIL POLLUTION AT SEA, THE ORGANIZATION, BOTH NATIONAL AND INTERNATIONAL, WHICH HAS BEEN SET UP TO DEAL WITH IT AND THE RESEARCH TAKING PLACE.
KEYW TANKERS, SKIMMERS, DISPERSANTS
CODE 6191F

AUTH ANONYMOUS
TITL BIENNIAL REVIEW 1975-1976
PUBL BEDFORD INSTITUTE OF OCEANOGRAPHY
ABST THIS CARRIES ON A POLICY OF 10 YEARS STANDING TO MAKE AVAILABLE AN OVERVIEW OF THE ACTIVITIES OF THE INSTITUTE IN A SINGLE PUBLICATION AT 2 YEAR INTERVALS.
KEYW BIENNIAL REVIEW, ACTIVITIES, BEDFORD INSTITUTE
CODE 7675F

AUTH ANONYMOUS
TITL BIOASSAY PROCEDURES FOR THE EVALUATION OF ACUTE TOXICITIES OF OILS AND OIL DISPERSANTS TO SMALL MARINE TELEOSTS AND MACROINVERTEBRATES
PUBL UNKNOWN
ABST THIS PAPER DISCUSSES THE PROCEDURES NECESSARY TO TEST ORGANISMS TO PRODUCE RESULTS TO BE COMPARED.
KEYW BIOASSAY PROCEDURES, TOXICITIES, DISPERSANTS
CODE 6503F

AUTH ANONYMOUS
TITL BIOLOGICAL AND OCEANOGRAPHICAL SURVEY OF THE SANTA BARBARA CHANNEL OIL SPILL 1969-70, VOL. I: BIOLOGY AND BACTERIOLOGY; VOL. II: PHYSICAL CHEMICAL AND GEOLOGICAL STUDIES
PUBL ALLAN HANCOCK FOUNDATION, UNIV. OF SO. CAL., SEA GRANT PUBLICATION NO. 2, 1971, VOL. 1 AND 2

CODE 5021A

AUTH ANONYMOUS
TITL BOOM BUSTS OIL SPILL
PUBL WATER AND WASTES ENG., 11(3):55
CODE 2000A

AUTH ANONYMOUS
TITL THE BRAVO BLOW OUT
PUBL INSTITUTE OF MARINE RESEARCH
ABST A REPORT ON MARINE RESEARCH ACTIVITIES APRIL 23 - MAY 5, 1977 INCLUDING SOME PRELIMINARY RESULTS.
KEYW BLOW OUT, RESEARCH ACTIVITIES, RESULTS
CODE 7111F

AUTH ANONYMOUS
TITL THE BRAVO BLOWOUT-IKU REPORT NO. 90
PUBL NORWEGIAN INFORMATION PUBLISHERS A/S SEPTEMBER 1977
ABST A COMPENDIUM OF THE INVESTIGATIONS, ANALYSES, AND EVALUATIONS ORGANIZED BY THE CONTINENTAL SHELF INSTITUTION IN CONNECTION WITH THE BRAVO BLOWOUT AT THE END OF APRIL 1977. PART 1 GIVES A SHORT SUMMARY OF THE RESULTS OF THE INVESTIGATIONS, SOME THOUGHTS OF A CRISES PLAN. PART 2 IS A DETAILED REPORT OF THE INVESTIGATIONS, ANALYSES AND ASSUMPTION OF WHICH THE WORK AND ITS RESULTS ARE BASED.
KEYW BRAVO, OIL SPILL, ANALYSES, FIELD OBSERVATIONS, CRISES PLAN
CODE 7112 F

AUTH ANONYMOUS
TITL BRIEF ON NORTH SEA OIL
PUBL REFERENCE UNIT, SCOTTISH INFORMATION OFFICE, NO. 1974
ABST THIS FOLDER HAS BEEN PRODUCED AS A CONVENIENT REFERENCE TO SIGNIFICANT DEVELOPMENTS WHICH HAVE FOLLOWED THE DISCOVERY OF OIL OFF THE NORTH SEA COAST OF SCOTLAND AND IN PARTICULAR TO THE PART PLAYED BY THE SCOTTISH OFFICE
KEYW DEVELOPMENT AND DISCOVERY, ECONOMIC AND PHYSICAL PLANNING, NORTH SEA COAST
CODE 2912F

AUTH ANONYMOUS
TITL CENTER FOR SHORT LIVED PHENOMENA
PUBL 1974 ANNUAL REPORT AND REVIEW OF EVENTS, DEC. 1975
ABST THIS VOLUNTEER BASED, INTERNATIONAL PROGRAM MONITORS DIVERSE EVENTS AND THESE ARE RECORDED HERE.
KEYW EARTHQUAKES,ERUPTIONS, METEORITE FALLS, OIL SPILLS, ANIMAL MIGRATIONS AND INFESTATIONS

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CODE  4024E

AUTH  ANONYMOUS
TITL  CHANGES ON THE DIFFERENTIATION OF THE SEA URCHIN
      LARVA BY ACTION OF A DETERGENT UPON THE
      UNSEGMENTED EGG
PUBL  EXPERIENTIA 24/8 SPECIALIA PP1022-1023
ABST  THIS PAPER DISCUSSES THE EFFECTS OF CHEMICAL
      DISPERSANTS ON THE SEA URCHIN LARVA.
KEYW  SEA URCHIN, DISPERSANTS, DIFFERENTIATION
CODE  7120F

AUTH  ANONYMOUS
TITL  CHARACTERISTICS OF THE AREA IN WHICH FAST CURRENT
      OIL CONTROL IS NEEDED
PUBL  USCG, NO. ADA 000 452, NOV. 1973
CODE  0200F

AUTH  ANONYMOUS
TITL  CHEMICAL ADDITIVES TO CONTROL OIL SPILLS - A
      STATE-OF-THE-ART SURVEY
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. CG-D-65-74
CODE  0783P

AUTH  ANONYMOUS
TITL  CHEMICAL ADDITIVES TO CONTROL OIL SPILLS A STATE
      OF THE ART SURVEY
PUBL  RENSSELEA POLYTECHNIC INSTITUTE, JAN. 1974, AD 770
      557
KEYW  CHEMICAL ADDITIVES, CONTROL
CODE  0198R

AUTH  ANONYMOUS
TITL  CHEMICAL ADDITIVES TO CONTROL OIL SPILLS'A
      STATE-OF-THE-ART SURVEY
PUBL  USCG, AD 776 557
KEYW  CHEMICAL ADDITIVES, CONTROL
CODE  0196R

AUTH  ANONYMOUS
TITL  CHEMICAL AGENT USE FOR OIL SPILL CONTROL -
      SUPPLEMENT
PUBL  ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION,
      DIVISION OF ENVIRONMENTAL CONTROL TECHNOLOGY
ABST  DISCUSSES THE OBJECTIVES OF A STUDY TO REDUCE THE
      OVERALL ENVIRONMENTAL IMPACT FROM OIL SPILLS
      THROUGH THE PROPER USE OF CHEMICAL AGENTS.
KEYW  CHEMICAL AGENTS, DISPERSANTS, ENVIRONMENTAL
      IMPACT, REDUCTION
CODE  9081F

AUTH  ANONYMOUS
TITL  CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM
      PROJECT PRELIMINARY SYSTEM PLAN
PUBL  A.D. LITTLE MAY 1972
CODE  0235F

AUTH  ANONYMOUS
TITL  CHEMICAL TREATMENT OF OIL SLICKS
PUBL  EDISON WATER QUALITY LAB., NORTHWEST REGION
ABST  THE EFFECTIVENESS AND POTENTIAL POLLUTIONAL
      EFFECTS OF CHEMICALS AND OTHER MATERIALS USED TO
      DISPERSE, SINK, BURN, OR OTHERWISE DISSIPATE OIL
      SLICKS ARE DISCUSSED.
KEYW  CHEMICAL TREATMENT, DISPERSION, SINKING.
CODE  0044R

AUTH  ANONYMOUS
TITL  CHEMICALS  VS. CRUDE OIL
PUBL  CHEMICAL WEEK, MAY 20, 1967, URI, V.37
CODE  5020R

AUTH  ANONYMOUS
TITL  CIRCULATOR BATHS
PUBL  BATH CIRCULATORS AND CONTROLLERS CATALOG,
      COLE-PARMER/CHICAGO
ABST  VARIOUS TYPES OF CIRCULATOR BATHS ARE OFFERED.
KEYW  CATALOG, CIRCULATOR BATHS, CONTROLLERS
CODE  7002F

AUTH  ANONYMOUS
TITL  CIVIL LIBERTIES FOR OIL POLLUTION DAMAGE
      INTERNATIONAL CONVENTION
PUBL  IMCO JULY 1970
ABST  IMCO CIVIL LIBERTIES CONVENTION, HEARINGS BEFORE
      SUB COMMITTEE ON AIR AND WATER POLLUTION, 1ST
      1045
CODE  6013P

AUTH  ANONYMOUS
TITL  CLEAN UP EQUIPMENT FOR SPILLS IS ARRAYED FOR
      IMMEDIATE USE IN GULF OF MEXICO
PUBL  OFFSHORE TECHNOLOGY
CODE  0319R

AUTH  ANONYMOUS
TITL  CLEANING OIL CONTAMINATED BEACHES WITH CHEMICALS
PUBL  NORTHEAST REGION RESEARCH AND DEVELOPMENT PROGRAM,
      NO. 15080FHS 08/69, AUG.1969
ABST  A STUDY OF THE EFFECTS OF CLEANING OIL
      CONTAMINATED BEACHES WITH CHEMICAL DISPERSANTS.
KEYW  DISPERSANTS, CLEANUP, EROSION, COHESIVENESS
CODE  2924F

AUTH  ANONYMOUS
TITL  CLEANING UP OIL SPILLS - SPEED COUNTS MOST
PUBL  NEW ENGLAND RESOURCES INFORMATION, URI, MAY 1970
ABST  THIS ARTICLE DEALS WITH THE FIRM OF COASTAL
      SERVICES, INC. AND THEIR OPERATIONS AND PROCEDURES
      WHEN THEY GET A CALL FOR OIL SPILL CLEAN-UP. THEY
      ARE A GROUP WHICH OPERATES 24 HOURS A DAY AND DEAL
      MAINLY WITH EMERGENCIES.
KEYW  CLEANUP, OPERATIONS, PROCEDURES
CODE  3024R

AUTH  ANONYMOUS
TITL  CLEANING UP OIL SPILLS ISN'T SIMPLE
PUBL  ENVIRONMENTAL SCIENCE AND TECHNOLOGY SERIES
CODE  0461R

AUTH  ANONYMOUS
TITL  CLEANUP PLAN FOR OIL SPILLAGE
PUBL  DOCK AND HARBOR AUTHORITY
CODE  0420R

AUTH  ANONYMOUS
TITL  COASTAL EFFECTS OF OFFSHORE ENERGY DEVELOPMENT:
      OIL AND GAS SYSTEMS
PUBL  ENERGY RESEARCH AND DEVELOPMENT, MARCH 16, 1976,
      ADMINISTRATION LIBRARY, PREPARED BY THE OFFICE OF
      TECHNOLOGY ASSESSMENT
ABST  ANALYSIS OF COASTAL EFFECTS AND CONSEQUENCES FOR
      N.J. AND DEL. OF 3 PROPOSED OFFSHORE ENERGY
      SYSTEMS.
KEYW  OFFSHORE ENERGY SYSTEMS, DEVELOPMENT, CONSTRUCTION
CODE  7679F

AUTH  ANONYMOUS
TITL  COASTAL EFFECTS OF OFFSHORE ENERGY SYSTEMS OIL AND
      GAS DEEPWATER PORTS, AND FLOATING NUCLEAR
      POWERPLANTS
PUBL  US CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, NOV.
      1976
ABST  AN ASSESSMENT OF OIL AND GAS SYSTEMS, DEEPWATER
      PORTS AND NUCLEAR POWERPLANTS OFF THE COAST OF NEW
      JERSEY AND DELAWARE.
KEYW  OIL AND GAS SYSTEMS, DEEPWATER PORTS, FLOATING
      NUCLEAR POWER PLANTS
CODE  7175a, A,B

AUTH  ANONYMOUS
TITL  COASTAL SERVICES
PUBL  COASTAL SERVICES
ABST  THE BROCHURE DETAILS THE SCOPE OF THE CS IN
      FIGHTING OIL SPILLS AND THE SERVICES AND TESTED
      EQUIPMENT AVAILABLE FROM CS.
CODE  3054R

AUTH  ANONYMOUS
TITL  COLLECTION, UNDERWATER STORAGE, AND DISPOSAL OF
      PLEASURECRAFT WASTES
PUBL  FEDERAL WATER POLLUTION CONTROL ADMINISTRATION,
      PROGRAM NO. 15020, SEPT. 1969
ABST  THE PROJECT DEMONSTRATED THAT ON-BOARD STORAGE OF
      WATER CRAFT WASTE AND SUBSEQUENT DISCHARGE INTO AN
      UNDERWATER STORAGE TANK WAS EFFECTIVE AND
      ECONOMICAL. THIS PROJECT SHOWED THAT THE DISCHARGE
      OF SEWAGE FROM BOATS INTO RIVERS, LAKES,
      WATERWAYS, AND ESTUARIES COULD BE ELIMINATED.
CODE  3053R

AUTH  ANONYMOUS
TITL  COMPENSATION FOR OIL POLLUTION DAMAGE
PUBL  93RD CONGRESS, HR 4396, FEB. 1973
ABST  SECTION BY SECTION ANALYSIS OF PROPOSED ACT
      CONCERNING COMPENSATION FOR OIL POLLUTION DAMAGE.
CODE  6077A

AUTH  ANONYMOUS
TITL  COMPUTER EVALUATES COST OF NORTH SEA BLOWOUT OIL
      SPILL
PUBL  OCEAN INDUSTRY JUNE 1978
ABST  ARTICLE DISCUSSES CALCULATIONS OF COST OF BLOWOUT.
KEYW  BLOWOUT, PIPE LINE RUPTURE, STORAGE TANK RUPTURE,
      COST
CODE  7653F

AUTH  ANONYMOUS
TITL  COMPUTERIZED BIBLIOGRAPHIC LIBRARY SEARCH
PUBL  ENGINEERING INDEX, OCEAN ABSTRACTS, NTIS
CODE  2116F

AUTH  ANONYMOUS
TITL  CONCEPT DEVELOPMENT OF A FREE VORTEX OIL RECOVERY
      SYSTEM
PUBL  SCIENTIFIC ASSOCIATES, MAY 1973, AD 777 024
CODE  0166R

AUTH  ANONYMOUS
TITL  CONCEPT DEVELOPMENT OF A HEAVY DUTY OIL
      CONTAINMENT SYSTEM FOR USE IN THE HIGH SEAS VOL.I
PUBL  ATLANTIC RESEARCH CORP. AD 719 615
CODE  0174R

AUTH  ANONYMOUS
TITL  CONCEPT DEVELOPMENT OF A HYDRAULIC SKIMMER SYSTEM
      FOR RECOVERY OF FLOATING OIL
PUBL  EPA, PROJECT NO. 15080FWP, CONTRACT NO. 14-12-884,
      APRIL 1971
ABST  EXPERIMENTAL WORK WAS DIRECTED TOWARD COMPONENT
      DEVELOPMENT AND EVALUATION OF A LARGE SYSTEM MODEL
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     IN A SIMULATED ENVIRONMENT. OTHER EQUIPMENT SUCH
     AS AN ULTRASONIC OIL THICKNESS GAUGE, PROCESS
     PUMPS AND TANKAGE WERE ALSO USED.
KEYW RECOVERY, SKIMMERS, ULTRASONIC THICKNESS GAUGED
CODE 0052A

AUTH ANONYMOUS
TITL CONCEPT DEVELOPMENT OF A PROTOTYPE LIGHTWEIGHT OIL
     CONTAINMENT SYSTEM FOR USE ON HIGH SEAS
PUBL JOHNS-MANSVILLE PRODUCTS CORP. AD 723 601
CODE 0172A

AUTH ANONYMOUS
TITL THE CONDUCT OF A FEASIBILITY STUDY OF THE INVERTED
     WEIR OIL COLLECTION CONCEPT
PUBL BATTELLE MEMORIAL INSTITUTE
CODE 0189F

AUTH ANONYMOUS
TITL CONSORTIUM ON SPILL TRAINING
PUBL PETROLEUM ASSOCIATION FOR THE CONSERVATION OF THE
     CANADIAN ENVIRONMENT (PACE) MAY 1977
ABST LISTS INFORMATION, FILMS AVAILABLE, TRAINING
     MATERIALS TO IMPROVE RESPONSE CAPABILITIES WITHIN
     OIL INDUSTRY AND GOVERNMENT. REPRESENTATIVES FROM
     THE PETROLEUM ASSOCIATION FOR THE CONSERVATION OF
     THE CANADIAN ENVIRONMENT, THE ONTARIO MINISTRY OF
     THE ENVIRONMENT, THE CANADIAN COAST GUARD & THE
     FEDERAL DEPARTMENT OF FISHERIES AND THE
     ENVIRONMENT REVIEWED SOME OF THE REQUIREMENTS FOR
     SPILL TRAINING PEOPLE IN CANADA, IN INDUSTRY AND
     GOVERNMENT.
KEYW OIL SPILL, CONTINGENCY GUIDELINES, CLEAN-UP
CODE 7733F

AUTH ANONYMOUS
TITL CONTINGENCY PLANNING GUIDELINES
PUBL CONSORTIUM ON SPILL TRAINING  PETROLEUM
     ASSOCIATION FOR THE CONSERVATION OF THE CANADIAN
     ENVIRONMENT  FEBRUARY 1975
ABST THE CONTINGENCY PLANNING GUIDELINES WERE DEVELOPED
     BY A SUB COMMITTEE OF THE CONSORTIUM ON SPILL
     TRAINING TO IDENTIFY PERTINENT CONSTITUENTS OF A
     CONTINGENCY PLAN.  THE GUIDELINES WILL ASSIST IN
     THE PREPARATION OF SPECIFIC CONTINGENCY PLANS FOR
     SPILLS OF OIL AND OTHER HAZARDOUS MATERIALS.
KEYW CONTINGENCY GUIDELINES, OIL SPILL, CLEAN-UP
CODE 7734F

AUTH ANONYMOUS
TITL CONTINUATION PROPOSAL TO EPA GRANT R 803902010, A
     FACILITY FOR THE EXPERIMENTAL ANALYSIS OF COASTAL
     MARINE ECOSYSTEMS
PUBL URI, GSO
ABST CONTINUATION OF PROGRESS REPORT COVERING
     PERFORMANCE OF EXPERIMENTAL ECOSYSTEMS SIMULATING
     A VARIETY OF MARINE ENVIRONMENTS.
KEYW MESO-SCALES, ECOSYSTEMS, COASTLINE MARINE
     ENVIRONMENT
CODE 7663AF

AUTH ANONYMOUS
TITL CONTROL AND CONFINEMENT OF OIL POLLUTION ON THE
     WATER WITH MONOMOLECULAR SURFACE FILMS
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
     NO. 724110.1/4.1, NO. 1971
CODE 0780A

AUTH ANONYMOUS
TITL CONTROL OF HAZARDOUS MATERIAL SPILLS
PUBL PROCEEDINGS OF THE 1972 NATIONAL CONFERENCE ON
     CONTROL OF HAZARDOUS SPILLS, ENVIRONMENTAL SOURCE,
     SER. VOL. 1, EPA
ABST PERTAINS TO ALL PHASES OF OIL SPILL CONTROL,
     PREVENTION, AND CLEANUP.
KEYW PREVENTION, CLEANUP, CONTROL
CODE 0059A

AUTH ANONYMOUS
TITL CONTROL OF HAZARDOUS MATERIAL SPILLS  VOL. 1
PUBL ENVIRONMENTAL PROTECTION AGENCY
ABST PROCEEDINGS OF THE 1972 NATIONAL CONFERENCE ON
     CONTROL OF HAZARDOUS MATERIAL SPILLS
KEYW CONTROL SYSTEMS, SPILLS, PREVENTION, RESTORATION
CODE 7769F

AUTH ANONYMOUS
TITL CONTROL OF OIL AND OTHER HAZARDOUS MATERIALS
PUBL EPA, OFFICE OF WATER PROGRAMS
ABST TOPICS DISCUSSED: TANKERS, OFFSHORE DRILLING, OIL
     SPILL PREVENTION, CONTROL AND TREATMENT.
KEYW TANKERS, OFFSHORE DRILLING, PREVENTION, TREATMENT
CODE 0023B

AUTH ANONYMOUS
TITL COOPERATIVE HURRICANE REPORTING NETWORK
     OBSERVATIONS
PUBL US DEPT. OF COMMERCE, WEATHER BUREAU
CODE 2952B

AUTH ANONYMOUS
TITL A COORDINATED SPILL RESPONSE SYSTEM FOR MAJOR
     HARBORS
PUBL CLEAN VENTURE
ABST THIS PAPER DESCRIBES THE NATURE OF THE CAPABILITY
     AVAILABLE FROM CLEAN VENTURE AND ILLUSTRATES A
     METHOD BY WHICH THAT CAPABILITY CAN BE APPLIED IN
     A PARTICULAR AREA, NEW YORK HARBOR.
KEYW SPILL RESPONSE SYSTEM, CLEAN VENTURE, NEW YORK
     HARBOR
CODE 6201B

AUTH ANONYMOUS
TITL CRC PRESS REVIEW
PUBL CRC PRESS INC.
ABST CATALOG - CRC COMPOSITE INDEX FOR CRC HANDBOOKS
KEYW CATALOG, INDEX HANDBOOKS
CODE 7670F

AUTH ANONYMOUS
TITL CRUDE OIL BEHAVIOR ON ARCTIC WINTER ICE
PUBL USCG, AD 754 261, SEPT. 1971
KEYW OIL BEHAVIOR, ARCTIC WINTER ICE
CODE 0194B

AUTH ANONYMOUS
TITL CRUDE OIL TRANSPORTATION SYSTEM VALDEZ, ALASKA TO
     MIDLAND, TX (AS PROPOSED BY SOHIO TRANSPORTATION
     CO.)
PUBL US DEPT. OF THE INTERIOR, BUREAU OF LAND
     MANAGEMENT, CHAPTER 2, VOL. 1,2,3 CHAPTERS 3-9
ABST THIS IS A DRAFT ENVIRONMENTAL IMPACT STATEMENT.
KEYW OIL TRANSPORTATION, ALASKA, ENVIRONMENTAL IMPACT
CODE 70006 ABCC

AUTH ANONYMOUS
TITL CRUDE TANKER POLLUTION ABATEMENT
PUBL EXXON CORP., APRIL 1976
ABST OUTLINES GOALS OF "INTERNATIONAL CONVENTION FOR
     THE PREVENTION OF POLLUTION FROM SHIPS, 1973".
KEYW CRUDE WASHING, LOAD ON TOP, SEGREGATED BALLAST
     RETROFIT, REDUCTION OF OPERATIONAL DISCHARGES,
     IMPROVED LOAD ON TOP SYSTEMS
CODE 2954F

AUTH ANONYMOUS
TITL CURRENT EPA RESEARCH PROJECTS
PUBL HAZARDOUS MATERIALS SPILLS RESEARCH NEWSLETTER,
     FEB. 1972
ABST INDEX OF CURRENT EPA PROJECTS.
CODE 3044A

AUTH ANONYMOUS
TITL DEEPWATER PORTS
PUBL H.R. REPORT NO. 668, 93RD CONGRESS 1ST SESSION
CODE 0477A

AUTH ANONYMOUS
TITL A DESCRIPTION OF THE ENVIRONMENTAL PREDICTION
     RESEARCH FACILITY HYDRODYNAMICAL-NUMERICAL MODEL,
     APPENDICES
PUBL EPA LAB., AD 745760
CODE 0411A

AUTH ANONYMOUS
TITL DESIGN AND DEVELOPMENT OF AN OPTIMUM OIL STORAGE
     CONTAINER FROM THE AIR DELIVERABLE ANTI-POLLUTION
     TRANSFER SYSTEM - ADAPTS.
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
     NO. 714101/6/002
CODE 0743B

AUTH ANONYMOUS
TITL DETERGENTS IN WATER, A BIBLIOGRAPHY
PUBL OFFICE OF WATER RESOURCES RESEARCH, REPORT NO.
     WASIC 71-214, DEC. 1971
ABST A COMPILATION OF 242 ABSTRACTS IS PRESENTED
     DEALING WITH DETERGENTS IN WATER
KEYW DETERGENTS, CHEMICAL WASTES, ENVIRONMENTAL EFFECTS
CODE 2521F

AUTH ANONYMOUS
TITL DETERMINATION OF OIL LOSS RATE FROM HIGH SEAS OIL
     CONTAINMENT BARRIER
PUBL USCG, AD 762 339
CODE 0165F

AUTH ANONYMOUS
TITL THE DETERMINATION OF OIL SLICK THICKNESS BY MEANS
     OF MULTIFREQUENCY PASSIVE MICROWAVE TECHNIQUES
PUBL USCG, ADA 001302
KEYW THICKNESS, MULTIFREQUENCY PASSIVE MICROWAVES
CODE 0247H

AUTH ANONYMOUS
TITL DETERMINATION OF THE LEEWAY OF OIL SLICKS
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
     NO. CG-D-75
CODE 2066A

AUTH ANONYMOUS
TITL DETERMINE PHYSICAL PARAMETERS WHICH AFFECT OIL
     SPILL CONTAINMENT
PUBL US EPA SSIE NO. 2HA-778
CODE 0355B

AUTH ANONYMOUS
TITL DEVELOPMENT OF  A HIGH SEAS OIL RECOVERY SYSTEM,
     PHASE II PROTOTYPE DESIGN, FABRICATION AND TESTING
PUBL USCG, AD A003533
KEYW HIGH SEAS, RECOVERY, DESIGN, FABRICATION, TESTING
CODE 0238A
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AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A FLOATING OIL SLICK DETECTOR
PUBL  UHS RESEARCH, NO. 1973
CODE  0218H

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A HIGH SEAS OIL RECOVERY SYSTEM
PUBL  OCEAN SYSTEMS INC. FEB. 1972, AD 759 523 AND AD
      759 524
CODE  0183H

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A HIGH SEAS OIL RECOVERY SYSTEM
      PHASE II APPENDIX II MATERIALS AND COMPONENT TESTS
PUBL  USCG, ADA 003934
KEYW  HIGH SEAS, RECOVERY, MATERIALS, COMPONENT TESTS
CODE  0240R

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A HIGH SEAS OIL RECOVERY SYSTEM,
      PHASE II APPENDIX III SYSTEM TEST
PUBL  USCG, ADA 003934
KEYW  HIGH SEAS, RECOVERY, SYSTEM TEST
CODE  0241R

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A HIGH SEAS OIL RECOVERY SYSTEM,
      PHASE II, APPENDIX I, DESIGN STUDIES AND
      SPECIFICATIONS
PUBL  USCG, ADA 003934
KEYW  HIGH SEAS, RECOVERY, DESIGN STUDIES,
      SPECIFICATIONS
CODE  0239F

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A LABORATORY METHOD FOR MEASURING
      EFFECTIVENESS OF OIL SPILL DISPERSANTS
PUBL  THE AMERICAN PETROLEUM INSTITUTE COMMITTEES ON
      ENVIRONMENTAL AFFAIRS, MAY 1973
ABST  A DEVELOPMENT AND REFINEMENT FOR DISPERSANT
      EFFECTIVENESS
KEYW  DISPERSANT EFFECTIVENESS, DEVELOPMENT, REFINEMENT
CODE  2567H

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A NOVEL HIGH VELOCITY OIL SLICK
      SKIMMER
PUBL  HYDRONAUTICS, INC. JUNE 1974, AD 786 880
KEYW  HIGH VELOCITY OIL SLICK SKIMMER
CODE  0199H

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A PROTOTYPE AIRBORNE OIL

      SURVEILLANCE SYSTEM VOL. I DESIGN REP., II
      SUBSYSTEM SPECIFICATIONS
PUBL  AEROJET ELECTROSYSTEMS CO., AZUSA, CA., NTIS,
      AD759483, JUNE 1973
ABST  AIRBORNE OIL SURVEILLANCE SYSTEM - CONFIGURED TO
      ASSIST THE USCG IN ENFORCEMENT OF ANTIPOLLUTION
      LEGISLATION AND ASSESSMENT/CLEANUP OF ACCIDENTAL
      SPILLS.
KEYW  OIL SURVEILLANCE SYSTEM, CLEANUP
CODE  3117H

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF A SYSTEM FOR MEASUREMENT OF SURFACE
      CURRENTS AND OCEAN CURRENT OBSERVATION
PUBL  USCG
KEYW  MEASUREMENT, SURFACE CURRENTS, OCEANIC CURRENTS
CODE  0255H

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF BUOY MOUNTED HYDROCARBON VAPOR
      SENSORS FOR USE IN LOCAL AREA POLLUTION
      SURVEILLANCE SYSTEMS
PUBL  US DEPT. OF TRANSPORTATION, USCG, NTIS
CODE  6518R

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF THE AIR DELIVERABLE ANTI-POLLUTION
      TRANSFER SYSTEM
PUBL  USCG, DAT-4, REPORT NO. 714101/001, 1971, RESPONSE
      AD 732-576
CODE  0742R

AUTH  ANONYMOUS
TITL  DEVELOPMENT OF THE AIR-DELIVERABLE ANTI-POLLUTION
      TRANSFER SYSTEM (ADAPTS)
PUBL  USCG, AUG. 6, 1971, AD 732-576
CODE  0156H

AUTH  ANONYMOUS
TITL  DIRECTORY OF TECHNOLOGY PERSONNEL
PUBL  ASME ANNUAL AS-2 1974
CODE  4037H

AUTH  ANONYMOUS
TITL  DISASTER OFF THE BRITTANY COAST
PUBL  TIME, APRIL 3, 1978
ABST  REPORT ON HISTORY'S BIGGEST OIL SPILL DESPOILS ON
      THE FRENCH SHORELINE
KEYW  OIL SPILL, BRITTANY COAST
CODE  2659F

AUTH  ANONYMOUS
TITL  THE DISASTERS THAT DIDN'T
PUBL  EXXON, USA THIRD QUARTER 1977
ABST  A REPORT ON OIL SPILLS.
CODE  7518R

AUTH  ANONYMOUS
TITL  DISPERSANTS INFORMATION FILE
PUBL  VARIOUS
ABST  LETTERS AND PAMPHLETS REGARDING INFORMATION ON
      DISPERSANTS
KEYW  DISPENSANTS, LETTERS, GENERAL INFORMATION
CODE  5084F

AUTH  ANONYMOUS
TITL  DISPOSAL IN THE MARINE ENVIRONMENT (AN
      OCEANOGRAPHIC ASSESSMENT)
PUB.  NATIONAL ACADEMY OF SCIENCES
ABST  THIS STUDY REVIEWS AND INTEGRATES SCIENTIFIC AND
      TECHNICAL INFORMATION ON OCEAN DISPOSAL TO DEVELOP
      CONCEPTS FOR MONITORING AND REGULATING THIS
      PRACTICE.  THE OBJECTIVE IS TO PROVIDE AS A  BASIS
      FOR EPA'S FUTURE REGULATORY DECISIONS A RATIONALE
      THAT CONSIDERS OCEAN DISPOSAL IN TERMS BOTH OF THE
      NEED FOR OCEAN DISPOSAL AND OF THE CAPACITY OF THE
      MARINE ECOSYSTEM TO RECEIVE WASTES.  IT DESCRIBES
      CURRENT LEGISLATION AND REGULATIONS. THE AMOUNT
      AND PROPERTIES OF WASTE MATERIAL AND THE PROCESSES
      THAT AFFECT THEIR FATE AND DISTRIBUTION IN THE
      MARINE ENVIRONMENT.
KEYW  OCEAN DISPOSAL, LEGISLATION, OCEAN POLLUTION
CODE  7718 F

AUTH  ANONYMOUS
TITL  DISTRIBUTION OF VOLATILE HYDROCARBONS
PUBL  UNKNOWN
ABST  CHARTS OF VOLATILE HYDROCARBONS, INCLUDING
      AROMATICS, IN PACIFIC OCEAN WATER.
KEYW  VOLATILE HYDROCARBONS, CHARTS, AROMATICS
CODE  2967F

AUTH  ANONYMOUS
TITL  DOCTORAL DISSERTATIONS ON CIVIL ENGINEERING
PUBL  UNIVERSITY MICROFILMS INTERNATIONAL
ABST  1973-1976 DISSERTATIONS - A BIBLIOGRAPHY
KEYW  DISSERTATIONS, BIBLIOGRAPHY
CODE  7671F

AUTH  ANONYMOUS
TITL  ECO/+ DISPERSING AGENT
PUBL  DUTCH PRIDE PRODUCTS
ABST  USE OF ECO/+ AS A DISPERSANT IS SHOWN. LICENSE
      CERTIFICATES FOR OIL SPILL CLEAN AGENT FROM STATE
      OF CAL. AND MASS. ARE PRESENTED.
KEYW  DISPERSING AGENT, LICENSES, ECO/+
CODE  7656F

AUTH  ANONYMOUS
TITL  ECONOMIC ANALYSIS OF PROPOSED AND INTERIM FINAL
      EFFLUENT GUIDELINES OF THE OFFSHORE OIL AND GAS
      PRODUCING INDUSTRY)
PUBL  USEPA, 230/1-75-063(A), 68-01-1541 NO. 20, JULY
      1975
ABST  THE PURPOSE OF THE STUDY WAS TO ANALYZE THE
      ECONOMIC IMPACT OF THE F.W.P.C.A.
KEYW  INTERNATIONAL REGULATIONS, WASTE TREATMENT
      CONTROLS, COSTS
CODE  6570F

AUTH  ANONYMOUS
TITL  THE EFFECT OF WAVES ON OIL SPILL MOVEMENTS
PUBL  UNIV. OF MISSOURI, MARCH 1972
KEYW  WAVES, OIL SPILL MOVEMENTS, EFFECTS
CODE  0192P

AUTH  ANONYMOUS
TITL  THE EFFECTS OF CURRENTS AND WAVES ON AN OIL SLICK
      RETAINED BY A BARRIER
PUBL  USCG, ADA 004675
KEYW  CURRENTS, WAVES, BARRIER
CODE  0243H

AUTH  ANONYMOUS
TITL  EFFECTS OF CURRENTS AND WAVES ON FLOATING OIL
      SLICKS RETAINED BY A BARRIER
PUBL  TEXAS A&M UNIV. FOR USCG, SSIE NO. GZP-43
CODE  0440H

AUTH  ANONYMOUS
TITL  EFFECTS OF OIL AND CHEMICALLY DISPERSED OIL ON
      SELECTED MARINE BIOTA - A LABORATORY STUDY
PUBL  API, REPORT NO. 4191, NOV. 1973
ABST  THIS REPORT CONCLUDES A TWO YEAR DEVELOPMENT STUDY
      ON ACUTE, CHRONIC AND SUBLETHAL EFFECTS OF OIL
      UPON MARINE BIOTA USING A REFINED OIL AND TWO
      CRUDE OILS. EFFECTS WERE BIOASSAYED WITH
      UNDISPERSED AND DISPERSED OILS.
KEYW  DISPERSANTS, TOXICITY, MARINE BIOTA
CODE  2991F

AUTH  ANONYMOUS
TITL  ENERGY AND ENVIRONMENTAL GOALS:  COMPATIBILITY
      THROUGH ENVIRONMENTAL CONTROLS
PUBL  U. S. DOE ENVIRONMENTAL CONTROL SYMPOSIUM
ABST  DOCUMENT CONSISTS OF ABSTRACTS FROM THE ABOVE
      NAMED SYMPOSIUM.
KEYW  OIL SPILL, ENVIRONMENT, RECOVERY
CODE  7714 F
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AUTH  ANONYMOUS
TITL  ENERGY SYSTEMS OF EXTENDED ENDURANCE IN THE  1-100
      KILOWATT RANGE FOR UNDERSEA APPLICATIONS
PUBL  NAVAL UNDERWATER SYSTEMS CENTER, NATIONAL ACADEMY
      OF SCIENCES, 1978
ABST  THIS REPORT PRESENTS A DISCUSSION OF REQUIREMENTS
      AS WELL AS THE PRESENT AND PROSPECTIVE TECHNOLOGY
      IN ENERGY SYSTEMS FOR UNDER SEA NAVAL
      APPLICATIONS.
KEYW  FUEL SUPPLY SYSTEMS, ENERGY CONSERVATION, HEAT
      TRANSFER
CODE  6523F

AUTH  ANONYMOUS
TITL  ENGINEERING CONCEPT EVALUATION PROGRAM FOR HIGH
      SEAS OIL SPILL RECOVERY
PUBL  OCEAN SYSTEMS DIVISION, LOCKHEED MISSILES AND
      SPACE CO., AD 725 863
CODE  0188R

AUTH  ANONYMOUS
TITL  ENGINEERING FEASIBILITY STUDY OF THE BISHOP SYSTEM
      FOR OPEN OCEAN SPILLS
PUBL  WILLIAM P. BISHOP ASSOCIATES AD 723 600
CODE  0190R

AUTH  ANONYMOUS
TITL  ENVIRONMENTAL ASSESSMENT OF TREATED OIL SPILLS
      VERSUS UNTREATED SPILLS
PUBL  URI, NEAR, APR. 30, 1976
ABST  A PROPOSAL FOR RESEARCH ON ENVIRONMENTAL
      ASSESSMENT OF TREATED OIL SPILLS VERSUS UNTREATED
      SPILLS.
KEYW  PLANNING AND ANALYSIS, EXPERIMENTAL ASSESSMENT,
      ENVIRONMENTAL ASSESSMENT, TREATED, UNTREATED
CODE  6084B

AUTH  ANONYMOUS
TITL  ENVIRONMENTAL MONITORING AT MAJOR US ENERGY
      RESEARCH AND DEVELOPMENT ADMINISTRATION CONTRACTOR
      SITES, CALENDAR YEAR 1975, VOL. 0 OF 1
PUBL  DIVISION OF SAFETY, STANDARDS AND COMPLIANCE,
      ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION,
      76-104(1975)UC-11
ABST  THE PURPOSE OF THIS COMPILATION IS TO PRESENT IN A
      CENTRAL REFERENCE DOCUMENT ALL OF THE INDIVIDUAL
      ANNUAL REPORTS SUMMARIZING THE RESULTS OF THE
      ENVIRONMENTAL MONITORING PROGRAMS CONDUCTED AT
      EACH OF THE ERDA SITES HAVING A POTENTIAL FOR
      ENVIRONMENTAL IMPACT OR WHICH RELEASE A
      SIGNIFICANT QUANTITY OF RADIOACTIVITY OR
      NONRADIOACTIVE POLLUTANTS.
KEYW  ANNUAL REPORTS, ENVIRONMENTAL MONITORING
CODE  6178B

AUTH  ANONYMOUS
TITL  ENVIRONMENTAL RESEARCH ANNUAL REPORT
PUBL  API, ANNUAL REPORT NO. 4245, JAN. 1975
ABST  THIS REPORT SUMMARIZES COMPLETED API RESEARCH AND
      COMPLETED APRAC RESEARCH,AS WELL AS ON-GOING API
      PROJECTS.
KEYW  REMOVAL, SKIMMERS, TOXICITY, SORBENT RECOVERY
CODE  2909F

AUTH  ANONYMOUS
TITL  ENVIRONMENTAL RESEARCH OUTLOOK FY 1977-1981,
      REPORT TO CONGRESS
PUBL  US DEPT. OF COMMERCE, EPA, OFFICE OF PLANNING AND
      REVIEW, RL 675, 600/9-77-002, FEB. 1977
ABST  THIS REPORT IS THE SECOND OF A SERIES OF ANNUAL
      REPORTS TO CONGRESS PRESENTING A FIVE-YEAR
      PROJECTION OF ENVIRONMENTAL RESEARCH ACTIVITIES TO
      BE CONDUCTED BY THE USEPA.
KEYW  RESEARCH MANAGEMENT, OIL POLLUTION, WATER
      POLLUTION, SOLID WASTE
CODE  6595F

AUTH  ANONYMOUS
TITL  ESTUARIES, GEOPHYSICS AND THE ENVIRONMENT
PUBL  NATIONAL ACADEMY OF SCIENCES
ABST  GEOPHYSICAL INVESTIGATIONS ON LONGITUDINAL
      CIRCULATION AND MIXING RELATIONS IN ESTUARIES
      LATERAL CIRCULATION EFFECTS IN ESTUARIES RIVER
      PLUMES AND ESTUARY FRONTS FJORD AND SALT-WEDGE
      CIRCULATION TURBULENT PROCESSES IN ESTUARIES THE
      COASTAL BOUNDARY LAYER. THE LAST SIX PAPERS
      ENGINEERING AND ENVIRONMENTAL ASPECTS EXTEND THE
      DISCUSSION INTO THE AREAS OF THE CHEMISTRY AND
      BIOLOGY OF THE ESTUARINE CIRCULATION AND OF THE
      PHYSICALLY SUSPENDED PARTICULATE MATTER.
KEYW  CIRCULATION, TURBULENCE, BIOGEOCHEMICAL MODELS
CODE  7717 F

AUTH  ANONYMOUS
TITL  EVALUATION OF AN INFRARED OIL FILM MONITOR
PUBL  USCG, ADA 004912
KEYW  EVALUATION, INFRARED OIL FILM MONITOR
CODE  0250R

AUTH  ANONYMOUS
TITL  EVALUATION OF AN INFRARED OIL FILM MONITOR
PUBL  WRIGHT AND WRIGHT ENV. ENG., NOV. 1973, AD 778 814
CODE  0222R

AUTH  ANONYMOUS
TITL  EVALUATION OF AN INFRARED OIL FILM MONITOR
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PUBL  WRIGHT AND WRIGHT ENVIRONMENTAL ENGINEERING FOR
      USCG, SSIE NO. GZ-30339
CODE  0465R

AUTH  ANONYMOUS
TITL  EVALUATION OF CONCEPTS FOR SEPARATING OIL FROM
      WATER DISCHARGED FROM SHIPS
PUBL  USCG, G-DET-1, AUG. 1973, AD 770 346
CODE  0233R

AUTH  ANONYMOUS
TITL  EVALUATION OF SELECTED EARTH MOVING EQUIPMENT FOR
      THE RESTORATION OF OIL-CONTAMINATED BEACHES
PUBL  DEPT. OF THE INTERIOR, OCT. 1970
KEYW  EARTH MOVING EQUIPMENT, RESTORATION, BEACHES
CODE  0044R

AUTH  ANONYMOUS
TITL  EVALUATION OF THE STRENGTH AND SEAKEEPING ABILITY
      OF POLLUTION CONTROL BARRIERS
PUBL  ADA 004674
KEYW  STRENGTH, SEAKEEPING ABILITIES, CONTROL BARRIERS
CODE  0237R

AUTH  ANONYMOUS
TITL  EXPAC 75
PUBL  EPA, OFFICE OF RESEARCH AND DEVELOPMENT, JULY 1974
ABST  A LISTING OF EXTRAMURAL PROJECTS TO BE FUNDED IN
      FISCAL YEAR 1975 IS GIVEN.
KEYW  HEALTH EFFECTS, ECOLOGICAL PROCESSES, MUNICIPAL
      POLLUTION, INDUSTRIAL POLLUTION
CODE  6020B

AUTH  ANONYMOUS
TITL  A FACILITY FOR THE EXPERIMENTAL ANALYSIS OF
      COASTAL MARINE ECOSYSTEMS
PUBL  EPA PROPOSAL URI/GSO, SUBMITTED 3/31/75
ABST  THE PRIMARY OBJECTIVE OF THE PROPOSAL IS TO
      DESIGN, DEVELOP AND OPERATE A FACILITY FOR THE
      EXPERIMENTAL ANALYSIS OF COASTAL MARINE
      ECOSYSTEMS.
KEYW  COASTAL MARINE ECOSYSTEMS, RESEARCH, ENVIRONMENTAL
      STRESSES
CODE  7678F

AUTH  ANONYMOUS
TITL  A FACILITY FOR THE EXPERIMENTAL ANALYSIS OF
      COASTAL MARINE ECOSYSTEMS, YEARS 2 AND 3.
PUBL  TECHNICAL PROGRESS REPORT AND CONTINUATION
      PROPOSAL, EPA GRANT, NO. R803902020, MARINE
      ECOSYSTEMS RESEARCH LAB., URI GRAD. SCHOOL OF
      OCEANOGRAPHY, 1976-1977
ABST  THIS IS A STUDY ON EXPERIMENTAL MARINE ECOSYSTEMS.
KEYW  ECOSYSTEMS, BEHAVIOR, SPECIES, ELEMENTS
CODE  6059B

AUTH  ANONYMOUS
TITL  FAST SURFACE DELIVERY SYSTEMS FOR POLLUTION
      CONTROL EQUIPMENT A FEASIBILITY STUDY
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. 734122.1/2, JAN. 1974
KEYW  FAST DELIVERY SYSTEM, CONTROL
CODE  0788F

AUTH  ANONYMOUS
TITL  THE FATE OF OIL SPILLS AT SEA
PUBL  GOVERNMENT REPORT ANNOUNCEMENTS
CODE  0326R

AUTH  ANONYMOUS
TITL  A FEASIBILITY DEMONSTRATION OF AN AERIAL
      SURVEILLANCE SPILL PREVENTION SYSTEM
PUBL  EPA, EARTH SATELLITE CORP., CONTRACT NO.
      EPA-68-01-0145, EPA 15080-HUL, JAN. 1972
ABST  ACQUISITION AND INTERPRETATION OF MULTISPECTRAL
      AERIAL PHOTOGRAPHY AND THERMAL INFRARED IMAGERY
      WAS PERFORMED TO EVALUATE REMOTE SENSING
      APPLICATIONS TO OIL AND OTHER HAZARDOUS SPILL
      PREVENTION SURVEILLANCE.
KEYW  SURVEILLANCE, MULTISPECTRAL AERIAL PHOTOGRAPHY,
      THERMAL INFRARED IMAGERY
CODE  0036R

AUTH  ANONYMOUS
TITL  THE FEASIBILITY OF SURFACE SKIMMING OIL COLLECTION
      DEVICES
PUBL  THE CHARLES RIVER ASSOCIATION, AD 716 324
CODE  0182R

AUTH  ANONYMOUS
TITL  A FEASIBILITY STUDY OF THE USE OF THE OLEOPHILIC
      BELT OIL SCRUBBER
PUBL  SHELL PIPELINE CORP. AD 723590
CODE  0180R

AUTH  ANONYMOUS
TITL  A FEASIBILITY ANALYSIS OF INCINERATOR SYSTEMS FOR
      RESTORATION OF OIL CONTAMINATED BEACHES
PUBL  EPA, PROGRAM NO. 15080DAE, CONTRACT NO. 14-12-595
ABST  THE FEASIBILITY OF EMPLOYING A COMBUSTION PROCESS
      FOR RESTORING OIL CONTAMINATED BEACHES WAS
      INVESTIGATED.
KEYW  INCINERATOR SYSTEMS, RESTORATION, CONTAMINATED
      BEACHES
CODE  0051R
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AUTH  ANONYMOUS
TITL  FEDERAL AND LOCAL RESPONSE TO AN OIL SPILL IN RI.
      ONGOING GOVERNMENT RESEARCH AND DEVELOPMENT
      PROGRAMS, A LIST OF MAJOR OIL SPILLS, VARIOUS
      CHARTS, OIL SPILL STATISTICS
PUBL  UNKNOWN
ABST  THIS PAPER DISCUSSES FEDERAL AND LOCAL RESPONSE TO
      AN OIL SPILL.
KEYW  FEDERAL RESPONSE, LOCAL RESPONSE, GOVERNMENT
      RESEARCH, CHARTS
CODE  7606F

AUTH  ANONYMOUS
TITL  FERTILIZER THAT REDUCES OIL SLICKS DEVELOPED BY
      THE NAVY
PUBL  UNKNOWN
ABST  A SPECIAL FERTILIZER FORMULA, FOR USE ON FLOATING
      OIL SLICKS THAT INCREASES BY TEN-FOLD THE NATURAL
      BIODEGRADATION PROCESS, HAS BEEN DEVELOPED BY A
      NAVY RESEARCH PROGRAM.
KEYW  BACTERIAL DEGRADATION, GROWTH STIMULATION, CLEANUP
CODE  2607F

AUTH  ANONYMOUS
TITL  FIGHTING POLLUTION: LATEST GOVERNMENT ACTION IS
      AIMED AT REDUCING OIL SPILLS AND DISCHARGE
PUBL  MARINE ENGINEERING LAB., 1974
CODE  0392H

AUTH  ANONYMOUS
TITL  FILTERBELT OIL RECOVERY SYSTEM
PUBL  MARTIN MARIETTA CORP., DEC. 1971, AD A 003631
CODE  0106A

AUTH  ANONYMOUS
TITL  FINAL ENVIRONMENTAL IMPACT STATEMENT: REGULATIONS
      FOR U.S. TANK VESSELS CARRYING OIL IN FOREIGN
      TRADE AND FOREIGN TANK VESSELS THAT ENTER THE
      NAVIGABLE WATERS OF THE U.S.
PUBL  USCG, DEPT. OF TRANSPORTATION, OFFICE OF MERCHANT
      MARINE SAFETY, REPORT NO. USCG-M-06-77, NOV. 1976
ABST  THIS STATEMENT ASSESSES THE ENVIRONMENTAL IMPACT
      OF CHANGING THE POLLUTION PREVENTION REQUIREMENTS.
KEYW  PREVENTION, OIL TANK VESSELS, MARINE ENVIRONMENTAL
      PROTECTION
CODE  1012F

AUTH  ANONYMOUS
TITL  FINAL ISSUE - ORD PUBLICATIONS SUMMARY
PUBL  EPA, OFFICE OF RESEARCH AND DEVELOPMENT
ABST  COMPREHENSIVE LISTING OF ORD AND PREDECESSORS
      FINAL REPORT.
KEYW  BIBLIOGRAPHY, FINAL REPORTS, GRANT, CONTRACT,
      INTERAGENCY
CODE  7124B

AUTH  ANONYMOUS
TITL  FINAL REPORT - AN INVESTIGATION OF OIL
      FLOURESCENCE AS A TECHNIQUE FOR REMOTE SENSING OF
      OIL SPILLS
PUBL  DOT TRANSPORTATION SYSTEMS CENTER, JUNE 1971, PB
      203 585
CODE  0211A

AUTH  ANONYMOUS
TITL  FINAL REPORT - SHELL OIL SPILL
PUBL  RESOURCES TECHNOLOGY CORP., LOUISIANA WILDLIFE AND
      FISHERIES COMM. CONTRACT NO. 60-01-0351, JAN. 1972
ABST  REPORT OF STUDIES AND INVESTIGATION OF FATE AND
      EFFECTS OF SHELL OIL SPILL PLATFORM B BLOCK 26,
      SOUTH TIMBALIER BAY
CODE  6068H

AUTH  ANONYMOUS
TITL  FINAL REPORT, MARKING THE SEA SURFACE WITH
      ARTIFICIAL SEA SLICKS AND FLUORESCENT DYES TO AID
      SEARCH AND RESCUE OF OCEAN DUMPING SURVEILLANCE
      OPERATIONS
PUBL  USCG, US. DEPT. OF TRANSPORTATION  NO. CG-D-107-76
ABST  A NEW TECHNIQUE OF MARKING THE OCEAN SURFACE WAS
      STUDIED TO DEVELOP A SEA MARKER WHICH CAN BE
      DETECTED BY AIRBORNE SENSING DEVICES.
KEYW  SURFACE FILMS, SEA MARKERS, SEARCH AND RESCUE
CODE  6521F

AUTH  ANONYMOUS
TITL  FINAL REPORT, REGULATIONS PURSUANT TO GEOLOGICAL
      AND GEOPHYSICAL EXPLORATIONS OF THE OUTER
      CONTINENTAL SHELF
PUBL  U.S. DEPT. OF THE INTERIOR, GEOLOGICAL SURVEY, FES
      76-23
ABST  THIS REPORT DISCUSSES PERMITS ISSUED FOR
      EXPLORATION OF THE OUTER CONTINENTAL SHELF.
KEYW  EXPLORATION, CONTINENTAL SHELF
CODE  2520B

AUTH  ANONYMOUS
TITL  FINAL STATEMENT - REGULATIONS FOR TANK VESSELS
      ENGAGED IN THE CARRIAGE OF OIL IN DOMESTIC TRADE
PUBL  USCG, DEPT. OF TRANSPORTATION, CG-M-07-77, AUG.
      1975
ABST  THIS STATEMENT ASSESSES THE ENVIRONMENTAL IMPACT
      OF PROPOSED CHANGES TO THE POLLUTION REGULATIONS
      IN TITLE 33, CODE OF FEDERAL REGULATIONS.
KEYW  OIL TANK VESSELS, SEGREGATED BALLAST, PROTECTION,
      REGULATIONS
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CODE  6593F

AUTH  ANONYMOUS
TITL  FIRST PNEUMATIC BUBBLE BARRIER AGAINST THE SPREAD
      OF OIL AND WATER, INSTALLED IN THE NETHERLANDS
PUBL  HOLLAND SHIPBUILDING
CODE  0363F

AUTH  ANONYMOUS
TITL  FLEXIBLE HOLDING TANK FOR PLEASURE CRAFT SANITARY
      SYSTEM
PUBL  EPA, CONTRACT NO. 14-12-506, AUG. 1970
KEYW  FLEXIBLE HOLDING TANK, PLEASURE CRAFT, SANITARY
      SYSTEM
CODE  0068A

AUTH  ANONYMOUS
TITL  FLOATING OIL RECOVERY DEVICE
PUBL  EPA PROJECT NO 15080FWC, CONTRACT NO. 14-12-903
ABST  FLOW BENCH TESTS OF A MODEL ROTATING BELT-COUETTE
      FLOW OIL RECOVERY DEVICE WERE CONDUCTED IN A CALM
      WATER ENVIRONMENT PRIMARILY ALTHOUGH SOME TESTS
      WERE MADE IN WAVES. ANALYSIS WAS CONDUCTED TO
      DESIGN A CATAMARAN VESSEL SUITABLE FOR MOUNTING
      THE OIL PICKUP UNIT.
KEYW  RECOVERY DEVICES, CATAMARANS, CALM WATERS AND
      WAVES
CODE  0058A

AUTH  ANONYMOUS
TITL  FLOATING OIL SKIMMER
PUBL  SURFACE SEPARATOR SYSTEMS INC. BULLETIN 10UA
ABST  THIS ADVERTISEMENT CONCERNS MODEL BP-20E FLOATING
      OIL SKIMMER. INCLUDES VARIOUS SPECIFICATION AND
      PHOTOGRAPHS.
CODE  3007F

AUTH  ANONYMOUS
TITL  FLOATING OIL SKIMMER
PUBL  SURFACE SEPARATOR SYSTEMS, INC. BULLETIN NO. 200
ABST  THIS ADVERTISEMENT DISCUSSES MODEL BU-213M AND
      CONTAINS THE SPECIFICATION OF THE MODEL AS WELL AS
      SOME BACKGROUND INFORMATION ON FLOATING SKIMMER
      RETRIEVERS.
CODE  3004A

AUTH  ANONYMOUS
TITL  FLOATING OIL SPILL BOOMS:THEIR USE FOR
      COUNTERACTING SPILLAGES
PUBL  REPRINTED FROM THE DOCK AND HARBOR AUTHORITY, VOL.
      XLII, NO. 498, APRIL 1962
ABST  THIS ARTICLE DISCUSSES THE USE OF FLOATING OIL
      SPILL BOOMS TO CHASE ESCAPING OIL PATCHES AND AS
      PERMANENT BARRIERS PROVIDING CATCHMENT AREAS IN
      THE PLACES WHERE SPILLS ARE MOST LIKELY TO OCCUR.
      IT SPECIFIES AN INFLATABLE BOOM USED ON A SHIP
      CANAL AS A SATISFACTORY TYPE BOOM.
CODE  3006A

AUTH  ANONYMOUS
TITL  FLOATING-SUBMERGING FENCE CONTAINS OIL SPILLS IN
      MINUTES
PUBL  RUBBER WORLD
CODE  0364A

AUTH  ANONYMOUS
TITL  FLUID MECHANICS CURRENT INDEX
PUBL  FLUID MECHANICS BI-MONTHLY PUBLICATION, VOL. 2,
      NO. 2/3 APR.-JUNE 1973
ABST  VARIOUS ARTICLES.
KEYW  AERODYNAMICS, HYDRODYNAMICS, WAVE MOTION
CODE  7007F

AUTH  ANONYMOUS
TITL  GELLING CRUDE OILS TO REDUCE MARINE POLLUTION FROM
      TANKER OIL SPILLS
PUBL  EPA, PROJECT NO. 15080DJN
ABST  LABORATORY EVALUATION OF PETROLEUM SOLIDIFICATION,
      OR GELLING, TECHNIQUES AND SYSTEMS WERE CONDUCTED
      UTILIZING FOREIGN AND DOMESTIC CRUDE OILS.
KEYW  GELLING, SOLIDIFICATION, CRUDE OILS, TANKERS
CODE  0057A

AUTH  ANONYMOUS
TITL  GEOGRAPHICAL ANALYSIS OF OIL SPILL POTENTIAL
      ASSOCIATED WITH ALASKAN OIL PRODUCTION AND
      TRANSPORTATION SYSTEMS
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. CG-D-79-74, 744108.2/5FEB. 1974
CODE  2057A

AUTH  ANONYMOUS
TITL  THE GEORGES BANK PET. STUDY - IMPACT ON NEW
      ENGLAND VOL. I AND II
PUBL  MIT SEA GRANT PROG. MIT, REPORT NO. MITSG 73-5,
      FEB. 1973
CODE  2088A

AUTH  ANONYMOUS
TITL  GREAT AMERICAN TECHNICAL REPORT
PUBL  UNKNOWN
ABST  CATALOG ORDER FORMS
CODE  2562F

AUTH  ANONYMOUS
TITL  GUIDE TO WATER CLEANUP, MATERIALS AND METHODS
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PUBL  ARTHUR D. LITTLE, INC.
ABST  THE OBJECTIVE OF THE GUIDE HAS BEEN TO INCLUDE THE
      IMPORTANT DOMESTIC AND FOREIGN PRODUCERS OF WATER
      CLEANUP EQUIPMENT AND MATERIALS + AND TO DESCRIBE
      THEIR FUNCTION, PROPERTIES, DIMENSIONS,
      PERFORMANCE CHARACTERISTICS AND APPLICATIONS.
KEYW  CLEANUP EQUIPMENT PRODUCERS, FUNCTIONS,
      PROPERTIES, PERFORMANCE
CODE  6200B

AUTH  ANONYMOUS
TITL  GUIDELINES FOR OIL SPILL BARRIER (BOOM) DEPLOYMENT
      AND STORAGE
PUBL  US DEPT. OF THE NAVY
ABST  THIS BOOKLET CONTAINS A REPAIR MANUAL, TABLE OF
      CONTENTS, FIFTY FOOT BOOM SECTION DESIGN DRAWING,
      GUIDANCE FOR BOOM DEPLOYMENT AND CARE, AND AN OIL
      BOOM ANALYSIS SHEET.
KEYW  BARRIERS AND BOOMS, DEPLOYMENT AND CARE, ANALYSIS
CODE  6572F

AUTH  ANONYMOUS
TITL  GUIDELINES FOR OIL SPILLAGE BARRIER DEPLOYMENT AND
      STORAGE
PUBL  REFERENCE NO. 1043C/JSP, US NAVAL FACILITIES ENG
      COMMAND, MAY 27, 1975
CODE  2025F
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AUTH  ANONYMOUS
TITL  HARMON'S HANDBOOK
PUBL  URI, ACADEMIC COMPUTER CENTER, JULY 1, 1977
ABST  A USER'S GUIDE TO HELP PEOPLE GET ACQUAINTED WITH
      THE FACILITIES AND POLICIES OF THE ACADEMIC
      COMPUTER CENTER.
KEYW  HANDBOOK, GUIDE, COMPUTER CENTER
CODE  7631F

AUTH  ANONYMOUS
TITL  HAZARDS OF MARITIME TRANSIT
PUBL  LAW OF THE SEA INSTITUTE WORKSHOP, THIRD WORKSHOP,
      MAY 1973
ABST  WORKSHOP TO EXAMINE THE MUTUAL MARITIME PROBLEMS
      ARISING FROM THE CONDUCT OF SHIPPING AND RELATED
      ACTIVITIES IN AREAS OF ACTUAL OR POTENTIAL
      CONGESTION.
KEYW  MARITIME COMMERCE, MARITIME RISK, SHIPPING
CODE  4010B

AUTH  ANONYMOUS
TITL  HEAVY DUTY OIL CONTAINMENT SYSTEM PNEUMATIC
      BARRIER SYSTEM
PUBL  WILSON INDUSTRIES INC. AD 749 278
CODE  0173H

AUTH  ANONYMOUS
TITL  HEAVYWEIGHT OIL CONTAINMENT SYSTEM
PUBL  OCEAN SYSTEMS INC., APPENDIX, I,II,III
KEYW  HEAVYWEIGHT OIL, CONTAINMENT
CODE  0242R

AUTH  ANONYMOUS
TITL  HEAVYWEIGHT OIL CONTAINMENT SYSTEM
PUBL  REPORT NO. 714102/A/005, USCG, OFFICE OF RESEARCH
      AND DEVELOPMENT
CODE  2002F

AUTH  ANONYMOUS
TITL  HIGH SEAS, EPA POOL, AND SPILL OF OPPORTUNITY
      TESTING
PUBL  LOCKHEED MISSILE AND SPACE CO., FOR USCG, SSIE NO.
      GZ-45388
CODE  0467H

AUTH  ANONYMOUS
TITL  HIGHLIGHTS OF OIL SPILL INFORMATION, UK, EUROPE,
      US
PUBL  MP., URI, DEPT. OF MECHANICAL ENGINEERING AND
      APPL. MECH.
ABST  THIS REPORT POINTS OUT SOME DIFFERENCES BETWEEN US
      AND GREAT BRITAINS OIL SPILL CLEANUP TECHNIQUES.
KEYW  DISPERSANTS, MECHANICAL CONTAINMENT, TOXICITY
CODE  4027B

AUTH  ANONYMOUS
TITL  HOW TO PREVENT OIL POLLUTION
PUBL  SCANDINAVIAN OIL SERVICE
ABST  BROCHURE DESCRIBING INFLATABLE EMERGENCY BOOMS
CODE  6025A

AUTH  ANONYMOUS
TITL  HYDRODYNAMIC EFFECTS OF OIL SLICK MECH CONTROL
      DEVICES
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. CG-D-64-74, FEB. 1974
CODE  7003H

AUTH  ANONYMOUS
TITL  IMPACT OF OIL ON THE MARINE ENVIRONMENT
PUBL  JOINT GROUP OF EXPERTS ON THE SCIENTIFIC ASPECTS
      OF MARINE POLLUTION - IMCO/FAO/UNESCO/WMO/IAEA/UN,
      FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED
      NATIONS, ROME., JAN. 1977
ABST  THIS REPORT HAS BEEN PREPARED TO ENABLE THE
      EFFECTS OF OIL IN ITS SEVERAL FORMS AND KINDS ON
      THE MARINE ENVIRONMENT TO BE EVALUATED.
KEYW  SPREADING,DISPERSANT, DETERGENTS, HYDROCARBONS
CODE  7134F

AUTH  ANONYMOUS
TITL  IMPACT OF OILY MATERIALS ON ACTIVATED SLUDGE
      SYSTEMS
PUBL  WATER POLLUTION CONTROL RESEARCH SERIES, 12050DSH
      03/71, HYDROSCIENCE INC.
ABST  SMALL SCALE CONTINUOUS ACTIVATED SLUDGE SYSTEMS
      WERE EXPOSED TO A VARIETY OF OIL COMPOUNDS AT
      SEVERAL LOADING LEVELS AND PERFORMANCE OBSERVED.
CODE  3062H

AUTH  ANONYMOUS
TITL  IN SITU DETECTION OF OIL SLICKS UTILIZING DIF.
      EVAPORATION. PHASE I FEASIBILITY STUDY
PUBL  ENVIRONMENTAL RESEARCH INSTITUTE OF MICH., JAN.
      1974, AD 775 615
CODE  0223F

AUTH  ANONYMOUS
TITL  IN THE WAKE OF THE ARGO MERCHANT
PUBL  CENTER FOR OCEAN MANAGEMENT STUDIES, URI, AUG.
      1978
ABST  THE PAPERS PRESENTED AT THE SYMPOSIUM HELD JAN.
      11-13, 1978, PROVIDE A COMPREHENSIVE YEARS
      DOCUMENTATION OF THE ENVIRONMENTAL AND
      SOCIOECONOMIC IMPACTS OF THE SPILL.
KEYW  OIL SPILL, RESEARCH, BIOLOGICAL IMPACTS,
      HYDRODYNAMICS
CODE  7694F

AUTH  ANONYMOUS
TITL  IN-SITU DETECTION OF OIL SLICKS UTILIZING
      DIFFERENTIAL EVAPORATION, PHASE II SYSTEM DESIGN
PUBL  ENVIRONMENT RESEARCH INSTITUTE OF MICH., MARCH
      1974, ADA 005083
KEYW  DETECTION, DIFFERENTIAL EVAPORATION
CODE  0249F

AUTH  ANONYMOUS
TITL  INTEGRATED LOGISTICS SUPPORT PLAN FOR HARBOR OIL
      SPILL REMOVAL/RECOVERY SYSTEMS
PUBL  DEPT. OF THE NAVY, NAVAL FACILITIES ENG., NAVFAC
      ILSP-001, JAN. 14, 1975
ABST  THIS INTEGRATED LOGISTICS SUPPORT PLAN SETS FORTH
      THE COMPOSITE OF ELEMENTS REQUIRED TO ENSURE
      EFFECTIVE INTRODUCTION AND SUPPORT OF THE HARBOR
      OIL SPILL RECOVERY/REMOVAL SYSTEMS.
KEYW  RECOVERY, REMOVAL, LOGISTICS
CODE  5087F

AUTH  ANONYMOUS
TITL  AN INTEGRATED PROGRAM FOR THE CONTROL OF OIL
      SPILLS
PUBL  RETREC INDUSTRIES INC. MAY 19, 1969
ABST  THE EFFECTIVE CONTROL PROGRAM PRESENTED HERE IS
      GENERAL IN NATURE AND ITS FRAMEWORK CAN BE EASILY
      ADAPTED TO LOCAL NEEDS AND THE REQUIREMENTS OF
      BOTH LARGE AND SMALL FACILITIES. BASICALLY, THE
      PROGRAM COVERS FOUR MAIN AREAS: 1. EQUIPMENT, 2.
      PERSONNEL, 3. INFORMATION AND 4. PLANS AND
      TRAINING
CODE  3003R

AUTH  ANONYMOUS
TITL  INTERIM REPORT - FAST CURRENT OIL CONTROL STUDY
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. 4111.2.2, JULY 1974
CODE  0762F

AUTH  ANONYMOUS
TITL  INTERIM REPORT NO. 1 - SPECIAL TRANSFER PUMP
      DEVELOPMENT 750 HR. ENDURANCE TEST OF DIESEL PRIME
      MOVER
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. 714101/004/1
CODE  0745R

AUTH  ANONYMOUS
TITL  INTERNATIONAL PETROLEUM ENCYCLOPEDIA, 1974
PUBL  THE PETROLEUM PUBLISHING CO., TULSA, OK 74101
ABST  ENCYCLOPEDIA
CODE  4022B

AUTH  ANONYMOUS
TITL  INTERVENTION ON HIGH SEAS ACT
PUBL  SENATE REPORTS ON PUBLIC BILLS, REPORT FROM
      COMMITTEE ON COMMERCE TO ACCOMPANY S 1070, NOV.
      1973
CODE  6099R

AUTH  ANONYMOUS
TITL  INVENTORY OF ENERGY RESEARCH AND DEVELOPMENT,
      1973-75, VOL. III, SERIAL U
PUBL  ERDA, DEPT. OF COMMERCE, JAN. 1976, PART 1, PB-265
      127
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ABST  BIBLIOGRAPHY OF ENERGY RESEARCH AND DEVELOPMENT
KEYW  BIBLIOGRAPHY, RESEARCH DEVELOPMENT
CODE  6583F

AUTH  ANONYMOUS
TITL  INVENTORY OF ENERGY RESEARCH AND DEVELOPMENT,
      1973-75, VOL. III, SERIAL U
PUBL  ERDA, US DEPT. OF COMMERCE, JAN. 1976, PART II,
      PB-265 127
ABST  BIBLIOGRAPHY OF ENERGY RESEARCH AND DEVELOPMENT.
KEYW  BIBLIOGRAPHY, RESEARCH, DEVELOPMENT
CODE  6582F

AUTH  ANONYMOUS
TITL  INVENTORY OF ENGINEERING RESEARCH AND DEVELOPMENT,
      VOLUMES I,II,III,IV,V, 1973-1975
PUBL  COMMITTEE ON SCIENCE AND TECHNOLOGY, U.S. HOUSE OF
      REPRESENTATIVES
ABST  THIS IS A UNIQUE COMPILATION OF CURRENT ENERGY
      RELATED RESEARCH AND DEVELOPMENT.
KEYW  INVENTORY, RESEARCH, DEVELOPMENT
CODE  4017B

AUTH  ANONYMOUS
TITL  INVESTIGATION OF OIL FLOURESCENCE AS A TECHNIQUE
      FOR REMOTE SENSING OF SPILLS
PUBL  DOT, TRANSPORTATION SYSTEMS CENTER, JUNE 1971, PB
      203 585
CODE  0205A

AUTH  ANONYMOUS
TITL  INVESTIGATION OF THE USE OF A VORTEX FLOW TO
      SEPARATE OIL FROM AN OIL WATER MIXTURE
PUBL  UNITED AIRCRAFT CORP. RESEARCH LABS. AD 716 309
CODE  0179A

AUTH  ANONYMOUS
TITL  JBF DIP OIL RECOVERY SYSTEMS
PUBL  JBF SCIENTIFIC CORP., 1976, 1976
ABST  FIVE SYSTEMS ARE AVAILABLE  FOR OPERATION IN
      LAKES, RIVERS, HARBORS, AND THE OPEN SEA.,
KEYW  RECOVERY, CLEANUP, SKIMMERS
CODE  6189G

AUTH  ANONYMOUS
TITL  JOINT CANADA - US MARINE POLLUTION CONTINGENCY
      PLAN FOR SPILLS OF OIL AND OTHER NOXIOUS
      SUBSTANCES
PUBL  USCG, AD 782895, JUNE 1974
ABST  A PLAN PROVIDING FOR COORDINATED AND INTEGRATED
      RESPONSE TO POLLUTION INCIDENTS BY FEDERAL, STATE,
      PROVINCIAL AND REGIONAL PLANS OF BOTH PARTIES.
CODE  6103F
AUTH  ANONYMOUS
TITL  JOURNAL OF SHIP RESEARCH
PUBL  THE SOCIETY OF NAVAL ARCHITECTS AND MARINE
      ENGINEERS, VOL. 15, NO. 2, JUNE 1971
ABST  VARIOUS ARTICLES PERTAINING TO THE SEA.
KEYW  BODY OF REVOLUTION, WAVE FORCES, HYDROFOIL,
      CYLINDERS, PROPELLER SHAFTS, ANALYSIS OF
      GRILLAGES, RECTANGULAR PLATES
CODE  0833F

AUTH  ANONYMOUS
TITL  KEEPING THE OIL IN
PUBL  FINANCIAL TIMES, MONDAY, OCT. 23, 1961
ABST  A DESCRIPTION OF A BOOM USED A PERMANENT PROTECTOR
      TO THE OIL-TANKERS BASIN AT THE NEW DUNKERQUE
      HARBOUR.
CODE  6006A

AUTH  ANONYMOUS
TITL  LABORATORY EVALUATION OF THE EMULSIFYING
      CHARACTERISTICS OF PUMPS
PUBL  FOSTER - MILLER ASSOCIATES, INC., OCT. 1973, AD
      779 629
CODE  0234A

AUTH  ANONYMOUS
TITL  LABORATORY EVALUATION OF THE EMULSIFYING
      CHARACTERISTICS OF PUMPS
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. 734305.3/2, OCT. 1973
CODE  0011AB

AUTH  ANONYMOUS
TITL  LAKE MARACAIBO ECOLOGY - SUMMARY REPORT
PUBL  BATTELLE, PACIFIC NORTHWEST LABORATORIES
ABST  SUMMARY REPORT ON EFFECTS OF OIL DISCHARGES,
      DOMESTIC AND INDUSTRIAL WASTEWATERS ON THE
      FISHERIES OF LAKE MARACAIBO, VENEZUELA - A 3 YEAR
      STUDY, 1971-1974.
KEYW  OIL DISCHARGES, DOMESTIC WASTEWATERS, INDUSTRIAL
      WASTEWATERS
CODE  5083F

AUTH  ANONYMOUS
TITL  LAW OF THE SEA INSTITUTE 1973-1974 ANNUAL REPORT
PUBL  UNIVERSITY OF RHODE ISLAND, 1974
ABST  DESCRIBES FUNCTIONS AND ACTIVITIES OF LAW OF THE
      SEA INSTITUTE AND INCLUDES A PUBLICATION LIST.
CODE  3100A

AUTH  ANONYMOUS
TITL  LAW OF THE SEA: THE EMERGING REGIME OF THE OCEANS
PUBL  LAW OF THE SEA INSTITUTE, EIGHTH ANNUAL
      CONFERENCE, JUNE 18-21, 1973, URI
ABST  THE AIM IS TO FOCUS ON THE CRUCIAL OCEAN POLICY
      ISSUES.
KEYW  TRANSFER OF TECHNOLOGY, MERCHANT SHIPS, OFFSHORE
      PETROLEUM
CODE  4016B

AUTH  ANONYMOUS
TITL  LEVEL GAUGE FOR THE MOVEMENT OF THE TIDE
PUBL  EPA
ABST  A REPORT ON THE PERFORMACNE OF THE LEVEL GAUGE
CODE  2663A

AUTH  ANONYMOUS
TITL  LEVEL GAUGE FOR THE MOVEMENT OF THE TIDE
PUBL  EPA
ABST  A REPORT ON THE PERFORMANCE ON THE LEVEL GAUGE.
KEYW  ULTRASONIC LEVEL GAUGE, TIDE MEASUREMENT
CODE  2663F

AUTH  ANONYMOUS
TITL  LIBERIAN TANKER SPILLS BUNKER C IN BANTRY BAY
PUBL  THE OIL AND GAS JOURNAL 1974
CODE  0354A

AUTH  ANONYMOUS
TITL  LIGHTWEIGHT OIL CONTAINMENT SYSTEM
PUBL  OCEAN SYSTEMS INC.
CODE  0171A

AUTH  ANONYMOUS
TITL  LIGHTWEIGHT OIL CONTAINMENT SYSTEM LOW TENSION
      BARRIER SYSTEM
PUBL  WILSON INDUSTRIES INC. AD 719 277
CODE  0166A

AUTH  ANONYMOUS
TITL  LONG TERM RECOVERY POTENTIAL OF COLD WATER MARINE
      ENVIRONMENTS AFTER OIL SPILLS
PUBL  AN INTERNATIONAL SYMPOSIUM DEDICATED TO THE MEMORY
      OF DR. MAX BLUMER, WOODS HOLE OCEANOGRAPHIC
      INSTITUTE  OCT. 11-14, 1977
ABST  THIS SYMPOSIUM IS ON THE LONG TERM RECOVERY
      POTENTIAL OF COLD WATER MARINE COMMUNITIES AFTER A
      LARGE OIL SPILL. LONG TERM FOLLOW UP ON 4 MAJOR
      SPILLS.
KEYW  RECOVERY, COLD WATER ENVIRONMENTS, DEGRADATION
CODE  6601F

AUTH  ANONYMOUS
TITL  LUTTE CONTRE LES DEVERSEMENTS ACCIDENTELS PRODUITS
      ABSORBANTS ET ADSORBANTS: CRITERES DE SELECTION ET
      ESSAIS EN LABORATOIRE
PUBL  GENERAL DIRECTOR OF THE CONSERVATION OF THE
      ENVIRONMENT, APRIL 1976
ABST  THIS REPORT IS PRESENTED IN FRENCH.
CODE  7150F

AUTH  ANONYMOUS
TITL  M E P C NEWSLETTERS
PUBL  UNKNOWN
ABST  VARIOUS ARTICLES, MONTHLY PUBLICATION
CODE  7693F

AUTH  ANONYMOUS
TITL  MARINE ADVISORY SERVICE NEWSLETTER, MARCH/APRIL
      1977
PUBL  URI SEA GRANT PROJECT
ABST  VARIOUS ARTICLES
KEYW  USING THE SEA-CONSTRUCTION OF HOUSES, COASTAL
      MANAGEMENT CONFERENCE, GEORGES BANK
CODE  6513F

AUTH  ANONYMOUS
TITL  MARINE ENVIRONMENT PROTECTION PROGRAM
PUBL  UNKNOWN
ABST  THIS PAPER DISCUSSES LEGISLATION IN REGARD TO THE
      MARINE ENVIRONMENT PROTECTION PROGRAM.
KEYW  FEDERAL WATER POLLUTION CONTROL ACT, OCEAN DUMPING
      CONTROL, COAST GUARD RESPONSIBILITIES
CODE  6132 F

AUTH  ANONYMOUS
TITL  MARINE ENVIRONMENTAL PROTECTION PROGRAM
PUBL  EPA
ABST  OUTLINES THE FOUR MAIN ELEMENTS OF THE PROGRAM
      PREVENTION AND ENFORCEMENT, RESPONSE, IN-HOUSE
      ABATEMENT AND IMPACT ASSESSMENT.
KEYW  PREVENTION, IMPACT ASSESSMENT, ENFORCEMENT,
      RESPONSE
CODE  5091F

AUTH  ANONYMOUS
TITL  MARINE POLLUTION MONITORING (PETROLEUM),
      PROCEEDINGS
PUBL  US DEPT. OF COMMERCE, NBS SPECIAL PUBLICATION 409,
      DEC. 1974
ABST  THESE PROCEEDINGS CONTAIN THE INVITED PLENARY
      LECTURES REPRESENTING PERTINENT SCIENTIFIC,
      ENVIRONMENTAL AND REGULATORY ASPECTS OF PETROLEUM
      HYDROCARBON MEASUREMENTS, THE SUMMARIES OF THE
      CONTRIBUTED PAPERS, DEALING WITH SPECIFIC
      SCIENTIFIC DEVELOPMENTS AND RECOMMENDATIONS AND
      THE RECOMMENDATIONS OF THE TOPICAL DISCUSSION
      GROUPS.
KEYW  ANALYTICAL METHODS, DATA REPORTING PROCEDURES.
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MONITORING
CODE 40236

AUTH ANONYMOUS
TITL MARINE TECHNOLOGY
PUBL THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
ABST VARIOUS ARTICLES PERTAINING TO MARINE INDUSTRY
CODE 0347F

AUTH ANONYMOUS
TITL MARINE TYPE OIL RETENTION AND RECOVERY EQUIP.
PUBL SURFACE SEPARATOR SYSTEMS
ABST SOME EXAMPLES AND USES OF BOOMS AND OTHER OIL RETENTION EQUIP.
CODE 6019A

AUTH ANONYMOUS
TITL MARITIME REPORTER AND ENGINEERING NEWS
PUBL MARITIME REPORTER AND ENGINEERING NEWS, VOL. 38, NO. 6, MARCH 15, 1976
ABST VARIOUS ARTICLES
KEYW TANKERS
CODE 61908

AUTH ANONYMOUS
TITL MATERIALS FOR HANDLING PETROLEUM PRODUCT SPILLS
PUBL ILLINOIS CHEMICAL CORP., HIGHLAND PARK, ILL.
ABST PRODUCTS DESCRIBED IN BROCHURE ARE PRIMARILY FOR INLAND SPILLS.
KEYW INLAND SPILLS, CLEANUP, RECOVERY
CODE 5083F

AUTH ANONYMOUS
TITL MEASURE AN OIL SLICK AND DISPERSE IT HARMLESSLY
PUBL NEW SCIENTIST, LONDON, VOL. 47, NO. 716, AUG. 1970
CODE 5023R

AUTH ANONYMOUS
TITL MEASUREMENTS PROGRAM FOR OIL SLICK CHARACTERISTICS
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 714104/002
CODE 2065R

AUTH ANONYMOUS
TITL MEASUREMENTS PROGRAM FOR OIL-SLICK CHARACTERISTICS
PUBL UNIV. OF MICH., AD 753 591
CODE 0209A

AUTH ANONYMOUS
TITL MECHANICAL ENGINEERING
PUBL MECHANICAL ENGINEERING MAY 1974
ABST VARIOUS ARTICLES ARE PRESENTED IN THIS MAGAZINE
KEYW FUELS FOR TRANSPORTATION, ENGINEERING TEAMS, ENERGY CONSERVATION, CONTINUOUS STACK GAS MONITORING
CODE 0868F

AUTH ANONYMOUS
TITL MECHANICAL EQUIPMENT FOR THE CLEANUP OF OIL SPILLS
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 4103-1/1
CODE 0754R

AUTH ANONYMOUS
TITL MECHANISM OF HYDROCARBON UPTAKE BY MICROORGANISMS
PUBL BIOTECHNOLOGY AND BIOENGINEERING, VOL. XVI, 1974
ABST THIS COMMUNICATION EXTENDS THE IDEA OF SOLUBILIZATION OF HYDROCARBONS BY SURFACE ACTIVE COMPOUNDS AND ATTEMPTS TO EXPLAIN SOME EXPERIMENTAL RESULTS REPORTED IN THE LITERATURE.
KEYW SOLUBILIZATION, HYDROCARBONS, SURFACE ACTIVE COMPOUNDS, MICROBIAL GROWTH
CODE 2916F

AUTH ANONYMOUS
TITL MEETING OF THE OUTER CONTINENTAL SHELF ENVIRONMENTAL STUDIES ADVISORY COMMITTEE
PUBL DEPT. OF THE INTERIOR, AUG. 26-27, 1976
ABST THIS MEETING COVERED THE ITEMS OF THE OFFICIAL AGENDA.
KEYW LEASING, SALES
CODE 2927F

AUTH ANONYMOUS
TITL MICRO-POR - POROUS PLASTIC TUBING SYSTEMS
PUBL MICRO-POR PRODUCTS
ABST THIS ADVERTISEMENT RECOMMENDS A TYPE OF TUBING APPLICABLE TO AERATION, OXYGENATION, DIFFUSION OF LIQUIDS AND GASSES, AND FILTRATION AND OSMOTIC PROCESSES.
CODE 3049R

AUTH ANONYMOUS
TITL MICROBIAL DEGRADATION OF OIL POLLUTANTS
PUBL US NAVY, SSIE NO. GZ 38168
CODE 0472A

AUTH ANONYMOUS
TITL MID-ATLANTIC REGIONAL STUDY - AN ASSESSMENT OF THE ONSHORE EFFECTS OF OFFSHORE OIL AND GAS DEVELOPMENT
PUBL WOODWARD - CLYDE CONSULTANTS, OCT. 1975
ABST THIS REPORT DISCUSSES THE DEVELOPMENT OF PETROLEUM RESOURCES ON THE OUTER CONTINENTAL SHELF.
KEYW DEVELOPMENT, RESOURCES, OUTER CONTINENTAL SHELF
CODE 25226

AUTH ANONYMOUS
TITL MINUTES: PROPOSED ASTM COMMITTEE ON OIL SPILL BARRIERS
PUBL ASTM, JAN. 23, 1975
ABST DISCUSSES THE PURPOSE AND PHILOSOPHY OF THE ASTM AND PROPOSES STANDARDS ON OIL BARRIER SYSTEMS. THE ARTICLE ALSO INCLUDES A LISTING OF THE MEMBERS, THEIR ADDRESSES AND THE ORGANIZATIONS THEY REPRESENT.
CODE 3070A

AUTH ANONYMOUS
TITL MISCELLANEOUS STATISTICS
ABST XEROX COPIES OF LOCATION OF OIL SPILLS, SUMMARY OF TERMINAL SURVEY, VARIOUS CALCULATIONS AS TO SPILL SIZE.
CODE 3072A

AUTH ANONYMOUS
TITL MICROWAVE RADIOMETRIC DETECTION OF OIL SLICKS
PUBL AEROJET GENERAL CORP., AD 702 402
CODE 0210A

AUTH ANONYMOUS
TITL MOMENTUM AND MASS TRANSFER IN STRATIFIED FLOWS
PUBL DELFT HYDRAULICS LAB. DEC. 1974
ABST AS PART OF A STUDY ON THE EFFECTS OF STABLE DENSITY GRADIENTS ON STEADY AND NON-STEADY FLOWS A LITERATURE SURVEY WAS PERFORMED. THIS STUDY IS INCORPORATED IN A BASIC RESEARCH PROGRAM.
KEYW EXPERIMENTAL DATA, TURBULENCE THEORIES, INTERNAL WAVES
CODE 2573F

AUTH ANONYMOUS
TITL MULTI-SENSOR DETECTION AND TRACKING OF CONTROLLED OIL SPILLS
PUBL SPECTRAN, INC. JUNE 1971, AD 741 953
CODE 0206A

AUTH ANONYMOUS
TITL NATIONAL CONTINGENCY PLAN - REGION I, OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN FOR INLAND NAVIGABLE WATERS. VOLUMES 1-7
PUBL USEPA, DIVISION OF SURVEILLANCE AND ANALYSIS, JAN. 1972
ABST THIS PLAN PROVIDES FOR A PATTERN OF COORDINATED AND INTEGRATED RESPONSES TO POLLUTION SPILLS BY DEPARTMENTS AND AGENCIES OF THE FEDERAL GOV'T.
KEYW ASSIGNMENTS OF DUTIES, ESTABLISH STRIKE FORCES, SYSTEM OF SURVEILLANCE
CODE 4026,4,8

AUTH ANONYMOUS
TITL NATIONAL ENVIRONMENTAL RESEARCH CENTER ANNUAL REPORT, 1974
PUBL USEPA, 670/9-75-002, MARCH 1975
ABST ANNUAL REPORT - VARIOUS ARTICLES
KEYW ANNUAL REPORT
CODE 6061F

AUTH ANONYMOUS
TITL NAVAL RESEARCH REVIEWS, JAN. 1976
PUBL DEPT. OF THE NAVY
ABST THIS BOOKLET CONTAINS VARIOUS ARTICLES. IN PARTICULAR "NEW SYSTEM ABSORBS OIL SPILL", RESEARCH NOTES.
KEYW RECOVERY, BROADCASTER-BARRIER, HARVESTER
CODE 6512F

AUTH ANONYMOUS
TITL NAVY PROPOSES NEW WEAPONS TO COMBAT HARBOR OIL SPILLS
PUBL NAVY ENGINEER CIVIL NEWS, VOL. 21, NO. 8, AUG. 1970
ABST THE NAVY TESTS THREE NEW WAYS FOR CLEANING UP HARBOR OIL SPILLS SUCTION TYPES AND BACTERIAS.
CODE 3040A

AUTH ANONYMOUS
TITL NEW IDEA: PROCESS CRUDE OIL WHILE TANKER IS AT SEA
PUBL OCEAN INDUSTRY, VOL. 5, NO. 7, JULY 1970
ABST DUE TO JAPAN'S PROBLEM WITH AVAILABLE LAND AREA, THE JAPANESE HAVE COME UP WITH A PLAN TO REFINE OIL ONBOARD THE TANKERS IN TRANSIT. IT DISCUSSES THE OUTLINE OF THE PLAN, INCLUDING COST, ADVANTAGES, ETC.
KEYW AVAILABE LAND AREA, TANKERS, REFINE OIL
CODE 3027A

AUTH ANONYMOUS
TITL NEW OIL SPILL BOOM ANNOUNCED
PUBL OIL AND GAS JOURNAL, 1974
CODE 0365R

AUTH ANONYMOUS
TITL NEW SIMULATED OIL-SPILL TEST TANK
PUBL OIL AND GAS JOURNAL 1975
CODE 0366R

AUTH ANONYMOUS
TITL THE NEW YORK BIGHT PROJECT 1975 STONY BROOK LONG ISLAND, NEW YORK
PUBL MARINE ECOSYSTEMS ANALYSIS PROGRAM, US DEPT. OF

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     COMMERCE, PB265280, MARCH 1976
ABST THIS IS A REPORT ON THE NEW YORK BIGHT PROJECT TO
     MEASURE THE IMPACT OF MAN IN THE MARINE
     ENVIRONMENT.
KEYW BASELINE STUDIES, RESOURCES DEVELOPMENT, WATER
     QUALITY CONTROL
CODE 6592F

AUTH ANONYMOUS
TITL NO TITLE
PUBL ACME PRODUCTS CO., MARCH 22, 1973
ABST BULLETINS, SPECIFICATIONS AND PRICES ON THE TOTAL
     PACKAGE AS MOST WIDELY USED FOR CLEANUP OPERATIONS
     FOR OIL SPILLAGES.
CODE 6017H

AUTH ANONYMOUS
TITL NO TITLE
PUBL OIL AND HAZARDOUS MATERIALS RESEARCH NEWSLETTER,
     MAY 1970
ABST DEALS WITH OIL SPILLS CONTAINMENT AND CLEANUP AND
     LEGISLATION ALL TOPICS DISCUSSED BRIEFLY.
CODE 3061F

AUTH ANONYMOUS
TITL NO TITLE
PUBL RI INTERAGENCY POLLUTION ABATEMENT COMMITTEE
ABST A SURVEY ON COMMUNITIES, THEIR COMMUNICATION
     FACILITIES AND AUTHORIZATIONS TO USE EQUIPMENT.
CODE 3071F

AUTH ANONYMOUS
TITL NO TITLE
PUBL SLICKBAR INC., SAUGATUCK STATION, WESTPORT, CONN.
ABST CALCULATION OF WIND DRIVEN CURRENTS, FORCE ON
     BOOMS, PERPENDICULAR TO CURRENT FLOW AND TOTAL
     LOADS.
CODE 6003F

AUTH ANONYMOUS
TITL NOTES ON INDUSTRY'S OIL SPILL CONTROL ACTIVITIES
     POLLUTION CONTROL REPORT
PUBL OCEAN INDUSTRY, JUNE 1970
ABST THIS ARTICLE DEALS WITH THE OIL INDUSTRY APPROACH
     TO OIL SPILL POLLUTION, THEIR DEVICES AND THE
     LEGAL PROCESSES NEEDED TO AID IN OIL SPILL
     PREVENTION.
KEYW INDUSTRY, DEVICES, LEGAL PROCESSES
CODE 3025F

AUTH ANONYMOUS
TITL NTISEARCH ECOLOGY OF THE MARINE ENVIRONMENT  VOL.
     2  DEC. 1974-MARCH 1976
PUBL NTIS U.S. DEPARTMENT OF COMMERCE
ABST THE SELECTED ABSTRACTS OF GOVERNMENT-SPONSORED
     RESEARCH REPORTS COVER SALT WATER ECOLOGY OF
     SHELLFISH, FISHES, AQUATIC PLANTS, AQUATIC
     ANIMALS, AND AQUATIC MICROORGANISMS. ESTUARY
     STUDIES ARE INCLUDED.  POLLUTION EFFECTS ARE
     INCLUDED EXCEPT FOR REPORTS DEALING WITH
     PESTICIDES AND OIL POLLUTION.
KEYW ESTUARY STUDIES, POLLUTION EFFECTS
CODE 7781F

AUTH ANONYMOUS
TITL NTISEARCH ECOLOGY OF THE MARINE ENVIRONMENT  VOL.
     3  APRIL 1976-MARCH 1977
PUBL NTIS U.S. DEPARTMENT OF COMMERCE
ABST THE SELECTED ABSTRACTS OF RESEARCH REPORTS COVER
     SALT WATER ECOLOGY OF SHELLFISH, FISHES, AQUATIC
     PLANTS, AQUATIC ANIMALS, AND AQUATIC
     MICROORGANISMS. ESTUARY STUDIES ARE INCLUDED AS
     ARE POLLUTION EFFECTS, EXCEPT FOR REPORTS DEALING
     WITH PESTICIDES AND OIL POLLUTION.
KEYW ESTUARY STUDIES, POLLUTION EFFECTS
CODE 7782F

AUTH ANONYMOUS
TITL NTISEARCH, JUNE 1977
PUBL NTIS, US DEPT. OF COMMERCE
ABST FULLY ANNOTATED BIBLIOGRAPHIES PREPARED BY
     INFORMATION SPECIALISTS AT NTIS FROM ITS ON-LINE
     INTERACTIVE BIBLIOGRAPHIC RETRIEVAL SYSTEM.
KEYW BIBLIOGRAPHY, RETRIEVAL SYSTEM, ON-LINE
     INTERACTIVE BIBLIOGRAPHIC
CODE 6519F

AUTH ANONYMOUS
TITL A NUMERICAL MODEL OF DROPLET ENTRAINMENT FROM A
     CONTAINED OIL SLICK
PUBL USCG, OFFICE OF R + D, REPORT NO. CG-D-65-75
CODE 0494P

AUTH ANONYMOUS
TITL OCEAN INDUSTRY, ENGINEERING CONSTRUCTION AND
     OPERATIONS
PUBL GULF PUBLISHING CO.
ABST NUMEROUS ARTICLES IN VOL. 10, NO. 12 AND VOL. 11,
     NOS. 1, 2, 7, 8, 10, 11 AND 12
CODE 2646F

AUTH ANONYMOUS
TITL OCEAN MASTER
PUBL CHARLES KERR ENTERPRISES INC., 1972
ABST CATALOG ON OCEANOGRAPHIC EQUIPMENT AND
     INSTRUMENTATION
KEYW CATALOG, EQUIPMENT, INSTRUMENTATION
CODE 6173B

AUTH ANONYMOUS
TITL OCEAN PRODUCTS AND LITERATURE
PUBL OCEAN SCIENCE ON STATION
CODE 0308R

AUTH ANONYMOUS
TITL OCEAN RESEARCH IN THE 1980S
PUBL CENTER FOR OCEAN MANAGEMENT STUDIES, URI, AUG.
     1977
ABST A SERIES OF WORKSHOPS WERE SET UP TO DISCUSS THE
     NEED FOR OCEAN RESEARCH. THESE PAPERS WILL BE USED
     AS A PLANNING TOOL IN THE DEVELOPMENT OF A MAJOR
     RESEARCH PROGRAM FOR THE 1980S.
KEYW PHYSICAL, BIOLOGICAL, CHEMICAL, GEOLOGICAL
CODE 1204F

AUTH ANONYMOUS
TITL OCEANOGRAPHIC OBSERVATIONS AND THEORETICAL
     ANALYSIS OF OIL SLICK DURING THE CHEVRON SPILL,
     MARCH 1970
PUBL LOUISIANA STATE UNIV. AD 716 374
CODE 0215A

AUTH ANONYMOUS
TITL OFF-LINE CITATION LIST - GENERATED BY ORBIT III
PUBL S.D.C.'S INTERNATIONAL SEARCH SERVICE
ABST THIS SEARCH WAS PERFORMED ON POLLUTION
CODE 2516F

AUTH ANONYMOUS
TITL OHMSETT, INDUSTRIAL WASTE TREATMENT RESEARCH
     LABORATORY
PUBL USEPA
ABST THIS ARTICLE DISCUSSES THE FACILITY THE EPA IS
     USING TO CONDUCT TESTS AND DEVELOP DEVICES AND
     TECHNIQUES FOR THE CONTROL OF OIL AND HAZARDOUS
     MATERIAL SPILLED IN INLAND AND COASTAL WATERS.
KEYW ENVIRONMENTAL SAFETY, CONTROL, HAZARDOUS MATERIALS
CODE 2932F

AUTH ANONYMOUS
TITL OIL AND DISPERSANTS
PUBL S.D.C. INTERNATIONAL SEARCH SERVICE, AUG. 6, 1976
ABST THIS IS AN OFF LINE CITATION LIST.
KEYW OIL AND DISPERSANTS
CODE 2117F

AUTH ANONYMOUS
TITL OIL AND HAZARDOUS MATERIALS, TECHNICAL ASSISTANCE
     DATA SYSTEM
PUBL EPA, OIL AND SPECIAL MATERIALS CONTROL DIVISION,
     OFFICE OF WATER PROGRAM OPERATIONS
ABST DESCRIPTION OF THE OIL AND HAZARDOUS MATERIALS,
     TECHNICAL ASSISTANCE DATA SYSTEM AND ITS
     APPLICATIONS TO EMERGENCY SITUATIONS WHERE ON
     SCENE COORDINATOR WOULD  NEED FAST, ACCURATE DATA
     ON THE DEGREE OF HAZARD INVOLVED, THE
     COUNTERMEASURES TO BE UTILIZED AND THE PERSONNEL
     SAFETY PRECAUTIONS TO BE TAKEN.
KEYW SAFETY PRECAUTIONS, EMERGENCIES, HAZARD,
     COUNTERMEASURES
CODE 2657F

AUTH ANONYMOUS
TITL OIL AND WATER MIX: PHENOMENON OCCURS WITH CERTAIN
     DETERGENTS
PUBL COLUMBIA UNIV. OFFICE OF PUBLIC INFO. JAN. 13,
     1973
ABST DETERGENT FILMS ARE USED IN LABORATORY FOR MIXING
     OIL AND WATER.
KEYW DETERGENT FILMS, OIL AND WATER MIXING
CODE 2138R

AUTH ANONYMOUS
TITL OIL BARRIER STANDARD TEST REQUIREMENTS
PUBL USCG, SSIE NO. GZF-54
CODE 0442P

AUTH ANONYMOUS
TITL OIL BOOM GEOMETRY
PUBL UNKNOWN
ABST GRAPHS SHOWING STEADY STATE OIL BOOM GEOMETRY FROM
     MODEL TESTS, MOORING FIXED, AT VARIOUS CURRENTS.
CODE 6040R

AUTH ANONYMOUS
TITL OIL BOOMS FOR POLLUTION CONTROL
PUBL UNIROYAL
ABST EXPLAINS UNIROYAL'S SEALED BOOM AND GIVES
     SPECIFICATIONS.
CODE 3058F

AUTH ANONYMOUS
TITL OIL CLEANUP UNDERWAY
PUBL EVENING BULLETIN, VOL. CXI, NO. 72, WED. APRIL 11,
     1973
ABST ARTICLE DISCUSSES THE OIL SPILL WHEN THE PENNANT
     HIT AN UNDERWATER OBSTRUCTION OFF POPPASQUASH PT.
     AT RUMSTICK BEACH. IT DESCRIBES CLEANUP
     PROCEDURES.
CODE 3074A

AUTH ANONYMOUS
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TITL  OIL COMPANIES SPILL AND RUN
PUBL  DOLLARS AND SENSE, MONTHLY PUBLICATION, VOL. 24,
      FEB. 1977
ABST  ARTICLE PERTAINING TO THE ARGO MERCHANT SPILL AND
      TANKER TRANSPORT.
KEYW  TANKER TRANSPORT, ARGO MERCHANT
CODE  2651F

AUTH  ANONYMOUS
TITL  OIL CONTAINMENT METHOD SLATED FOR FULL TESTING
PUBL  ENVIRONMENTAL CURRENTS, VOL. 4, NO. 12, DEC. 1970
ABST  ONE MILLION DOLLAR CONTRACT AWARDED TO
      JOHNS-MANVILLE CORP. FROM USCG FOR FURTHER
      DEVELOPMENT OF OIL CONTAINMENT SYSTEM FOR OFFSHORE
      OIL SPILLS.
CODE  6028R

AUTH  ANONYMOUS
TITL  OIL CONTAINMENT SYSTEM
PUBL  TEXAS A+M UNIV. FOR USCG, SSIE NO. GZ-38326-1
CODE  0443R

AUTH  ANONYMOUS
TITL  OIL CONTAINMENT SYSTEMS
PUBL  EPA, SURVEILLANCE AND ANALYSIS DIVISION, OCT.
      1970, JAN. 1973
ABST  THIS REPORT PROVIDES A DESCRIPTION OF VARIOUS OIL
      SPILL CONTAINMENT SYSTEMS
KEYW  ACCIDENTS AT SEA, NATURAL DISASTERS, RESOURCES
      AFFECTED
CODE  0803F

AUTH  ANONYMOUS
TITL  OIL CONTAINMENT SYSTEMS
PUBL  FEDERAL WATER QUALITY ADMIN., US DEPT. OF THE
      INTERIOR
ABST  CONTAINMENT SYSTEMS, COMMERCIALLY AVAILABLE, AND
      UNDER PATENT OR DEVELOPMENT ARE DISCUSSED AND
      ILLUSTRATED.
KEYW  CONTAINMENT SYSTEMS, PATENTS, DEVELOPMENT
CODE  0040R

AUTH  ANONYMOUS
TITL  OIL CONTAINMENT SYSTEMS - CHEMICALLY JELLIED ACCM.
PUBL  ENVIRONMENTAL PROTECTION AGENCY, SSIE NO. GZ-12106
CODE  2010P

AUTH  ANONYMOUS
TITL  OIL IN THE ARCTIC
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO CG-D-96-75, 4108.2.3
CODE  7058R
AUTH  ANONYMOUS
TITL  OIL INDUSTRY DIRECTORY HANDBOOK INDUSTRY
PUBL  US DEPT OF THE INTERIOR, GEOLOGICAL SURVEY
ABST  LIST OF SELECTED REFERENCES ON OIL SPILLS
CODE  2960F

AUTH  ANONYMOUS
TITL  OIL ON THE BEACH STATE ACTION NEEDED
PUBL  NEW SCIENCE, LONDON 48(730):486
CODE  1112R

AUTH  ANONYMOUS
TITL  OIL ON TROUBLED WATERS
PUBL  RESEARCH NEWS, DIV. OF RESEARCH DEVELOPMENT AND
      ADMINISTRATION, UNIVERSITY OF MICHIGAN, VOL. XXVI,
      NO. 2, AUG. 1975
ABST  THIS PAPER DISCUSSES THE PROBLEMS DUE TO OIL
      TRANSPORT.
KEYW  CLEANUP, PREVENTION, TANKERS
CODE  2535F

AUTH  ANONYMOUS
TITL  OIL POLLUTION
PUBL  EPA, EDISON WATER QUALITY LAB. OIL POLLUTION
      RESEARCH NEWSLETTER, VOL. 14, JULY 1971
CODE  5026F

AUTH  ANONYMOUS
TITL  OIL POLLUTION ACT
PUBL  93RD CONGRESS, HR 8917, OCT. 4, 1973
ABST  ACT TO AMEND OIL POLLUTION ACT, 1961 AS AMENDED,
      TO IMPLEMENT 1969 AND 1971 AMENDMENTS TO
      INTERNATIONAL CONVENTION FOR PREVENTION OF
      POLLUTION OF SEA BY OIL
CODE  6092R

AUTH  ANONYMOUS
TITL  OIL POLLUTION ACT AMMENDMENTS OF 1973
PUBL  REPORT FROM THE COMMITTEE ON MERCHANT MARINE AND
      FISHERIES TO ACCOMPANY HR 5451, APRIL 13, 1973,
      93RD CONGRESS
CODE  6076R

AUTH  ANONYMOUS
TITL  OIL POLLUTION AN INDEX CATALOG TO THE COLLECTION
      OF THE OIL SPILL INFORMATION CENTER, VOL. II,
      AUTHOR INDEX
PUBL  UNIVERSITY OF CALIFORNIA LIBRARY, 1972
ABST  AUTHOR INDEX
KEYW  CATALOG, AUTHOR INDEX
CODE  6083B

AUTH  ANONYMOUS
TITL  OIL POLLUTION AN INDEX CATALOG TO THE COLLECTION
      OF THE OIL SPILL INFORMATION CENTER, VOL. IV
PUBL  UNIVERSITY OF CALIFORNIA LIBRARY, 1972
ABST  OIL POLLUTION PROBLEMS , HARBORS - I
KEYW  CATALOG
CODE  6081B

AUTH  ANONYMOUS
TITL  OIL POLLUTION AT SEA  HOW MUCH IS TOO MUCH?
PUBL  BIOSCIENCE VOL. 25, 1975
ABST  THIS PAPER DISCUSSES THE TOPIC OF LEVELS OF
      HYDROCARBONS INPUT INTO THE SEA
KEYW  TRANSPORTATION, REFINERIES, INDUSTRIAL
CODE  7127F

AUTH  ANONYMOUS
TITL  OIL POLLUTION CONTROL - SPECIAL TECHNIQUES -
      BACTERIOLOGICAL DEGRADATION OF OIL SLICKS
PUBL  USCG, SSIE NO. GZF-55
CODE  0473R

AUTH  ANONYMOUS
TITL  OIL POLLUTION CONTROL R+D REQUIREMENTS, VOL. I
      METHODS, VOL. II PLANS
PUBL  A.D. LITTLE, INC. AD 696 635
CODE  0167, 0167AR

AUTH  ANONYMOUS
TITL  OIL POLLUTION CONTROL RESEARCH AND DEVELOPMENT
      REQUIREMENTS VOL. I - METHODS
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. 714102/002-1
CODE  0748R

AUTH  ANONYMOUS
TITL  OIL POLLUTION CONTROL RULES AND  REGULATIONS
PUBL  RI DEPT. OF HEALTH
ABST  STATES THE RULES AND REGULATIONS PREVENTING THE
      DISCHARGE OR ESCAPE OF ANY PETROLEUM, GASOLINE,
      KEROSENE, TAR, ASPHALT, OIL, OR ANY OTHER PRODUCT
      OR MIXTURE THEREOF, INTO THE WATER OF THE STATE OF
      RI.
CODE  6023R

AUTH  ANONYMOUS
TITL  OIL POLLUTION CONTROL RULES AND REGULATIONS
PUBL  RI DEPT. OF HEALTH, 1971
CODE  0022R

AUTH  ANONYMOUS
TITL  OIL POLLUTION DETECTION AND SENSING VOLUME 2
      1970-AUGUST 1978
PUBL  NTIS
ABST  CITATIONS OF RESEARCH ON SAMPLING, DETECTION AND
      CHEMICAL ANALYSIS OF OIL IN WATER ARE PRESENTED.
      STUDIES ON REMOTE SENSING PRINCIPALLY USING RADAR,
      OCEAN WAVE DAMPING AND INFRARED DETECTION ARE
      INCLUDED.  THE MAJORITY OF THESE CITATIONS CONCERN
      OIL SPILLS, BUT STUDIES ON OIL WASTES, INDUSTRIAL
      WASTES, BILGE WATER AND SEWAGE ARE ALSO COVERED.
KEYW  OIL SPILLS, CHEMICAL ANALYSIS, DETECTION
CODE  7703 F

AUTH  ANONYMOUS
TITL  OIL POLLUTION IN THE SANTA BARBARA CHANNEL
PUBL  UNIVERSITY OF CALIFORNIA LIBRARY
ABST  A COMPREHENSIVE BIBLIOGRAPHY WITH PARTICULAR
      EMPHASIS ON THE OIL SPILL OF JAN. 28, 1969
KEYW  PUBLIC RESPONSE, COURT ACTIONS, LEGISLATION, SANTA
      BARBARA CHANNEL
CODE  6082B

AUTH  ANONYMOUS
TITL  OIL POLLUTION INDEX CATALOG, VOL. III, A - OIL
      POLLUTION
PUBL  UNIVERSITY OF CALIFORNIA LIBRARY, 1972
ABST  AN INDEX CATALOG TO THE COLLECTION OF THE OIL
      SPILL INFORMATION CENTER.
KEYW  CATALOG, OIL SPILL INFORMATION CENTER
CODE  6080B

AUTH  ANONYMOUS
TITL  OIL POLLUTION INDEX CATALOG, VOL. I
PUBL  UNIVERSITY OF CALIFORNIA LIBRARY, 1972
ABST  ANONYMOUS ARTICLES
KEYW  CATALOG
CODE  6079B

AUTH  ANONYMOUS
TITL  OIL POLLUTION OF THE SEA: CLEANING UP
PUBL  MAR. INTL. J., VOL. 10, NO. 2, SPRING 1969
CODE  5027R

AUTH  ANONYMOUS
TITL  OIL POLLUTION RESEARCH NEWSLETTER
PUBL  EDISON WATER QUALITY LABORATORY, VOL. V, EPA,
      SEPT. 1971
ABST  OBSERVATIONS AT A LOCAL OIL SPILL AND
      EFFECTIVENESS OF CLEANUP OPERATIONS.
KEYW  CLEANUP, COLLECTING AGENT, CONTROL
CODE  5082F

AUTH  ANONYMOUS
TITL  OIL RETRIEVAL SKIMMER DEVELOPMENT - DAT-4
PUBL  USCG, DEC 1971
CODE  0164R
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AUTH  ANONYMOUS
TITL  OIL SLICK ANSWER FROM ICI - TANKER CLEANING AT SEA
PUBL  SHIPBUILDING AND SHIPPING RECORD, AUG. 8, 1969
CODE  2133A

AUTH  ANONYMOUS
TITL  OIL SLICK MOVEMENT - A BIBLIOGRAPHY WITH ABSTRACTS
      APRIL 1975
PUBL  NTIS  PS-79/0311
ABST  THE BIBLIOGRAPHY CITES GOVERNMENT-SPONSORED
      RESEARCH REPORTS COVERING THE MOVEMENT OF OIL
      SLICKS IN THE OCEAN.  SOME OF THE TOPICS INCLUDE
      OCEAN CURRENT INTERACTIONS, MODELING OF DRIFT,
      OCEAN WAVE DISPERSION, AND OCEAN CURRENT STUDIES
      NEAR VARIOUS COASTS.  (CONTAINS 35 ABSTRACTS)
KEYW  OIL SPILLS, OCEAN CURRENT INTERACTIONS, MODELING
      OF DRIFT
CODE  7741F

AUTH  ANONYMOUS
TITL  OIL SLICK SURVEILLANCE  AND FORECASTING, SLICK
      THICKNESS MEASURING DEVICE
PUBL  USCG, NO. 12138; SSIE NO. GZ-12138
CODE  0434R

AUTH  ANONYMOUS
TITL  OIL SLICKS AND FILMS
PUBL  DEFENSE DOCUMENTATION CENTER, JAN. 1953-NOV. 1971,
      REPORT DATED 3/72 NO. DDC-TAS-71-64
ABST  REFERENCES PERTAINING TO THE CLEANING AND REMOVAL
      OF OIL SLICKS, OIL FILMS, AND RELATED FILMS FROM
      SEA SURFACES, OR WATER SURFACES HAVE BEEN COMPILED
      IN THIS BIBLIOGRAPHY.
KEYW  CLEANUP, REMOVAL, BIBLIOGRAPHY
CODE  9044F

AUTH  ANONYMOUS
TITL  OIL SPILL  RECOVERY VESSEL
PUBL  NETHERLANDS PATENT NL 7315-128, JUNE 20-1974
ABST  OIL FLOATING ON WATER IS RECOVERED USING A VESSEL
      WITH A CYCLONE CHAMBER INTO WHICH A SKIMMED LAYER
      IS ADMITTED VIA A LATERAL OPENING, ONE EDGE OF
      WHICH IS DEFINED BY AN ADJUSTABLE SKIMMER. THE
      INFLOW TO THE CHAMBER BODY SOLELY DEPENDENT ON THE
      TRANSLATERAL SPEED OF THE VESSEL.
CODE  3134R

AUTH  ANONYMOUS
TITL  OIL SPILL - SANTA BARBARA
PUBL  UNIV. OF CAL. DEPT. OF BIOLOGICAL SCIENCE, FEB.
      1971
ABST  SHORT TERM ANALYSIS OF MACROPLANKTON AND FISH FROM
      SANTA BARBARA OIL SPILL.
CODE  6052A

AUTH  ANONYMOUS
TITL  OIL SPILL AND OIL POLLUTION REPORTS, JULY 1974 -
      OCT. 1974
PUBL  EPA, NO. EPA 670/2-75-003
CODE  6008R

AUTH  ANONYMOUS
TITL  OIL SPILL AND POLLUTION NEWS ARTICLES
PUBL  UNKNOWN
ABST  VARIOUS NEWSPAPER ARTICLES
KEYW  NEWS ARTICLES, OIL SPILL, POLLUTION
CODE  61818

AUTH  ANONYMOUS
TITL  OIL SPILL BARRIERS
PUBL  MINUTES OF THE ASTM COMMITTEE, JAN. 23, 1976
ABST  MINUTES OF PROPOSED ASTM COMMITTEE.
KEYW  OIL SPILL, OPERATION, DISCUSSION
CODE  2913F

AUTH  ANONYMOUS
TITL  OIL SPILL CONFERENCE
PUBL  API, OIL SPILL CONFERENCE, MARCH 8, 1977
ABST  PROCEEDING OF THE OIL SPILL CONFERENCE, NEW
      ORLEANS, LA.
KEYW  PROCEEDINGS, CONFERENCE, OIL SPILL
CODE  4041B

AUTH  ANONYMOUS
TITL  OIL SPILL CONTAINMENT
PUBL  USAF FOR USCG, SSIE NO GZF-65
CODE  0445R

AUTH  ANONYMOUS
TITL  OIL SPILL CONTAINMENT SYSTEMS
PUBL  EPA, JAN. 1973
ABST  THIS REPORT DESCRIBES VARIOUS OIL SPILL
      CONTAINMENT SYSTEMS. INCLUDES CONCEPTUAL DESIGN,
      SYSTEMS UNDER PATENT, SYSTEMS IN STAGES OF FINAL
      DEVELOPMENT, AND VARIOUS FULL SCALE COMMERCIAL
      EQUIPMENT AVAILABLE TODAY.
KEYW  CONTAINMENT, DESIGNS, CONSTRUCTION
CODE  0038R

AUTH  ANONYMOUS
TITL  OIL SPILL DETECTION
PUBL  US EPA AND USCG SSIE NO. GZ-38169-1
CODE  0432R

AUTH  ANONYMOUS
TITL  OIL SPILL DRIFT CAUSED BY THE COUPLED EFFECTS OF
      WIND AND WAVES
PUBL  UNIV. OF MISSOURI, OCT. 1973, AD 777 702
CODE  0219A

AUTH  ANONYMOUS
TITL  OIL SPILL FIGHTER ADMINISTERING THE OCEAN DUMPING
      ACT
PUBL  UNKNOWN
ABST  THIS PAPER DISCUSSES KENNETH BIGLANE'S ROLL IN
      COPING WITH OIL SPILLS. THE OCEAN DUMPING ACT,
      FORMALLY KNOWN AS THE MARINE PROTECTION RESEARCH
      AND SANCTUARIES ACT, GIVES EPA THE RESPONSIBILITY
      FOR REGULATING THE DUMPING OF ALL MATERIALS EXCEPT
      DREDGED MATERIALS.
KEYW  OCEAN DUMPING ACT, REGULATING, DUMPING OF
      MATERIALS
CODE  7351AF

AUTH  ANONYMOUS
TITL  OIL SPILL SPOILER
PUBL  ENVIRONMENTAL SCIENCE AND TECHNOLOGY, 1974
CODE  0372R

AUTH  ANONYMOUS
TITL  OIL SPILL TREATING AGENTS - A COMPENDIUM
PUBL  PACIFIC NORTHWEST LAB. CONTRACT NO. 212A00083, MAY
      1970
ABST  A SINGLE SOURCE COMPENDIUM OF INFORMATION ON
      AVAILABLE OIL SPILL TREATING AGENTS AS AN INITIAL
      BASIS OF SELECTION OF TREATING AGENTS. THIS VOLUME
      IS INTENDED TO AID IN LOGISTIC PLANNING BY
      INDICATING THE QUANTITIES AND LOCATIONS OF
      WAREHOUSED MATERIALS AND POTENTIAL PRODUCTION
      RATES.
KEYW  TREATING AGENTS, LOGISTIC PLANNING, WAREHOUSED
      MATERIALS
CODE  0024R

AUTH  ANONYMOUS
TITL  OIL SPILL TREATING AGENTS SELECTION BASED ON
      ENVIRONMENTAL FACTORS
PUBL  ARTHUR D. LITTLE, INC., OCT. 1970
ABST  A CROSS-SECTION OF ENVIRONMENTAL CHARACTERISTICS
      REPRESENTATIVE OF CONDITIONS ALONG THE US
      COASTLINES AND INLAND WATERWAYS. SPECIFICALLY,
      WHICH CHARACTERISTICS ARE IMPORTANT AND HOW THEY
      INFLUENCE OIL SPILL TREATING AGENTS AND TECHNIQUES
KEYW  TREATING AGENTS, CONDITIONS, CHARACTERISTICS
CODE  0042R

AUTH  ANONYMOUS
TITL  OIL SPILL TREATING AGENTS TEST PROCEDURES: STATUS
      AND RECOMMENDATIONS
PUBL  BATTELLE MEMORIAL INSTITUTE, PACIFIC NORTHWEST
      LAB. MAY 1, 1970
ABST  EXISTING EFFECTIVENESS AND TOXICITY MEASUREMENT
      METHODS ARE ASSESSED. IT IS ALSO TO BE DETERMINED
      WHETHER ANY COMBINATION OF EXISTING BIOASSAY
      TECHNIQUES WILL ADEQUATELY MEASURE THE TOXICITY OF
      THE TREATING AGENTS.
KEYW  TREATING AGENTS, TOXICITY, BIOASSAY TECHNIQUES
CODE  0043R

AUTH  ANONYMOUS
TITL  OIL SPILL, LONG ISLAND SOUND, MARCH 21, 1972,
      ENVIRONMENTAL EFFECTS
PUBL  OIL AND HAZARDOUS MATERIALS PROGRAM SERIES, JAN.
      1973, EPA NO. 68-01-0044
ABST  THIS STUDY WAS PRINCIPALLY UNDERTAKEN TO DETERMINE
      THE EFFECTS OF A NO. 2 FUEL OIL ON THE
      ENVIRONMENT.
KEYW  SEDIMENTS, NO. 2 FUEL OIL, MORTALITY RATES
CODE  0152R

AUTH  ANONYMOUS
TITL  OIL SPILLAGE STUDY - LITERATURE SEARCH AND
      CRITICAL EVALUATION FOR SELECTION OF PROMISING
      TECHNIQUES TO CONTROL AND PREVENT DAMAGE
PUBL  USCG, DEPT. OF TRANSPORTATION, REPORT NO. AD
      784463, DAPG-319, JUNE, 1967
ABST  THIS REPORT DISCUSSES POLLUTION OF LARGE EXPANSES
      OF OCEAN DUE TO TANKERS, OPERATIONAL PRACTICES,
      TRAFFIC DENSITY AND HUMAN FAILINGS.
KEYW  CONTROL, PREVENTION, REMOVAL, RECOVERY, CLEANUP,
      TANKERS
CODE  2911F

AUTH  ANONYMOUS
TITL  OIL SPILLAGE STUDY LITERATURE SEARCH AND CRITICAL
      EVALUATION FOR SELECTION OF PROMISING TECHNIQUES
      TO CONTROL AND PREVENTIVE DAMAGE
PUBL  USCG, DEPT. OF TRANSPORTATION, BATTELLE MEMORIAL
      INSTITUTE, REPORT NO. TCG-15560-A, NOV. 1967
ABST  THE PURPOSE OF THIS REPORT IS TO PROVIDE REVIEW
      AND EVALUATION OF CURRENT TECHNOLOGY OF PREVENTION
      AND CONTROL OF SPILLS, RESTORATION OF SHORE AND
      WATER FOWL, AND EFFECTS ON AQUATIC LIFE. OBJECT OF
      THE STUDY IS TO ASSIST IN ESTABLISHING PROCEDURES
      FOR CONTROL AND CLEANUP AND IMPROVED CAPABILITY
      FOR PREVENTION.
KEYW  RECOVERY, CLEANUP, CONTROL, PREVENTION
CODE  4018B

AUTH  ANONYMOUS
TITL  OIL SPILLS AND SPILLS OF HAZARDOUS SUBSTANCES
PUBL  OIL AND SPECIAL MATERIALS CONTROL DIVISION, OFFICE
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      OF WATER PROGRAM OPERATIONS, EPA, MARCH 1977
ABST  THIS PUBLICATION IS EFFECTIVE IN DESCRIBING SOME
      OF THE MORE SIGNIFICANT SPILL INCIDENTS AND THE
      MECHANISMS TO DEAL WITH THEM.
KEYW  PROTECTION, PREVENTION, MINIMIZE ENVIRONMENTAL
      IMPACT  -
CODE  6203F

AUTH  ANONYMOUS
TITL  OIL SPILLS AT SEA
PUBL  UNKNOWN
ABST  PHOTOGRAPHS ILLUSTRATING SOME OF THE CONSEQUENCES
      OF ACCIDENTS INVOLVING OIL.
KEYW  ACCIDENTS, CONSEQUENCES
CODE  7351F

AUTH  ANONYMOUS
TITL  OIL SPILLS: PROBLEMS AND OPPORTUNITIES
PUBL  MIT/MARINE INDUSTRY COLLEGIUM, OPPORTUNITY BRIEF,
      MIT SEA GRANT PROGRAM NO. 9, WORKING DRAFT 4/22/77
ABST  THIS IS A WORKING DRAFT WHICH TOUCHES THE PROBLEMS
      INVOLVED IN OIL SPILLS.
KEYW  CLEANUP, PREVENTION, TANKERS
CODE  6150F

AUTH  ANONYMOUS
TITL  OIL TAGGING SYSTEM STUDY
PUBL  FEDERAL WATER POLLUTION CONTROL ADMIN., DEPT. OF
      THE INTERIOR, MAY 1970
ABST  SEVERAL METHODS OF IDENTIFYING THE SOURCE OF OIL
      POLLUTION ARE CRITICALLY EXAMINED.
KEYW  IDENTIFICATION, SOURCES, TAGGING SYSTEM
CODE  0056A

AUTH  ANONYMOUS
TITL  OIL WATER SEPARATORS, A BIBLIOGRAPHY WITH
      ABSTRACTS
PUBL  US DEPT. OF COMMERCE, NTIS, SPRINGFIELD VA
CODE  6517A

AUTH  ANONYMOUS
TITL  OIL-ON-WATER DETECTOR
PUBL  HALTIKAINEN, MODEL 1475
ABST  THE ELECTRONIC OIL DETECTOR CONSISTS OF A SENSOR
      DEVICE SUSPENDED BETWEEN PONTOONS, CONNECTED BY A
      WIRE TO A CONTROL BOX ON SHORE. IT CAN DETECT OIL
      ON THE WATER IN VERY SMALL QUANTITIES BY MEASURING
      THE REFRACTIVE INDEX OF WATER. THE BROCHURE GIVES
      SPECIFICS.
CODE  3055P

AUTH  ANONYMOUS
TITL  OPERATION, ORGANIZATIONAL, DIRECT AND GENERAL
      SUPPORT AND DEPOT MAINTENANCE MANUAL REPAIR PARTS
PUBL  RECO INDUSTRIES, CINCINNATI OH
ABST  THIS MANUAL IS PUBLISHED FOR THE USE OF THE
      PERSONNEL OF RECO INDUSTRIES INC. PROVIDES
      INFORMATION ON OPERATION, MAINTENANCE,
      ACCESSORIES, COMPONENTS AND ATTACHMENTS.
KEYW  OPERATION, MAINTENANCE, ACCESSORIES
CODE  7003B

AUTH  ANONYMOUS
TITL  OPTICAL REMOTE SENSING OF OIL SLICKS: SIGNATURES
      ANALYSIS AND SYSTEMS EVALUATION
PUBL  UNIV. OF MICH. OCT. 1971
CODE  0204A

AUTH  ANONYMOUS
TITL  OUR DIRTY WATER
PUBL  PROVIDENCE SUNDAY JOURNAL, PROVIDENCE JOURNAL AND
      EVENING BULLETIN, OCT. 1971
ABST  A WEEK LONG EXAMINATION OF RI'S WATER POLLUTION
      CONTROL PROGRAM.
KEYW  SEWAGE TREATMENT, SHELLFISHING, TOXICITY
CODE  4034B

AUTH  ANONYMOUS
TITL  PART THREE COST ANALYSIS
PUBL  COMBATTING POLLUTION BY OIL SPILLS, VOL. 1
      METHODS, ARTHUR D. LITTLE, INC., AD 696635, JUNE
      1969, REPORT TO THE DEPARTMENT OF TRANSPORTATION
ABST  THIS REPORT DISCUSSES COSTS ASSOCIATED WITH
      COMBATANT METHODS.
KEYW  MATERIAL, OPERATION COSTS, CAPITAL COSTS
CODE  7135F

AUTH  ANONYMOUS
TITL  PARTICLE VACUUM ACCELERATED GRAVITY CONCEPT
PUB.  MECHANIC RESEARCH INC. FOR COAST GUARD
CODE  0350A

AUTH  ANONYMOUS
TITL  PARTICLE VACUUM ACCELERATED GRAVITY CONCEPT
PUBL  MECHANICS RESEARCH INC., SSIE NO. GZF-34
CODE  0452A

AUTH  ANONYMOUS
TITL  PERFORM A SCIENTIFIC STUDY TO DETERMINE THE DECAY
      OF OIL SLICKS UNDER VARING WINDS AND SEAS
PUBL  USCG, NO. CG-33, 18A-4, MARCH 19, 1973
CODE  2060A

AUTH  ANONYMOUS
TITL  PERFORMANCE EVALUATION OF AN OIL CONTAINMENT
      BARRIER AERIAL DELIVERY SYSTEM
PUBL  USCG, OFFICE OF R + D, REPORT NO. 734102-5/8, JAN.
      1974
CODE  0493A

AUTH  ANONYMOUS
TITL  PETROLEUM IN THE MARINE ENVIRONMENT
PUBL  WORKSHOP ON INPUTS, FATES, AND THE EFFECTS OF
      PETROLEUM IN THE MARINE ENVIRONMENT, OCEAN AFFAIRS
      BOARD, NATIONAL ACADEMY OF SCIENCES, MAY 21, 1973
ABST  PRIMARY CONCERN OF THE WORKSHOP WAS TO EVALUATE
      EXISTING INFORMATION RATHER THAN DEVELOP NEW
      RESEARCH.
KEYW  PETROLEUM INPUTS, FATES, EFFECTS
CODE  4035B

AUTH  ANONYMOUS
TITL  PHOTOGRAPHIC DETECTION OF SHIP-GENERATED OIL
      SLICKS
PUBL  USCG(DAT-41
CODE  0214A

AUTH  ANONYMOUS
TITL  PHYSICAL AND CHEMICAL BEHAVIOR OF CRUDE OIL SLICKS
      ON THE WATER
PUBL  JBF SCIENTIFIC CORP., PUBLICATION NO. 4290, APRIL
      30, 1976, PHOTOGRAPHS
ABST  FOUR SMALL RESEARCH OIL SPILLS WERE MADE IN THE
      NO. ATLANTIC TO DETERMINE THE PHYSICAL AND
      CHEMICAL BEHAVIOR OF FRESH OIL SLICKS ON THE OPEN
      OCEAN. EACH SPILL WAS MADE FROM A RESEARCH VESSEL
      AND THEN WAS TRACKED BY VESSEL AND AIRCRAFT FOR UP
      TO TWO DAYS. TWO CRUDE OILS WERE USED, AND EACH
      EXPERIENCED DIFFERENT SEA CONDITIONS.
KEYW  RESEARCH OIL SPILLS, PHYSICAL AND CHEMICAL
      BEHAVIOR, TRACKING
CODE  7672F (ORIGINAL PHOTOS WITH C. BROWN, 318 PASTORE
      HALL)

AUTH  ANONYMOUS
TITL  PHYSICAL PROCESS IN THE SPREAD OF OIL ON A WATER
      SURFACE
PUBL  MIT, AD 754 261
CODE  0193A

AUTH  ANONYMOUS
TITL  POLLUTING INCIDENTS IN AND AROUND US WATERS
      1971-1973
PUBL  USCG, DEPT. OF TRANSPORTATION
ABST  FOUR PAPERS WHICH LIST POLLUTING INCIDENTS
      ACCORDING TO WHERE, HOW MUCH, WHAT TYPE, ETC. OF
      OIL SPILLS.
CODE  3241P

AUTH  ANONYMOUS
TITL  POLLUTION INCIDENTS IN AROUND US WATERS, CALENDAR
      YEARS 1971,1972,1973
PUBL  USCG, DEPT. OF TRANSPORTATION
ABST  THESE REPORTS CONTAIN STATISTICS MAINTAINED BY THE
      COAST GUARD REPRESENTING DISCHARGES MADE IN THE US
      NAVIGABLE WATERS.
KEYW  STATISTICS, DISCHARGES, EFFECTS, US NAVIGABLE
      WATERS
CODE  6171F

AUTH  ANONYMOUS
TITL  PORT OF NEW BEDFORD, OFFSHORE OIL AND GAS
PUBL  MAYORS COMMITTEE ON OFFSHORE OIL, NEW BEDFORD
      PLANNING DEPT.
ABST  MAPS AND INFORMATION OF THE PORT OF NEW BEDFORD.
CODE  2663F

AUTH  ANONYMOUS
TITL  POTENTIAL OIL POLLUTION INCIDENTS FROM OIL AND GAS
      WELL ACTIVITIES IN LAKE ERIE - THEIR PREVENTION
      AND CONTROL
PUBL  INTERNATIONAL LAKE ERIE WATER POLLUTION BOARD,
      SEPT. 1969
ABST  THE REPORT DETERMINES THE ADEQUACY OF DRILLING
      OPERATIONS, CLEAN UP METHODS, AND CONTINGENCY
      PLANS TO CONFINE, REMOVE AND PREVENT OIL POLLUTION
      ON LAKE ERIE.
KEYW  DRILLING, CLEAN UP, CONTINGENCY, PREVENTION,
      REMOVAL, CONFINEMENT
CODE  0151A

AUTH  ANONYMOUS
TITL  PRELIMINARY GUIDE- FORECASTING OIL SLICK BEHAVIOR
PUBL  USCG, JULY 1971, AD 762 350
CODE  0191A

AUTH  ANONYMOUS
TITL  PRELIMINARY PHYSICAL IMPACTS OF OFFSHORE PETROLEUM
      DEVELOPMENTS
PUBL  MIT SEA GRANT PUBLICATION, MITSG 74-20
CODE  0385A

AUTH  ANONYMOUS
TITL  PRELIMINARY REPORT - ENVIRONMENTAL ASSESSMENT OF
      TREATED VERSUS UNTREATED OIL SPILLS
PUBL  COLLEGE OF ENGINEERING, DOE PROJECT, MARCH 1977
ABST  A DRAFT COPY OF THE ABOVE.
KEYW  TREATED SPILLS, ENVIRONMENTAL ASSESSMENT
CODE  REF.

AUTH  ANONYMOUS
TITL  PRELIMINARY REPORT, THE ARGO MERCHANT OIL SPILL
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PUBL US DEPT. OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ABST THIS IS A PRELIMINARY SCIENTIFIC REPORT CONTAINING A SUMMARY FACT SHEET REGARDING THE ARGO MERCHANT SPILL.
KEYW ARGO MERCHANT, SUMMARY FACT SHEET, SCIENTIFIC REPORT, OIL SPILL
CODE 6149F

AUTH ANONYMOUS
TITL PREVENTION AND CONTROL OF MARINE OIL POLLUTION REGIONAL MARINE OIL POLLUTION CONFERENCE-AUSTRALIA NOVEMBER 8-10, 1976
PUBL NATIONAL LIBRARY OF AUSTRALIA
ABST PAPERS PRESENTED: OIL POLLUTION OF THE SEA-THE WORLDWIDE SCENE; TANKER SAFETY AND THE ENVIRONMENT; OFFSHORE ACTIVITIES AND THE ENVIRONMENT; OIL SPILL CLEANUP; APPLICATION OF EQUIPMENT AND METHODS; THE CURRENT STATE OF OIL POLLUTION PREVENTION AND CONTROL IN THE US AND CANADA; THE SITUATION IN JAPAN; MARINE OIL POLLUTION LEGISLATION-WESTERN EUROPE; EVALUATION OF THE ENVIRONMENTAL IMPLICATIONS OF OIL SPILL DISPERSANT; EFFECTS OF OIL ON THE MARINE ENVIRONMENT; MARINE POLLUTION-LEGAL AND FINANCIAL ASPECTS.
KEYW OIL SPILL, PREVENTION, DISPERSANTS, OFFSHORE
CODE 7709 F

AUTH ANONYMOUS
TITL PREVENTION AND CONTROL OF OIL SPILLS
PUBL AMERICAN PETROLEUM INSTITUTE (LIBRARY OF CONGRESS CATALOG NO. 74-124324)
ABST PROCEEDINGS OF JOINT CONFERENCE ON PREVENTION AND CONTROL OF OIL SPILLS. JUNE 15-17, 1971 SHERATON PARK HOTEL, WASHINGTON, D.C.
KEYW OIL SPILL, PREVENTION, CONTROL
CODE 7771B

AUTH ANONYMOUS
TITL PREVENTION AND CONTROL OF OIL SPILLS
PUBL API, EPA, USCG, PROCEEDINGS OF JOINT CONFERENCE, JUNE 1971
ABST COMPREHENSIVE STUDY OF ALL SUBJECTS
CODE 6009A

AUTH ANONYMOUS
TITL PRIMARY PHYSICAL IMPACT OF OFFSHORE PETROLEUM DEVELOPMENTS
PUBL NOAA, MITSG 74-20, APRIL 1974, COM 74-11775
ABST THESE STUDIES ON THE INITIAL PHYSICAL EFFECTS OF OFFSHORE OIL DEVELOPMENT RESPOND TO THE NEED FOR INFORMATION ON POTENTIAL PETROLEUM PRODUCTION FROM THE ATLANTIC AND GULF OF ALASKAN CONTINENTAL SHELVES.
KEYW CONTINENTAL SHELVES, WEATHERING, EVAPORATION, DIFFUSION
CODE 6026B

AUTH ANONYMOUS
TITL PROBABLE BEHAVIOR AND FATE OF A WINTER OIL SPILL IN THE BEAUFORT SEA
PUBL TECHNOLOGY DEVELOPMENT REPORT NO. EPS-4OEC-77-5, ENVIRONMENTAL IMPACT CONTROL DIRECTORATE, AUG. 1978
KEYW DYNAMIC ICE, TRANSITION ZONE, MOVING ICE SHEET, BEAUFORT SEA
CODE 7141F

AUTH ANONYMOUS
TITL PROCEEDING FROM THE THIRTEENTH COASTAL ENGINEERING CONFERENCE
PUBL NATIONAL RESEARCH COUNCIL OF CANADA
ABST A DISCUSSION OF SOME MEASURED WAVE DATA HEIGHT AND PEAK PERIODS OF MEASURED WAVES IN OCEAN OF WESTERN HEAD, NOVA SCOTIA ARE COMPARED TO PARAMETER DERIVED FROM INDIVIDUAL WAVE HEIGHTS AND BY TUCKER METHOD.
CODE 6001F

AUTH ANONYMOUS
TITL PROCEEDINGS
PUBL JOINT CONFERENCE ON PREVENTION AND CONTROL OF OIL SPILLS, API, FWPCA, DEC. 1969
ABST OBJECTIVES WERE TO DELINEATE OVERALL DIMEN. OF OIL SPILL PROBLEMS. EXPLORE THE PRESENT STATE OF THE ART OF PREVENTION AND CONTROL OF OIL SPILLS. REVIEW OF THE RELEVANT RESEARCH AND DEVELOPMENT EFFORTS OF GOVERNMENT AND PRIVATE INDUSTRY.
KEYW OILSPILL, PREVENTION, CONTROL
CODE 6011A

AUTH ANONYMOUS
TITL PROCEEDINGS OF A WORKSHOP ON ENVIRONMENTAL OCEANOGRAPHY OF THE GULF OF MEXICO
PUBL DEPARTMENT OF OCEANOGRAPHY, TEXAS A & M UNIVERSITY
ABST THE AIM OF THE WORKSHOP WAS TO DEFINE THE MOST CRITICAL ENERGY-RELATED ENVIRONMENTAL PROBLEMS IN THE GULF OF MEXICO AND DEVELOP THE FRAMEWORK FOR A PROGRAM OF RESEARCH TO SOLVE THESE PROBLEMS.
KEYW ENERGY RELATED ENVIRONMENTAL PROBLEMS, RESEARCH, SOURCES OF ENERGY
CODE 2678F

AUTH ANONYMOUS
TITL PROCEEDINGS OF ECOLOGICAL DAMAGE ASSESSMENT CONFERENCE NOV. 12-14, 1979
PUBL SOCIETY OF PETROLEUM INDUSTRY BIOLOGISTS
ABST THE OBJECTIVE OF THIS CONFERENCE ON ECOLOGICAL DAMAGE ASSESSMENT IS TO BRING TOGETHER SCIENTISTS FROM GOVERNMENT, INDUSTRY AND UNIVERSITIES TO EXPLORE THE STATE-OF-THE-ART IN ECOLOGICAL DAMAGE ASSESSMENT.
KEYW ECOLOGICAL DAMAGE ASSESSMENT, OIL SPILL
CODE 7779F

AUTH ANONYMOUS
TITL PROCEEDINGS OF JOINT CONFERENCE ON PREVENTION AND CONTROL OF OIL SPILLS
PUBL API, EPA, USCG, MARCH 13-15, 1973
ABST VARIOUS ARTICLES REGARDING, PREVENTION, IDENTIFICATION OF OIL, CONTROL TECHNOLOGY, APPLIED CONTROL TECHNOLOGY AND BIOLOGICAL EFFECTS OF OIL SPILLS.
KEYW PREVENTION, IDENTIFICATION, TECHNOLOGY, BIOLOGICAL EFFECTS.
CODE 6002B

AUTH ANONYMOUS
TITL PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON WASTE OIL RECOVERY AND REUSE FEBRUARY 12 - 14, 1974
PUBL ASSOCIATION OF PETROLEUM RE-REFINERS
ABST OIL REUSE, WASTE OIL: CHARACTERISTICS AND USE AS A FUEL
KEYW WASTE OIL RECOVERY, MANAGEMENT, OIL SPILL
CODE 7768F

AUTH ANONYMOUS
TITL PROCEEDINGS ON A WORKSHOP ON THE PHYSICAL BEHAVIOR OF OIL IN THE MARINE ENVIRONMENT HELD IN PRINCETON, NEW JERSEY MAY 8-9, 1979
PUBL DEPARTMENT OF CIVIL ENGINEERING PRINCETON UNIVERSITY
ABST THE OBJECTIVE OF THE WORKSHOP IS TO EXAMINE CRITICALLY CURRENT KNOWLEDGE OF THE SUBJECT OF BRINGING TOGETHER FIFTY SCIENTISTS IN RELATED FIELDS OF RESEARCH. THE TWO DAYS OF INVITED PAPERS WERE DEVOTED TO THE EXAMINATION OF SIX AREAS INVOLVED WITH UNDERSTANDING THE PHYSICAL BEHAVIOR OF OIL.
KEYW OIL SPILL FORECASTING, MODELLING, ENTRAINMENT.
CODE 7780F

AUTH ANONYMOUS
TITL PROCEEDINGS: INDUSTRY GOVERNMENT SEMINAR OIL SPILL TREATING AGENTS, APRIL 8-9, 1970, WASHINGTON D.C.
PUBL API, COMMITTEE FOR AIR AND WATER CONSERVATION AND US DEPT. OF THE INTERIOR
ABST MAJOR OBJECTIVE: TO ARRANGE FOR A FORUM WHERE THE GUIDELINES FOR SAFE AND EFFECTIVE USE OF OIL SPILL TREATING AGENTS COULD BE CONSIDERED.
KEYW TREATING AGENTS, GUIDELINES FOR SAFETY, EFFECTIVE USE
CODE 0002A

AUTH ANONYMOUS
TITL PROCEEDINGS: JOINT CONFERENCE ON PREVENTION AND CONTROL OF OIL SPILLS
PUBL API - FWPCA, DEC. 15-17, 1969
ABST THE OBJECTIVE OF THE CONFERENCE WAS TO DELINEATE THE OVERALL DIMENSIONS OF THE OIL SPILLS PROBLEM, EXPLORE THE PRESENT STATE OF THE ART OF PREVENTION AND CONTROL AND REVIEW RELEVANT RESEARCH AND DEVELOPMENT EFFORTS.
KEYW FLUID DYNAMICS, DISPERSANTS, TOXICITIES
CODE 6001B

AUTH ANONYMOUS
TITL PRODUCT INFORMATION SHEET
PUBL UNKNOWN
ABST DISPERSANTS
KEYW DISPERSANTS
CODE 2675F

AUTH ANONYMOUS
TITL PROJECTS
PUBL HAZARDOUS MATERIAL SPILLS RESEARCH NEWSLETTER, VOL. 1, MAY 1971
ABST GIVES NEW PROJECTS PROPOSALS, DESCRIBES COMPLETION OF VARIOUS PROJECTS AND GENERAL INFORMATION ON RECENT OIL SPILLS.
CODE 3063H

AUTH ANONYMOUS
TITL PROTOTYPE HIGH SEAS OIL RECOVERY SYSTEM PHASE I
PUBL SYSTEM DEVELOPMENT - LOCKHEED MISSLES AND SPACE CO., FEB. 1972, AD 750 351, AD 750 352, AD 750 353
CODE 0185A

AUTH ANONYMOUS
TITL PUBLICATION AND MATERIALS
PUBL API
ABST CATALOG
CODE 2620G

AUTH ANONYMOUS
TITL PUBLICATION LIST FOR UNIVERSITIES
PUBL GENERAL ELECTRIC
ABST PUBLICATION PREPARED BY G.E.
CODE 2956H

AUTH ANONYMOUS
TITL RADAR IMAGERY OF OIL SLICKS
PUBL IEEE TRANSACTIONS ON AEROSPACE AND ELECTRONIC SYSTEMS, VOL. AES-9 SEPT. 1973

AUTH ANONYMOUS
TITL RADAR IMAGERY OF OIL SLICKS
PUBL IEEE TRANSACTIONS ON AEROSPACE AND ELECTRONIC SYSTEMS, VOL. AES-9, SEPT. 73, 630-636 PP
KEYW RADAR, OIL SLICK
CODE 0398R

AUTH ANONYMOUS
TITL RECENT OIL SPILLS
PUBL OIL AND HAZARDOUS MATERIALS RESEARCH NEWSLETTER, VOL. 1, JAN. 1970
ABST DISCUSSES THE HESS OIL SPILL AND THE GROUNDING OF THE BARGE FLORIDA.
CODE 3059R

AUTH ANONYMOUS
TITL RECOVERY OF FLOATING OIL ROTATING DISK TYPE SKIMMER
PUBL ATLANTIC RESEARCH SYSTEMS DIVISION, MARINE SYSTEMS, A DIVISION OF THE SUSQUEHANNA CORP., COSTA MESA, CA FOR EPA, JULY 1971
ABST LAB. TESTS OF DISC MATERIALS IN OILS RANGING FROM LIGHT DIESEL TO BUNKER C,INDICATING THAT ALUMINUM WAS BEST OVERALL. EXPERIMENTAL TESTS ON MODEL DISCS IN STILL WATER ESTABLISHED BASELINE PERFORMANCE DATA AND UNDERSTANDING OF SCALING EFFECTS. ALSO SHOWED THAT VELOCITY VECTOR IN THE FLUID SHOULD BE IN THE SAME DIRECTION AS THE CURRENT FLOW.
KEYW RECOVERY, ROTATING DISK, SKIMMERS
CODE 0004R

AUTH ANONYMOUS
TITL RECOVERY OF OIL SPILLS USING VORTEX ASSISTED AIRLIFT SYSTEM
PUBL EPA, PROJECT NO. 15080DJR, CONTRACT NO. 14-12-513, JULY, 1970
ABST STUDIES WERE CONDUCTED TO DETERMINE THE FEASIBILITY OF A CONCEPT FOR RECOVERY OF FLOATING OIL SLICKS WHICH UTILIZES A PUMP INDUCED VORTEX AND A VACUUM SUCTION OF COANDA NOZZLE.
KEYW RECOVERY, PUMP INDUCED VORTEX, VACUUM SUCTION, COANDA NOZZLE
CODE 0053R

AUTH ANONYMOUS
TITL RECYCLED OIL... A QUESTION OF QUALITY
PUBL NBS, STANDARD VOL. 21, NOV. 24 - DEC. 1, 1976
ABST THIS REPORT DISCUSSES THE REUSE OF WASTED OIL.
KEYW RECYCLING OIL, CONSUMPTION REDUCTION, HAZARD REDUCTION
CODE 2934F

AUTH ANONYMOUS
TITL REGULATION FOR VESSEL TO VESSEL TRANSFER OF PETROLEUM PRODUCTS
PUBL COASTAL RESOURCES MANAGEMENT COUNCIL, GENERAL LAWS OF RI, AUG. 1972
ABST A STATEMENT OF MINIMUM REQUIREMENTS OF PROCEDURES TO BE FOLLOWED DURING TRANSFER OF PETROLEUM AND PETROLEUM PRODUCTS FROM VESSEL TO VESSEL IN ORDER TO INSURE THAT SUCH TRANSFERS ARE CARRIED OUT IN A MANNER WHICH WILL NOT HARM MARINE ENVIRONMENT OF THIS STATE.
KEYW PETROLEUM TRANSFER
CODE 6045R

AUTH ANONYMOUS
TITL REGULATIONS FOR US TANK VESSELS CARRYING OIL IN FOREIGN TRADE AND FOREIGN TANK VESSELS THAT ENTER THE NAVIGABLE WATER OF THE US.
PUBL DEPT. OF TRANSPORTATION, USCG
CODE 7512A

AUTH ANONYMOUS
TITL REMOTE SAMPLER FOR DETERMINING RESIDUAL OIL CONTENTS OF SURFACE WATER
PUBL NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, NOV. 1972, AD 760 217
CODE 0217A

AUTH ANONYMOUS
TITL THE REMOTE SENSING OF OIL SLICKS BY RADAR
PUBL NAVAL RESEARCH LAB., AD 709 962
CODE 0212R

AUTH ANONYMOUS
TITL REMOTE SENSING OF SOUTHERN CALIFORNIA OIL POLLUTION EXPERIMENT
PUBL USCG, DAT-4, PB 203 194, JULY 1971
CODE 0203R

AUTH ANONYMOUS
TITL REMOTE SENSING OIL POLLUTION SYSTEM CONCEPT-CONCEPT EVALUATION
PUBL USCG DAT-4, JUNE 1971
CODE 0207R

AUTH ANONYMOUS
TITL REPORT BY THE DEPT. OF TRADE ON THE ACTION TAKEN TO DEAL WITH THE OIL SPILLED AS A RESULT OF THE COLLISION IN THE DOVER STRAIT ON NOV. 12, 1975 BETWEEN THE M/T OLYMPIC ALLIANCE AND HMS ACHILLES
PUBL ESSO EUROPE INC. LIBRARY, 1976
ABST THIS REPORT REFERS TO THE LAND BASED OPERATION, BUT IS PRIMARILY CONCERNED WITH THE COUNTER-MEASURES TAKEN AT SEA. THERE IS AN ANNEX WHICH DESCRIBES THE ANTI-OIL POLLUTION ORGANIZATION NATIONALLY AND THE FACILITIES AVAILABLE TO IT.
KEYW DISPERSANTS, ORGANIZATIONS, COUNTERMEASURES AT SEA
CODE 7681F

AUTH ANONYMOUS
TITL REPORT OF ACTIVITIES
PUBL SUB SEA OIL SERVICES SPA, AUG. 1969
ABST A DESCRIPTION OF VARIOUS PROJECTS UNDERTAKEN BY SSOS, THEIR PROCEDURES AND RESULTS. INCLUDES MANY PHOTOGRAPHS OF EQUIPMENT AND EXPLANATIONS OF THEM.
CODE 3046R

AUTH ANONYMOUS
TITL REPORT OF THE NATIONAL PLANNING CONFERENCE ON THE COMMERCIAL DEVELOPMENT OF THE OCEANS VOL. II PROGRAM ELEMENTS
PUBL ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION, US DEPT. OF COMMERCE, JUNE 1976, PB 265 705, DOC 5-36024
ABST VOL. II CONTAINS ALL OF THE PROGRAM ELEMENTS THAT WERE RECOMMENDED BY THE CONFERENCE.
KEYW OCEAN BASINS, ENVIRONMENTS, MARINE TRANSPORT
CODE 7212AF

AUTH ANONYMOUS
TITL REPORT OF THE NATIONAL PLANNING CONFERENCE ON THE COMMERCIAL DEVELOPMENT OF THE OCEANS VOL. I. CONFERENCE ADDRESSES AND SUMMARY
PUBL NOAA, ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION, PB 265 704, DOC 5-36024, JUNE 9-12, 1976
ABST CONFERENCE HELD IN WASHINGTON, D.C. AND ARLIE, VA., JUNE 1976. VOL. I CONTAINS THE ADDRESSES THAT OPENED THE SESSION AND THE SYNOPSIS REPORTS PRESENTED AT THE END OF THE SESSION.
KEYW OCEAN BASINS, ENVIRONMENTS, MARINE TRANSPORT
CODE 7212F

AUTH ANONYMOUS
TITL A REPORT ON POLLUTION OF THE NATION'S WATERS BY OIL AND OTHER HAZARDOUS SUBSTANCES
PUBL SECY OF INTERIOR, SECY OF TRANSPORTATION, FEB. 1968
ABST A STUDY TO EXAMINE HOW THE RESOURCES OF THE US COULD BEST BE MOBILIZED AGAINST THE POLLUTION OF WATER BY SPILLS OF OIL AND OTHER HAZARDOUS SUBSTANCES.
CODE 6018R

AUTH ANONYMOUS
TITL REPORT ON THE NORTH SEA OIL SPILL
PUBL U.S. ENVIRONMENTAL SCIENTISTS TEAM, U.S. DEPT. OF THE INTERIOR, FISH AND WILDLIFE SERVICE, MAY 1977
ABST THIS PAPER IS A TEAM REPORT ON THE NORTH SEA OIL SPILL.
KEYW RESPONSE, OIL SPILL, NORTH SEA
CODE 1232F

AUTH ANONYMOUS
TITL REPORT TO THE PRESIDENT AND CONGRESS
PUBL SECRETARY OF TRANSPORTATION, 92ND CONGRESS, APRIL 1971
ABST OIL POLLUTION LIABILITY AND FINANCIAL RESPONSIBILITY
CODE 6053A

AUTH ANONYMOUS
TITL RESEARCH AND DEVELOPMENT AND MONITORING PROGRAMS TO ASSESS OIL SPILL EFFECTS
PUBL OCEAN SCIENCE NEWS, JULY 4, 1977
ABST THIS MATERIAL POINTS OUT THE NEED FOR A WHOLE SYSTEM CONCEPT IN THE AREA OF RESEARCH, DEVELOPMENT AND MONITORING PROGRAMS TO ASSESS OIL SPILL EFFECTS ON THE MARINE ENVIRONMENT.
KEYW GOVERNMENT AGENCIES, DAMAGE ASSESSMENT, RESEARCH
CODE 2666F

AUTH ANONYMOUS
TITL RESEARCH AND DEVELOPMENT FOR A SHIPBOARD OIL AND WATER SEPARATION SYSTEM
PUBL US DEPT OF COMMERCE, PROJECT NO. 0108D3310A, JUNE 1963
ABST A MEANS OF SEPARATION WAS DEVELOPED WHICH INVOLVED THE USE OF A CAPACITANCE PROBE TO DIVERT THE RELATIVELY SMALL AMOUNT OF BALLAST WATER CONTAINING OVER ONE PERCENT OIL TO A HOLDING TANK OF EXISTING BALLAST TANK. THE REMAINDER OF THE WATER, WITH LESS THAN ONE PERCENT THROUGH A SERIES OF DUTCH WEAVE COALESCING SCREENS.
KEYW SEPARATION, CAPACITANCE PROBE BALLAST WATER
CODE 0062R

AUTH ANONYMOUS
TITL RESEARCH AND DEVELOPMENT FOR A SHIPBOARD OIL AND WATER SEPARATION SYSTEM
PUBL US DEPT. OF COMMERCE, MARITIME ADMINISTRATION, CONTRACT NO. MA-2722, DEC. 1966
ABST PART I OF THIS INVESTIGATION WAS TO OBTAIN INFORMATION ON WHICH TO BASE THE DEVELOPMENT OF A

PRACTICAL PACKAGE TYPE UNIT SUITABLE FOR SHIPBOARD SEPARATION OF BALLAST WATER FROM BUNKER C FUEL OIL. PART II DESCRIBES A LAND BASED PROTOTYPE UNIT CONSTRUCTED AND TESTED AT PORT MOBIL, STATEN ISLAND, NY.
KEYW SEPARATION, SHIPBOARD USE, BALLAST WATER, PROTOTYPE, COALESCENCE, FILTRATION BARRIERS
CODE 5125F

AUTH ANONYMOUS
TITL RESEARCH AND DEVELOPMENT PLANS, VOL. 2, (RESTRICTED)
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 71402/002-2
CODE 8749A

AUTH ANONYMOUS
TITL RESEARCH DEVELOPMENT AND DEMONSTRATION PROJECTS ON OIL POLLUTION CONTROL
PUBL OIL AND HAZARDOUS MATERIALS RESEARCH SECTION, EDISON WATER QUALITY LABORATORY, SEPT. 1970
ABST INDEX - LISTS PROJECTS ON OIL POLLUTION CONTROL
CODE 3060A

AUTH ANONYMOUS
TITL RESEARCH NEEDED TO DETERMINE CHRONIC EFFECTS OF OIL ON THE MARINE ENVIRONMENT
PUBL EXXON COMPANY, NOV. 4-6, 1974
ABST DELIBERATIONS AND RECOMMENDATIONS OF A WORKSHOP.
KEYW IDENTIFICATION, MEASUREMENT, MARINE ENVIRONMENT, FUNDING
CODE 3513F

AUTH ANONYMOUS
TITL RESEARCH NEEDED TO DETERMINE EFFECTIVENESS OF CHEMICALS IN TREATING OIL SPILLS AND THE TOXICITY OF CHEMICALLY DISPERSED OIL
PUBL EXXON PRODUCTION RESEARCH CO.
ABST DELIBERATIONS AND RECOMMENDATIONS OF A WORKSHOP SPONSORED BY EXXON PRODUCTION RESEARCH COMPANY, HELD IN HOUSTON, TEXAS, NOVEMBER 29-30,1976. A PANEL OF 14 RECOGNIZED INTERNATIONAL SCIENTISTS MET AND CONSIDERED RESEARCH NEED TO DETERMINE (1) THE EFFECTIVENESS OF CHEMICALS TO ACCELERATE NATURAL PROCESSES IN THE ENVIRONMENT, PRIMARILY DISPERSION, ACTING ON OIL SPILLS; & (2) THE EFFECTS ON THE MARINE ENVIRONMENT (TOXICITY) BOTH ACUTE AND CHRONIC OF OIL SPILLS TREATED WITH CHEMICALS COMPARED WITH UNTREATED SPILLS.
KEYW OIL SPILL, CHEMICAL, DISPERSANT
CODE 7749F

AUTH ANONYMOUS
TITL RESPONSES TO: "CRISIS SCIENCE: INVESTIGATIONS IN RESPONSE TO THE ARGO MERCHANT OIL SPILL" BY STOLZENBACH AND PARSONS
PUBL URI, GRADUATE SCHOOL OF OCEANOGRAPHY, DEC. 1977
ABST COMMENTS ON THE ABOVE ARTICLE FROM VARIOUS URI FACULTY MEMBERS.
KEYW OILSPILL, ARGO MERCHANT
CODE 7654F

AUTH ANONYMOUS
TITL RESULTS OF OVERFLIGHT OF CHEVRON OIL SPILL IN THE GULF OF MEXICO
PUBL NASA, AD 714 681
CODE 0213A

AUTH ANONYMOUS
TITL RESULTS OF THE REGION I WORKSHOP ON OIL SPILL ECOLOGICAL DAMAGE ASSESSMENT
PUBL METREK DIVISION THE MITRE CORPORATION
ABST THE BROAD AIM OF THE WORKSHOP WAS TO IDENTIFY SCIENTIFIC NEEDS AND RESOURCES THAT MIGHT BE INCORPORATED IN A NEW ENGLAND REGIONAL RESPONSE PLAN FOR ECOLOGICAL DAMAGE ASSESSMENT
KEYW ASSESSMENT, DISPERSANTS, OILSPILL
CODE 7726F

AUTH ANONYMOUS
TITL A REVIEW OF MECHANICAL SYSTEMS FOR THE RECOVERY OF OIL SPILLED ON WATER
PUBL INSTITUTE OF PETROLEUM, COORD. COM. FOR THE PREV. OF SEA POLL. APRIL 1974
CODE 0725A

AUTH ANONYMOUS
TITL A REVIEW OF THE DRAFT ENVIRONMENTAL IMPACT STATEMENT ON THE PROPOSED OUTER CONTINENTAL SHELF OIL AND GAS LEASE SALE (NO. 42) OFFSHORE THE NORTH ATLANTIC STATES
PUBL COASTAL RESOURCES CENTER, URI, GRADUATE SCHOOL OF OCEANOGRAPHY, NOV. 3, 1976
ABST THIS REPORT IS TO PERFORM A REVIEW OF ALL SECTIONS WITH EMPHASIS ON TECHNICAL CONTENT AND QUALITY.
KEYW ENVIRONMENTAL IMPACT, LEASES, TECHNICAL CONTENT
CODE 6185G

AUTH ANONYMOUS
TITL REVIEW OF THE SANTA BARBARA CHANNEL OIL POLLUTION INCIDENT
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 714102/003
CODE 0750A

AUTH ANONYMOUS
TITL RFD/SANFORD BOOM
PUBL REPORT NO. INT 86, HYDRAULICS RESEARCH STATION, 1971
CODE 0733A

AUTH ANONYMOUS
TITL SAN FRANCISCO OIL SPILL
PUBL SPECIAL SUBCOMMITTEE, 92ND CONGRESS, FEB. 8-9, 1971
ABST HEARINGS ON TANKER COLLISION OF JAN. 8, 1971 IN SAN FRANCISCO BAY BETWEEN ARIZONA STANDARD AND OREGON STANDARD AND EFFECTS OF RESULTING MASSIVE OIL SPILL.
KEYW OILSPILL, SAN FRANCISCO
CODE 6051A

AUTH ANONYMOUS
TITL SANTA BARBARA - OIL POLLUTION, BIOLOGICAL EFFECTS
PUBL UNIV. OF CA., OCT. 1970
ABST 1969 STUDY OF BIOLOGICAL EFFECTS OF OIL SPILL WHICH OCCURRED AT SANTA BARBARA CAL. IN 1969.
CODE 6021A

AUTH ANONYMOUS
TITL SANTA BARBARA OIL SPILL: SHORT-TERM ANALYSIS OF MACROPLANKTON AND FISH
PUBL EPA, CONTRACT NO. 14-12-534, PROJECT NO. 15000EAL, 1971
ABST COLLECTIONS OF DEEP AND SHALLOW MACROPLANKTON FROM THE SANTA BARBARA CHANNEL AREA OF THE 1969 OIL SPILL AND FROM THE SANTA BARBARA BASIN FURTHER OFFSHORE WERE COMPARED WITH OTHERS FROM PREVIOUS YEARS FOR POSSIBLE OIL DAMAGE.
KEYW MACROPLANKTON, SANTA BARBARA CHANNEL, ANALYSIS
CODE 0050A

AUTH ANONYMOUS
TITL SANTA BARBARA OIL SYMPOSIUM
PUBL UNIVERSITY OF CALIFORNIA AT SANTA BARBARA, OFFSHORE PETROLEUM PRODUCTION, AN ENVIRONMENTAL INQUIRY, DEC. 16-18, 1970
ABST THE PURPOSE OF THE SYMPOSIUM WAS TO ASSEMBLE A GROUP OF KNOWLEDGEABLE SPEAKERS TO DISCUSS THE EFFECTS OF THE SANTA BARBARA OIL SPILL OF JAN. 28, 1969.
KEYW OILSPILL, SYMPOSIUM
CODE 4003A

AUTH ANONYMOUS
TITL SEA CURTAIN
PUBL KEPNER PLASTICS FABRICATORS INC.
ABST THESE BULLETINS DESCRIBE SEVERAL OIL SPILL CONTAINMENT BOOMS AND ACCESSORIES.
CODE 3069F

AUTH ANONYMOUS
TITL SEABOOM HOLDS OIL SPILLS
PUBL MECHANICAL ENGINEERING MAY 1974
CODE 0368A

AUTH ANONYMOUS
TITL SEARCH MOUNTS FOR SIX MEN MISSING AFTER SHIP HITS OIL RIG
PUBL PROVIDENCE JOURNAL BULLETIN, AUG. 16, 1975
ABST A BRITISH TANKER, THE ECOBIIA SUN, SLAMMED INTO AN OFFSHORE DRILLING PLATFORM.
KEYW TANKER, ACCIDENTS, OFFSHORE DRILLING PLATFORM
CODE 7641F

AUTH ANONYMOUS
TITL SEPARATORS
PUBL PETRECHEMICAL SEPARATOR CO.
ABST THIS BULLETIN DESCRIBES SEVERAL SEPARATORS USED FOR SEPARATION OF EMULSIFIED OILS FROM WATER.
CODE 3068F

AUTH ANONYMOUS
TITL SHIP GENERATED POLLUTION TANKER AND NON TANKER
PUBL UNKNOWN
ABST THIS PAPER PRESENTS ESTIMATES AND PROJECTIONS OF TANKER DISCHARGE AND LEGISLATURE REGARDING DISCHARGES.
KEYW TANKERS, DISCHARGES, LEGISLATION
CODE 5009F

AUTH ANONYMOUS
TITL SKIMMER FLOATS OIL OUT OF WATER
PUBL MACHINE DESIGN, 1974
CODE 0374A

AUTH ANONYMOUS
TITL SKIMMER PUMPING RATE ADJUSTABLE TO 300 GPM
PUBL OIL AND GAS JOURNAL, 1974
CODE 0373A

AUTH ANONYMOUS
TITL SLICK SOLUTION
PUBL SURFACE SEPARATOR SYSTEMS, AUG. 1962
ABST OIL SLICKS FROM SPILLAGE AROUND TANKER BERTHS CONFINED BY FLOATING BARRIER OF NEOPRENE COATED FABRIC PONTOONS.
CODE 6015A

AUTH ANONYMOUS
TITL SLICK THINKING
PUBL THE UNIVERSITY OF MICHIGAN, COLLEGE OF

ENGINEERING, JULY 1975
ABST A REPORT ON CONTAINMENT DEVICES TESTED.
KEYW CLEANUP, HYDROPHOBIC MOP, OLEOPHILIC MOP, CONTAINMENT DEVICES, PICKUP DEVICES, BARRIERS, HEADERS
CODE 2977F

AUTH ANONYMOUS
TITL SOLUBILITY IN WATER OF NORMAL C9 AND C10 HYDROCARBONS
PUBL SCIENCE
ABST A NEW METHOD FOR EQUILIBRATING WATER CONTAINING ALKANE HYDROCARBONS WITH GAS PHASE AND ANALYZING THE GAS FOR CHROMATOGRAPHY EXTENDS ANALYTICAL SENSITIVITY TO BETTER THAN 0.1 PAT PER BILLION.
CODE 2631A

AUTH ANONYMOUS
TITL SOURCES EFFECTS AND SINKS OF HYDROCARBONS IN THE AQUATIC ENVIRONMENT
PUBL AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES AUGUST 9-11 1976
ABST PROCEEDINGS OF THE SYMPOSIUM AMERICAN UNIVERSITY WASHINGTON DC AUGUST 9-11 1976 . A CURRENT LOOK AT THE EFFECTS OF CURRENT PRACTICES & PROCEDURES UPON BIOLOGICAL SYSTEMS INVOLVING THE INDUSTRIAL, GOVERNMENTAL, AND ACADEMIC R&D WORLDS. CONSIDERING THE LONG RANGE AS WELL AS THE SHORT RANGE EFFECTS.
KEYW HYDROCARBONS, WASTE DISPOSAL RECOVERY, TRANSPORT
CODE 4040 B

AUTH ANONYMOUS
TITL SPECIFICATION FOR MECH. OIL BARRIER SYSTEMS
PUBL MEMO NO. EOE-2-235, USCG, OCEAN ENGR. DIV., NOV. 1971
CODE 0719A

AUTH ANONYMOUS
TITL SPECIFICATION FOR MECHANICAL OIL BARRIERS SYSTEM
PUBL OCEAN ENGINEERING DIVISION, US COAST GUARD, REPORT NO. EOE-2-235, NOV. 26, 1971
ABST DESCRIBES SPECIFICATION OF A COMMERCIAL TYPE MECHANICAL FLOATING OIL BOOM.
KEYW CONTAINMENT, CONTROL, BOOMS
CODE 0873F

AUTH ANONYMOUS
TITL SPILL TRAINING AND EDUCATIONAL PROGRAM
PUBL TEXAS A & I, CONTRACT NO. E (40-1) 4995 WITH USERDA
ABST INCLUDES HISTORY AND CASE HISTORIES OF OIL SPILLS. NATIONAL POLICY, PROPERTIES OF OIL, CONTAINMENT, REMOVAL, DISPOSAL, SPILLS IN THE ENVIRONMENT, RECOMMENDED PROCEDURES FOR USE OF OIL SPILL RADIO FREQUENCIES, LEGAL, COSTS OF CLEANUP, CONTINGENCY PLANNING, INLAND OIL SPILLS, OPERATION RESCUE, SUGGESTED PROCEDURE FOR DEVELOPMENT OF SPILL PREVENTION CONTROL AND COUNTERMEASURES PLANS.
KEYW REMOVAL, CONTAINMENT, DISPOSAL, CONTINGENCY, CLEANUP, PREVENTION
CODE 7684B

AUTH ANONYMOUS
TITL STANDARD DISPERSANT EFFECTIVENESS AND TOXICITY TEST
PUBL NATIONAL ENVIRONMENTAL RESEARCH CENTER, OFFICE OF RESEARCH AND MONITORING, EPA R2-73-201, MAY 1973
ABST A BRIEF HISTORY OF THE DEVELOPMENT OF THE STANDARD EPA DISPERSANT EFFECTIVENESS IS DISCUSSED.
KEYW DISPERSANTS, TOXICITY
CODE 2536F

AUTH ANONYMOUS
TITL STORAGE WASTES FROM WATER CRAFT AND DISPOSAL AT SHORE FACILITIES
PUBL EPA, CONTRACT NO. 14-12-509
ABST TO TEST THE EFFECTIVENESS AND ACCEPTABILITY OF A WATERCRAFT IMPOUNDMENT SYSTEM IN CONTROLLING WASTE SOURCES, SANITARY AND GALLEY WASTE. DEMONSTRATION UNIT WAS DESIGNED AND BUILT AND TEST DATA WAS ANALYZED AND EVALUATED.
KEYW WATERCRAFT IMPOUNDMENT SYSTEM, CONTROLLING WASTE SURFACES
CODE 0049A

AUTH ANONYMOUS
TITL STUDIES OF OIL RETENTION BOOM HYDRODYNAMICS
PUBL HYDRODYNAMICS INC. AD 719 294
CODE 0175A

AUTH ANONYMOUS
TITL STUDY OF HYDRAULIC MEMBRANES FOR OIL-WATER SEPARATION
PUBL USCG
ABST HYDRAULIC MEMBRANES, OIL-WATER SEPARATION
CODE 0248A

AUTH ANONYMOUS
TITL A STUDY OF SPRAY ON LINES FOR PETROLEUM PRODUCT STORAGE AREAS ON THE NORTH
PUBL EBA ENGINEERING CONSULTANTS, EPS REPORT NO. EPS-4-EC-77-2, FEB. 1977
ABST THIS PAPER DISCUSSES A SPRAY ON LINES SYSTEM FOR STORAGE AREAS IN THE NORTH
KEYW SPRAY ON LINES SYSTEM, STORAGE AREAS, RETENTION
CODE 7140F

AUTH ANONYMOUS
TITL A STUDY OF THE BEHAVIOR OF OIL SPILLS IN THE ARCTIC
PUBL USCG, AD 717 142
KEYW ARCTIC, BEHAVIOR, STUDY
CODE 0195A

AUTH ANONYMOUS
TITL SUMMARY OF AWARDS 1975 DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY
PUBL NATIONAL SCIENCE FOUNDATION
ABST THIS REPORT PRESENTS BRIEF SUMMARIES OF PROJECTS FUNDED BY THE DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY IN 1975, AND PROJECTS FUNDED DURING PREVIOUS YEARS THAT WERE ACTIVE DURING THAT PERIOD. REPORT DESCRIBES THE NATURE OF THE DIVISION'S SEVEN PROGRAMS: ENVIRONMENTAL EFFECTS OF ENERGY, TRACE CONTAMINANTS: REGIONAL ENVIRONMENTAL MANAGEMENT, EARTHQUAKE ENGINEERING: FIRE RESEARCH, SOCIOECONOMIC RESPONSE TO NATURAL HAZARDS, WEATHER MODIFICATION
KEYW ENVIRONMENTAL IMPACTS, POLLUTION, HAZARDS, FIRES
CODE 2676 F

AUTH ANONYMOUS
TITL SUMMARY OF CAPABILITIES
PUBL US ARMY CORPS. OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, PAPER NO. 3-64
ABST THE MISSION, HISTORY, ORGANIZATION, AND PHYSICAL FACILITIES OF THE COASTAL ENGINEERING CENTER ARE PRESENTED.
CODE 3041A

AUTH ANONYMOUS
TITL SUMMARY OF COSTS OF COMBATTING OIL SPILLS
PUBL DEPT. OF MECHANICAL ENGINEERING AND APPLIED MECHANICS, JAN. 1976
ABST COMBATTING SPILLS, COST EVALUATION, CLEANUP
CODE 5090F

AUTH ANONYMOUS
TITL SUMMARY OF MIT HYDRODYNAMICS STUDIES
PUBL ASW ENVIRONMENTAL TECHNOLOGY GROUP-OCEAN TECHNOLOGY DIVISION, NAVAL UNDERWATER SYSTEMS CENTER, NEWPORT, RI, FEB. 1978
ABST THE OVERALL OBJECTIVE OF THIS PROGRAM IS TO DETERMINE THE INFLUENCE OF OIL SLICK CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES ON OIL SLICK DISPERSION.
KEYW TURBULENCE, WIND/WAVE, DISPERSION
CODE 2660F

AUTH ANONYMOUS
TITL SUPPORT SYSTEMS TO DELIVER AND MAINTAIN OIL RECOVERY SYSTEMS AND DISPOSAL OF RECOVERED OIL
PUBL BATTALLE COLUMBUS, JAN. 1974, AD 778 941
CODE 0187A

AUTH ANONYMOUS
TITL SURFACE COLLECTING AGENTS
PUBL SHELL OIL CO. LOSS PREVENTION DEPT., MARCH 1978
ABST VARIOUS ARTICLES
KEYW COLLECTING AGENTS, SPREADING, OIL HERDER
CODE 7676F

AUTH ANONYMOUS
TITL SURFACE SKIMMER FOR REMOVING FUEL OIL SPILLS FROM WATER SURFACE
PUBL FLORIDA POWER AND LIGHT CO., SSIE NO. AO-876
CODE 0447A

AUTH ANONYMOUS
TITL SURVEY OF COMMERCIAL OIL-WATER SEPARATORS
PUBL USCG, G-DET-1, AUG. 1973
CODE 0231A

AUTH ANONYMOUS
TITL SURVEY STUDY TO SELECT A LIMITED NUMBER OF HAZARDOUS MATERIALS TO DEFINE AMELIORATION REQUIREMENTS, VOL. 1
PUBL USCG, MARCH 1974
CODE 0256A

AUTH ANONYMOUS
TITL SURVEYS AND INVESTIGATIONS TO DETERMINE SOURCES, CAUSES, EFFECTS AND MOVEMENT OR DISPERSION OF OIL AND HAZARDOUS SUBSTANCES SPILLED IN THE COASTAL AND ESTUARINE ZONES
PUBL RFP WA 72A-3, EPA, OCT. 18, 1971
CODE 2059A

AUTH ANONYMOUS
TITL TANKER OIL SPILLS
PUBL WESTERN CO. OF NORTH AMERICA, RESEARCH DIVISION, JAN. 1971
ABST GETTING CRUDE OILS TO REDUCE MARINE POLLUTION FROM TANKER OIL SPILLS.
CODE 6049A

AUTH ANONYMOUS
TITL TECHNICAL DATA BOOK - PETROLEUM REFINING
PUBL API
ABST CHAPTERS 7-14, TECHNICAL DATA BOOK OF OIL REFINING
KEYW TECHNICAL DATA, REFINING
CODE 6177F

AUTH ANONYMOUS
TITL TECHNICAL PROGRESS REPORT - YEAR ONE, 1975-1976, A FACILITY FOR THE EXPERIMENTAL ANALYSIS OF COASTAL MARINE ECOSYSTEMS
PUBL URI, GRADUATE SCHOOL OF OCEANOGRAPHY
ABST THE PROGRESS REPORT COVERS PERFORMANCE DURING THE FIRST THREE QUARTERS OF THE YEAR WITH ACTIVITIES PROJECTED FOR THE FOURTH QUARTER. REPLICATE MESO-SCALE EXPERIMENTAL ECOSYSTEMS SIMULATING A VARIETY OF COMMON COASTAL MARINE ENVIRONMENTS WILL BE DEVELOPED AND MAINTAINED AT A SPECIAL SHORE BASED LAB.
KEYW MESO-SCALE, ECOSYSTEMS, COASTAL MARINE ENVIRONMENT
CODE 7683F

AUTH ANONYMOUS
TITL A TECHNIQUE FOR PREDICTING THE MOVEMENT OF OIL SPILLS IN NEW YORK HARBOR
PUBL FEB. 1974, AD 786 627
CODE 0229R

AUTH ANONYMOUS
TITL A TECHNIQUE FOR PREDICTING THE MOVEMENT OF OIL SPILLS IN NEW YORK HARBOR
PUBL USCG, NATIONAL TECHNICAL INFORMATION SERVICE, AD 786627, FEB. 1975
ABST A SAMPLE METHOD OF FORECASTING THE MOVEMENT OF AN OIL SLICK WITHIN THE HARBOR.
KEYW FORECASTING, MOVEMENT, HARBORS
CODE 3012R

AUTH ANONYMOUS
TITL TENTATIVE METHODS FOR COMPARISON OF WATERBORNE PETROLEUM OILS BY GAS CHROMATOGRAPHY
PUBL ASTM, DESIG., D3328-74T
ABST THIS PAPER DISCUSSES THE METHODS OF COMPARISON OF PETROLEUM OILS RECOVERED FROM WATER OFF BEACHES.
KEYW RECOVERY, GAS CHROMATOGRAPHY, SAMPLE ANALYSIS
CODE 1229F

AUTH ANONYMOUS
TITL TENTATIVE PRACTICE FOR IDENTIFICATION OF WATERBORNE OILS
PUBL ASTM, D-3415-75T
ABST THIS PAPER DISCUSSES THE BROAD CONCEPTS OF SAMPLING AND ANALYZING WATERBORNE OILS FOR IDENTIFICATION AND COMPARISION WITH SOURCE OILS.
KEYW IDENTIFICATION, CHEMICAL CHARACTERIZATION, SAMPLING AND ANALYZING
CODE 1228F

AUTH ANONYMOUS
TITL TESTING AND EVALUATION OF OIL SPILL RECOVERY EQUIPMENT
PUBL EPA, WATER QUALITY OFFICE, REPORT NO. PB 200 081
ABST A DETAILED REPORT CONTAINING BOTH THE TEST RESULTS ON THE CAPABILITIES AND LIMITATIONS OF THE VARIOUS EQUIPMENT TYPES WERE TESTED.
KEYW RECOVERY, CURTAIN BOOMS, FENCE BOOMS, AIR BARRIER, SKIMMERS
CODE 0408F

AUTH ANONYMOUS
TITL TESTING AND EVALUATION OF OIL SPILL RECOVERY EQUIPMENT
PUBL WATER POLLUTION CONTROL SERIES EPA, REPORT NO. 15080DOZ 12/70
KEYW BARRIERS, SKIMMERS
CODE 0715R

AUTH ANONYMOUS
TITL THEORETICAL STUDY TO DETERMINE THE SEA STATE LIMIT FOR THE SURVIVAL OF OIL SLICKS ON THE OCEAN
PUBL ARTHUR D. LITTLE, INC.ADL NO. 79244, FEB. 1977
ABST THE RESULTS FROM THIS PROGRAM ARE DISCUSSED UNDER TWO BROAD CLASSIFICATIONS, THOSE OBTAINED FROM THE BACKGROUND STUDY-LITERATURE SEARCH AND THOSE RESULTING FROM THE PHYSICAL MODELS DEVELOPED.
KEYW TRANSPORT, TANKERS, OIL DISCHARGE
CODE 8130B

AUTH ANONYMOUS
TITL TIDAL CURRENT TABLES 1979. ATLANTIC COAST OF NORTH AMERICA
PUBL NOAA NATIONAL OCEAN SURVEY
ABST DAILY PREDICTED TIMES OF SLACK WATER AND PREDICTED TIMES & VELOCITIES OF MAXIMUM CURRENT (FLOOD AND EBB) ARE PRESENTED IN A TABLE FOR A NUMBER OF REFERENCE STATIONS. CURRENT DIAGRAMS ARE GIVEN FOR A NUMBER OF IMPORTANT CHANNELS AND AN INDEX OF THE STATIONS IS ALSO GIVEN.
KEYW TIDAL CURRENTS, OCEAN TIDES, OCEANOGRAPHIC DATA
CODE 7701 F

AUTH ANONYMOUS
TITL THE TROPOSPHERIC TRANSPORT OF POLLUTANTS AND OTHER SUBSTANCES TO THE OCEANS
PUBL NATIONAL ACADEMY OF SCIENCES
ABST WORKSHOP WAS HELD ON DECEMBER 8-12, 1975. THE ULTIMATE OBJECTIVE OF EACH PANEL WAS TO PRODUCE A REPORT THAT CRITICALLY SUMMARIZED PRESENT KNOWLEDGE AND MADE SPECIFIC AND REALISTIC RECOMMENDATIONS AS TO THE TYPES OF MEASUREMENTS AND PROGRAMS THAT WOULD BE NECESSARY IN ORDER TO MAKE AN ACCURATE ASSESSMENT OF ATMOSPHERIC TRANSPORT FLUXES TO THE OCEANS.
KEYW MODELING HYDROCARBONS, RADIONUCLIDES, TROPOSPHERIC
CODE 7716 F

AUTH ANONYMOUS
TITL U.S./R.+D.
PUBL GOVERNMENT DATA PUBLICATIONS, SEPT. 1976
ABST A RESEARCH AND DEVELOPMENT INDEX.
KEYW RESEARCH, DEVELOPMENT, INDEX
CODE 7665F

AUTH ANONYMOUS
TITL ULTRASONIC EMULSIFICATION OF OIL TANKER CARGO
PUBL SONICS INTERNATIONAL INC., FEDERAL WATER POLLUTION CONTROL ADMINISTRATION, DEPT. OF THE INTERIOR, APRIL 1970, NO. PB 192 633
ABST THE ULTRASONIC EMULSIFICATION OF OIL FOR MARINE TRANSPORTATION HAS BEEN TESTED FOR FEASIBILITY, AS A POLLUTION PREVENTATIVE CONCEPT.
KEYW CONTINUOUS PROCESS, TOXICITY, TANKER, ULTRASONICS, EMULSION STABILITY
CODE 5038F

AUTH ANONYMOUS
TITL US CHECKING UP ON FIRMS SPILL PREVENTION PLANS
PUBL OIL AND GAS JOURNAL, VOL. 72, NO. 30, JULY 29, 1974
ABST SPOT CHECKS ON INDUSTRIES AND ENCOURAGEMENT TO CONTAIN OIL SPILLS.
CODE 3121R

AUTH ANONYMOUS
TITL US VS. BOTC
PUBL POLLUTION CONTROL GUIDE, VOL. 3, 6-3-74
ABST DISCHARGE OF OIL INTO NAVIGABLE WATERS, DEFENDENT COMPLAINED LAWS WERE VAGUE, COURT UPHELD LAWS.
CODE 3131R

AUTH ANONYMOUS
TITL USE OF CHEMICALS TO TREAT OIL ON WATER - STATUS REPORT
PUBL NORTHEAST REGION RESEARCH AND DEVELOPMENT PROGRAM, REPORT NO. PB 215 064, FEB. 20, 1969
ABST THIS PAPER DISCUSSES FACTORS TO BEAR IN MIND WHEN USING CHEMICALS TO TREAT OIL IN WATER.
KEYW DISPERSANTS, ENVIRONMENT, FLOATING ABSORBENTS, SINKING AGENTS, GELLING AGENTS, BURNING AGENTS
CODE 2919F

AUTH ANONYMOUS
TITL USE OF DISPERSANTS FOR OIL POLLUTION SUBMITTED BY THE UNITED KINGDOM
PUBL MARINE ENVIRONMENT PROTECTION COMMITTEE, III/INF9, JUNE 10, 1975
ABST LIST OF DISPERSANTS WHICH HAVE BEEN AUTHORIZED FOR USE AT SEA, IN COASTAL WATERS AND BEACHES AROUND THE UNITED KINGDOM.
KEYW DISPERSANTS, UNITED KINGDOM
CODE 5077F

AUTH ANONYMOUS
TITL THE USE OF LARGE MARINE MICROCOSMS TO STUDY THE FATES AND EFFECTS OF CHRONIC LOW LEVEL POLLUTANTS
PUBL THE MARINE ECOSYSTEMS RESEARCH LABORATORY, GRADUATE SCHOOL OF OCEANOGRAPHY, URI 1979
ABST CONTROLLED EXPERIMENTS IN MICROCOSMS OF THE NATURAL ECOSYSTEM PROVIDE AN OPPORTUNITY TO ACQUIRE DETAILED QUANTITATIVE UNDERSTANDING OF THE VARIOUS TYPES OF PROCESSES AFFECTING THE TRANSFER AND DEGRADATION OF SUBSTANCES IN NATURE AND ON THE EFFECTS SUCH SUBSTANCES MIGHT HAVE ON COASTAL MARINE ECOSYSTEMS. ACCORDINGLY, LARGE MICROCOSMS WERE ESTABLISHED AT THE MARINE ECOSYSTEM RESEARCH LABORATORY (MERL) TO PROVIDE SUCH INFORMATION TO THE EPA.
KEYW MICROCOSMS, ECOSYSTEMS, BIOLOGICAL & CHEMICAL
CODE 7739F

AUTH ANONYMOUS
TITL USING CHEMICALS FOR CLEANING UP OIL SPILLS
PUBL OCEAN INDUSTRY, VOL. 5, NO. 8, AUG. 1970, POLLUTION CONTROL REPORT, PART 3
ABST THIS PAPER DISCUSSES METHODS FOR CLEANING UP.
KEYW CLEANUP, DISPERSANTS
CODE 2126F

AUTH ANONYMOUS
TITL VIKOMA SYSTEM DESIGNED TO CONTROL AND LIMIT OIL SPILLS OCCURRING AT SEA
PUBL OIL AND GAS JOURNAL
CODE 8309R

AUTH ANONYMOUS
TITL VORTEX CONCEPT FOR SEPARATING OIL FROM WATER
PUBL UNITED AIRCRAFT RESEARCH LABS., JAN. 1973, AD 758 320
CODE 0232R

AUTH ANONYMOUS
TITL VORTEX SEPARATION FOR OIL SPILL RECOVERY SYSTEMS
PUBL AMERICAN PROCESS EQUIPMENT CORP.
ABST TWO PHASE PROGRAM, DESIGN, FABRICATE, AND TEST A 1 MGD PROTOTYPE OIL/WATER SEPARATOR. PHASE 1: EXPERIMENTAL 50 GPM SEPARATOR BUILT AND TESTED. PHASE 2: FULL SCALE PROTOTYPE TESTED BY STANDARD OIL CO. NOTE: PUBLISHED FOR THE WATER QUALITY OFFICE, EPA.

KEYW VORTEX SEPARATION, RECOVERY SYSTEMS, DESIGN, FABRICATION, TESTING
CODE 0003A

AUTH ANONYMOUS
TITL THE WARNE INFLATABLE OIL SPILLAGE BOOM
PUBL WILLIAM WARNE AND CO. LTD.
ABST A PICTORIAL SUPPLEMENT DESCRIBING THE WARNE BOOM.
CODE 6014B

AUTH ANONYMOUS
TITL WARNE OIL SPILLAGE BOOMS
PUBL SURFACE SEPARATOR SYSTEMS
ABST THIS ADVERTISEMENT DISCUSSES THE VARIOUS TYPES OF WARNE BOOMS AVAILABLE AS WELL AS SUGGESTED INSTALLATION TECHNIQUES.
CODE 3005B

AUTH ANONYMOUS
TITL WASTE OIL RECOVERY PRACTICES STATE OF THE ART
PUBL PRESENTATION OF EPA , DEC. 1972
ABST A STUDY OF WASTE OIL PRODUCTION, COLLECTION, REPROCESSING, RE/REFINING AND DISPOSAL WAS CARRIED OUT EMPHASIZING THE STATE OF MD.
KEYW RECOVERY, WASTE DISPOSAL, LIQUID WASTES DISPOSAL
CODE 0150A

AUTH ANONYMOUS
TITL WATERBOURNE DEBRIS IN MARINE POLLUTION INCIDENTS
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 744111.5/3, MARCH 1974
CODE 0786A

AUTH ANONYMOUS
TITL WEATHERING OF OIL AT SEA
PUBL EXXON RESEARCH AND ENGINEERING CO. R-035-74
CODE 0343A

AUTH ANONYMOUS
TITL WHAT'S A NICE PHYSICIST LIKE YOU DOING IN AN ENVIRONMENT LIKE THIS?
PUBL TECHNOLOGY REVIEW, OCT./NOV. 1976
ABST THIS ARTICLE ILLUSTRATES SOME OF THE WAYS THAT PHYSICISTS CAN HELP MEASURE AND CONTROL THE ENVIRONMENT - WAYS WHICH HAVE ESCAPED PHYSICISTS AND ENVIRONMENTALISTS ALIKE.
KEYW MEASURING OIL ON WATER, AIR POLLUTANTS, PHYSICISTS AND ENVIRONMENTALISTS
CODE 2935F

AUTH ANONYMOUS
TITL THE WHY AND HOW OF UNDERSEA DRILLING
PUBL AMERICAN PETROLEUM INSTITUTE
ABST OUR DWINDLING OIL AND GAS SUPPLIES, THE POTENTIAL FOR INCREASING THOSE RESERVES, AND THE ALTERNATIVES TO FINDING NEW DOMESTIC SOURCES OF PETROLEUM ARE DISCUSSED. HOW AND WHY WE MUST EXPLORE FOR AND PRODUCE FROM BENEATH OUR SEAS THE OIL AND GAS NECESSARY TO PRESERVE THE NATIONAL, ECONOMIC, AND CONSUMER SECURITY OF THE UNITED STATES.
KEYW INCREASING RESERVES, EXPLORATION, PRODUCTION
CODE 2668F

AUTH ANONYMOUS
TITL WIND DRIFT SURFACE CURRENTS AND SPREAD OF CONTAMINANTS IN SHELF WATERS
PUBL AUG. 1973, AD 786 610
CODE 0226F

AUTH ANONYMOUS
TITL 1973 CONFERENCE ON PREVENTION AND CONTROL OF OIL SPILLS
PUBL API, EPA, USCG, MARCH 1973
ABST ENVELOPE OF ADVERTISING FOR OIL CONTROLLING, BOOMS AND CLEANUP AND VACUUMS.
CODE 6016F

AUTH ANONYMOUS
TITL 1975 CONFERENCE ON PREVENTION AND CONTROL OF OIL POLLUTION PROCEEDINGS
PUBL EPA, API, USCG, MARCH 25-27, 1975
ABST VARIOUS ARTICLES PERTAINING TO LEGAL, TRAINING, MONITORING, PREVENTION, CLEANUP, CONTINGENCY PLANS, EQUIPMENT AND EFFECTS OF OIL POLLUTION.
KEYW PREVENTION, CLEANUP, CONTINGENCY
CODE 4003B

AUTH ANONYMOUS
TITL 1975 REPORT OF SPONSORED RESEARCH
PUBL U.R.I.
ABST EVERY SPONSORED RESEARCH PROJECT AT THE UNIVERSITY ACTIVE ON JULY 1, 1975 IS LISTED IN THIS BOOKLET UNDER THE NAME OF THE PROJECTS PRINCIPAL INVESTIGATOR AND HIS OR HER COLLEGE..
CODE 2642AF

AUTH ANONYMOUS
TITL 1977 OIL SPILL CONFERENCE, PREVENTION BEHAVIOR, CONTROL, CLEANUP, MARCH 8-10, 1977
PUBL NATIONAL CONVENTIONEER
ABST NEW TECHNIQUES AND EQUIPMENT BOOK.
KEYW SHIPPING, OFFSHORE DRILLING, SUPERPORT, PREVENTION, CONTROL, CLEANUP
CODE 6197B

AUTH ANONYMOUS
TITL 1979 OIL SPILL CONFERENCE
PUBL AMERICAN PETROLEUM INSTITUTE PUBLICATION NO. 4308
ABST MARCH 19-22, 1979. LOS ANGELES, CALIFORNIA
KEYW PREVENTION, BEHAVIOR, CONTROL, CLEANUP
CODE 7722E

AUTH ANONYMOUS
TITL 24 HOUR OIL SPILL CLEAN-UP SERVICE
PUBL COASTAL SERVICES, INC.
ABST OIL POLLUTION CONTROL AND CLEAN-UP SERVICE;HAZARDOUS MATERIALS SPILL CLEAN-UP SERVICE;WASTE OIL DISPOSAL
CODE 6514A

AUTH ANONYMOUS
TITL 3000 HR ENDURANCE TEST OF THE DIESEL PRIME MOVER FOR ADAPTS
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 714101/004, MARCH 1972
CODE 0744A

AUTH ANONYMOUS
TITL "MODEL STUDY OF THE DILUTION OF SOLUABLE LIQUIDS DISCHARGES FROM TANKERS"
PUBL STEVENS INSTITUTE OF TECHNOLOGY, SEPT. 1973, AD 768 681
CODE 0220F

AUTH ANONYMOUS
TITL "OIL IN WATER SENSOR FINAL ENGINEERING REPORT"
PUBL TEXAS INSTRUMENTS, FEB. 1974, AD 784 104
CODE 0221F

AUTH ANONYMOUS.
TITL MEETINGS OF THE OUTER CONTINENTAL SHELF ENVIRONMENTAL STUDIES ADVISORY COMMITTEE
PUBL DEPARTMENT OF THE INTERIOR, MAY 20-21, 1976
ABST THIS MEETING COVERED THE ITEMS ON THE OFFICIAL AGENDA BUT NOT IN THAT SEQUENCE.
KEYW LEASING SCHEDULE, SALES, REVENUE
CODE 2926F

AUTH ANYDER H.J.
TITL FEDERAL REGULATORY CONTROL OF OIL SPILL REMOVAL METHODS
PUBL DIV. OF OIL AND SPECIAL MATERIALS CONTROL FOR EPA 1975 CONVENTION
ABST THE DEVELOPMENT OF FEDERAL REGULATORY CONTROLS FOR OIL REMOVAL METHODS IS TRACED.
KEYW REMOVAL, FEDERAL CONTROL, DEVELOPMENT
CODE 0074B

AUTH APPEL B.R., WALL S.M., WESOLOWSKI J.J.
TITL FINAL REPORT - THE CHEMISTRY, DISPERSION AND TRANSPORT OF AIR POLLUTANTS EMITTED FROM FOSSIL FUEL POWER PLANTS IN CALIFORNIA
PUBL RESEARCH SECTION, CAL. AIR RESOURCES BOARD, NO. ARB 3-948, FEB. 1976
ABST CHEMICAL ANALYSIS OF PARTICULATE SAMPLES FOR SULFATE, NITRATE AND TRACE ELEMENT COMPOSITION IS DISCUSSED.
KEYW FIELD MONITORING, PLUMES, AUTOMATED SEQUENTIAL PARTICULATE SAMPLING
CODE 6591F

AUTH APT K.E., LEE V.J.
TITL ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1975
PUBL USERDA CONTRACT NO. W-7405-ENG. 36
ABST THIS REPORT DOCUMENTS THE CY 1975 ENVIRONMENTAL MONITORING PROGRAM OF THE LOS ALAMOS SCIENTIFIC LAB. DATA ARE PRESENTED FOR CONCENTRATIONS OF RADIOACTIVITY MEASURED IN AIR, GROUND AND SURFACE WATERS, SEDIMENTS, SOILS AND FOODSTUFFS AND ARE COMPARED WITH RELEVANT US ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION GUIDES.
CODE 6178F

AUTH ARD R.W.
TITL COAST GUARDS RESPONSE TO SPILLED OIL
PUBL ENVIRONMENTAL SCIENCE AND TECHNOLOGY, VOL. 10, NO. 3, MARCH 1976
ABST THE USCG IS RESPONSIBLE FOR POLLUTION ABATEMENT OUTSIDE THE TERRITORIAL LINE OF THE U.S.. IT DEVELOPS ALL REGULATIONS INCLUDING THOSE FOR POLLUTION ABATEMENT AND IS THE ON-SCENE COORDINATOR IN THE EVENT OF A SPILL.
KEYW MONITORING DETECTORS, SENSORS, RECOVERY
CODE 2914F

AUTH AREHART-TREICHEL J.
TITL OIL ON THE WATERS: MODEST PROGRESS IN CLEANUP TECHNOLOGY
PUBL SCIENCE NEWS, VOL. 102, NO. 16, OCT. 14, 1972
ABST VARIOUS METHODS OF CLEAN UP ARE DISCUSSED.
KEYW CLEANUP, DISPERSANTS, TOXICITY
CODE 2670F

AUTH ASPER J.J., BOLLI P.
TITL NEW DEVICE FOR REMOVING OIL SLICKS FROM THE SURFACE OF WATER
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST THE SYSTEM DESCRIBED IN THIS ARTICLE IS COMPOSED OF A ROTATING, MULTI-THREAD SCREW IN A CASING. THE OIL AND WATER ENTER THE SYSTEM AT A GIVEN SPEED

AND ARE TRAPPED BETWEEN THE THREADS. THE PAPER ALSO DESCRIBES THE RELATED LABORATORY DEVELOPMENT WORK AND DATA ON THE PERFORMANCE OF THE DEVICE.
KEYW REMOVAL, TERMINALS, ROTATING, MULTI-THREAD SCREW IN A CASING
CODE 5123F

AUTH ATLANTIC RESEARCH SYSTEMS DIVISION
TITL RECOVERY OF FLOATING OIL ROTATING DISK TYPE SKIMMER
PUBL EPA, WATER QUALITY OFFICE, JULY 1971
ABST DISCUSSES LABORATORY TESTS OF DISC MATERIALS.
KEYW DISC MATERIALS, MULTIPLE DISCS, ROTATIONAL VELOCITY VECTOR
CODE 0569F

AUTH ATLAS R.M., BERTHA R.
TITL DEGRADATION AND MINERALIZATION OF PETROLEUM BY TWO BACTERIA ISOLATED FROM COASTAL WATER
PUBL BIOTECHNOL. BIOENG., 14: 297-308
CODE 1035F

AUTH ATLAS R.M., BARTHA R.
TITL FATE AND EFFECTS OF POLLUTION PETROLEUM IN THE MARINE ENVIRONMENT
PUBL RESIDUE REVIEWS VOL. 49
CODE 0455R

AUTH ATLAS R.M., HOROWITZ A., BUSDOSH M.
TITL PRUDHOE CRUDE OIL IN ARCTIC MARINE ICE, WATER AND SEDIMENT ECOSYSTEMS: DEGRADATION AND INTERACTIONS WITH MICROBIAL AND BENTHIC COMMUNITIES
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST A VARIETY OF IN SITU MODELS WERE USED TO SIMULATE OIL SPILLS IN DIFFERENT ARCTIC ECOSYSTEMS.
KEYW CONTAMINATION, ARCTIC, MICROORGANISMS
CODE 2669F

AUTH ATLAS R.M.,BERTHA R.
TITL EFFECTS OF SOME COMMERCIAL OIL HERDERS, DISPERSANTS AND BACTERIAL INOCULA ON BIODEGRADATION OF OIL IN SEA WATER
PUBL THE MICROBIAL DEGRADATION OF OIL POLLUTANTS WORKSHOP HELD AT GEORGIA STATE UNIVERSITY, ATLANTA, 1972, PP 283-290
CODE 1034P

AUTH AUDUNSON T., BLANKENBURGH J.C., DALEN V.
TITL STATUS AND RESULTS OF REMOTE SENSING ACTIVITIES AT THE CONTINENTAL SHELF INSTITUTE PRESENTED AT THE UCD DAHL SYMPOSIUM IN REMOTE SENSING NOV. 2,1978
PUBL CONTINENTAL SHELF INSTITUTE
ABST THE CONTINENTAL SHELF INSTITUTE PARTICIPATES IN THE FIELD OF REMOTE SENSING BY STUDYING THE POSSIBILITIES FOR PRACTICAL APPLICATION OF REMOTE SENSING METHODS IN OCEANOGRAPHY AND MARINE GEODESY.
KEYW REMOTE SENSING, MARINE GEODESY, SATELLITES
CODE 7774F

AUTH AYERS R.R.
TITL A RIGID PERFORATED PLATE OIL BOOM FOR HIGH CURRENTS
PUBL INDUSTRIAL ENVIRONMENTAL RESEARCH LAB., EPA, NC. 68-03-0331, EPA 600/2-76-263, DEC. 1976
ABST THIS REPORT DISCUSSES THE PERFORMANCE OF A NEW BOOM CAPABLE OF DIVERTING OIL SPILLS TOWARD SHORE IN A 3 KNOT RIVER OF TIDAL CURRENT.
KEYW BOOMS, BAFFLES, FLOW RATES, TIDAL CURRENTS
CODE 6199F

AUTH AYERS R.R., FRASER J., KAZMIERCZAK L.J.
TITL DEVELOPING AN OPEN SEAS SKIMMER
PUBL CONFERENCE ON PREVENTION AND CONTROL OF OIL POLLUTION
ABST DISCUSSES A SKIMMING SYSTEM DEVELOPMENT THAT SHOULD SOLVE MANY PROBLEMS WITH SKIMMING OIL IN OFFSHORE WAVES.
KEYW OPEN-SEAS SKIMMER, "QUIESCENT POOL", FLOW-DIFFUSING BAFFLE SYSTEM
CODE 0556F

AUTH BAGNULO L.
TITL SKIMMING APPARATUS
PUBL OFFICIAL GAZETTE OF US PATENT OFFICE, VOL. 929, NO. 2.
ABST DESCRIPTION OF A SKIMMING APPARATUS.
CODE 3120R

AUTH BAIER R.E.
TITL ORGANIC FILMS ON NATURAL WATERS: THEIR RETRIEVAL, IDENTIFICATION AND MODES OF ELIMINATION
PUBL JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 77, NO. 27, SEPT 20, 1972
ABST AIR-WATER INTERFACIAL FILMS WERE SAMPLED AND SUBJECTED TO NONDESTRUCTIVE ANALYSIS BY MULTIPLY ATTENUATED INTERNAL REFLECTION (MAIR) INFRARED SPECTROSCOPY.
KEYW AIR WATER INTERFACE, SPECTROSCOPY, DEGRADATION
CODE 7621F

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PUBL WATER RESEARCH VOL. 8, SPT. 1973
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KEYW HYDROCARBONS, DISPERSANTS, TOXICITY, ICHTHYOTOXICITY
CODE 7125F

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CODE 0266P

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KEYW CONTAINMENT, ICE COVER, CLEANUP
CODE 0509F

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KEYW OILY WASTE, CONTINGENCY, TREATMENT.
CODE 7770F

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KEYW SOLID SPHERICAL PARTICLES, SEDIMENTATION, FLUIDISATION
CODE 6328F

AUTH BARNETT C.J., KONTOGIANNIS J.E.
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KEYW NONFERROUS METALS, METHODOLOGY, AWARENESS SYSTEM
CODE 6516F

AUTH BARTLETT S.F.
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KEYW CONCEPT, EQUIPMENT DEVELOPMENT, OIL SKIMMER, OPEN SEAS
CODE 0566F

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KEYW NUMERICAL SOLUTIONS, DROP VOLUME, LIQUID DROPS
CODE 7737F

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KEYW ACCIDENTS, TECHNICAL INFORMATION, RELEVANT DATA, ENVIRONMENTAL IMPACT STATEMENTS
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AUTH BECHER P.
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KEYW DISPERSANTS, ENVIRONMENTAL EFFECT, MARINE BIOTA
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KEYW CONTAINMENT, SORBENT SYSTEMS, CLEANUP
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KEYW REMOVAL, DISPERSION, PROPERTIES OF OIL
CODE 0870F

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KEYW CONTAINMENT, CLEANUP
CODE 0528F

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KEYW CLEANUP, DEVELOPMENT OF EQUIPMENT, HYDRAULIC DRIVE SYSTEMS
CODE 0585F

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KEYW CLEANUP, PREVAILING CONDITIONS, CONFINEMENT
CODE 2960F

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KEYW CLEAN UP, ORGANIZATION, EQUIPMENT AND MATERIALS
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KEYW OIL, DISPERSANTS, TOXICITY TESTING
CODE 6147B

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KEYW CONTINGENCY, TRAINING, PLANNING, DEVELOPING, PERSONNEL
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KEYW CLEANUP, SKIMMERS, PISTON FILMS, SORBENTS, BOSTON HARBOR
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KEYW REMOVAL, SKIMMERS, INCLINED PLANE
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KEYW CONTAINMENT, CLEANUP, SKIMMING, MOBILE STORAGE
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KEYW DISPERSANTS, REMOVAL, CLEANUP
CODE 2062F

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ABST THIS STUDY, WHICH COVERS THE THREE COASTS INCLUDES MOVEMENT FORECASTS AND ANALYSES OF ENVIRONMENTAL PROTECTION AND SHIPPING COSTS FOR BOTH LIQUID AND DRY BULK COMMODITIES.
KEYW DEEPWATER TERMINALS, FOREIGN TRADE, TERMINAL LOCATION
CODE 7198F

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CODE 0555F

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KEYW PREVENTION, MARINE LIFE, LONG TERM EFFECTS
CODE 3031R

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CODE 6577F

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KEYW HYDROCARBONS, TOXICITY TESTS, DISPERSANT
CODE 7775F

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CODE 0331F

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CODE 0343R

AUTH BROWN C., BAER C., AHMADJIAN M., WESTERVELT V., GRANT C., BENTZ A.
TITL REMOVAL OF WATER FROM WEATHERED PETROLEUM
PUBL AIDS FOR ANALYTICAL CHEMISTS, USCG, OCT. 13, 1975
ABST THIS PAPER DISCUSSES THE IDENTIFICATION OF WEATHERED PETROLEUM.
KEYW WEATHERED PETROLEUM, OCCLUDED WATER, INFRARED ANALYSIS
CODE 2550F

AUTH BROWN C., LYNCH P.
TITL INFRARED ANALYSIS OF WEATHERED PETROLEUM USING VACUUM TECHNIQUES
PUBL ANALYTICAL CHEMISTRY VOL 48, NO. 1, JAN. 1976
ABST TREATMENT OF UNWEATHERED OILS WITH SALT WATER AND SUBSEQUENT EVALUATION OF THE DRIED SAMPLE WAS FOUND TO SIMULATE THE NATURAL WEATHERING OF OILS WHICH HAD BEEN IN THE MARINE ENVIRONMENT FOR 2-7 DAYS.
KEYW TREATMENT, UNWEATHERED OILS, OIL CHANGES
CODE 2551F

AUTH BROWN C., LYNCH P., AHMADJIAN M.
TITL CHEMICAL ANALYSIS OF DISPERSED OIL IN THE WATER COLUMN
PUBL URI, DEPT. OF CHEMISTRY
ABST WATER AND AIR SAMPLES COLLECTED FROM TREATED AND UNTREATED SIMULATED OIL SPILLS HAVE BEEN ANALYZED FOR HYDROCARBONS. RESULTS ON LABORATORY, MESO SCALE AND A REAL SPILL ARE COMPARED.
KEYW DISPERSANTS, HYDROCARBONS, KUWAIT CRUDE
CODE 7018F

AUTH BROWN C.W.
TITL URI CHEMISTS DEVELOP A FAST, SURE METHOD OF IDENTIFYING THE SOURCES OF OILSPILLS
PUBL MARITIMES, VOL. 17, NO. 4, NOV. 1973
ABST THIS PAPER DISCUSSES A SPECTROSCOPIC "FINGERPRINTING" METHOD.
KEYW PREVENTION, CLEANUP, SPECTROSCOPIC FINGERPRINTING
CODE 2045F

AUTH BROWN C.W., LYNCH P.F.
TITL TANKER TRAGEDIES: IDENTIFYING THE SOURCE AND DETERMINING THE FATE OF PETROLEUM IN THE MARINE ENVIRONMENT
PUBL PROCEEDINGS OF THE TENTH ROCHESTER CONFERENCE ON ENVIRONMENTAL TOXICITY, MAY 1977
ABST THIS PAPER DISCUSSES THE INFRARED AND GAS CHROMATOGRAPHIC ANALYSES OF AIR, WATER, SEDIMENT AND TARBALL SAMPLES COLLECTED AT ONE OR MORE OF THE THREE MAJOR SPILL SITES IN THE NEW ENGLAND COASTAL AREA.
KEYW INFRARED, GAS CHROMATOGRAPHIC, ANALYSES
CODE 7069F

AUTH BROWN C.W., LYNCH P.F., AHMADJIAN M.
TITL COMPUTERIZED DISPERSIVE INFRARED SPECTROSCOPY
PUBL URI, DEPT. OF CHEMISTRY
ABST THIS REPORT SHOWS THAT A DISPERSIVE INFRARED SPECTROMETER CAN BE INTERFACED TO A MINICOMPUTER, THAT APPROPRIATE SOFTWARE CAN BE WRITTEN WITHOUT ANY GREAT DIFFICULTIES, AND THAT THE COMPUTERIZED DISPERSIVE SYSTEM CAN PROVIDE SPECTRAL RESULTS THAT ARE COMPARABLE TO THOSE OBTAINED WITH A COMPUTERIZED FOURIER TRANSFORM SYSTEM.
KEYW DISPERSIVE, INFRARED SPECTROMETER, SPECTRAL RESULTS
CODE 7062F

AUTH BROWN D.W.
TITL TOXICITY STUDIES ON THE COMPONENTS OF AN OIL-SPILL EMULSIFIER USING LICHINA PYGMAEA AND XANTHORIA PARIETINA
PUBL MARINE BIOLOGY, VOL. 18, 1973
ABST THIS PAPER DISCUSSES THE TOXIC COMPONENT OF EMULSIFIERS.
KEYW EMULSIFIERS, SOLVENT FRACTION, VOLATILE COMPONENTS
CODE 2127F

AUTH BROWN G., BARTLETT S.
TITL IN-SITU MEASUREMENTS OF OIL BARRIER SHAPE AND LOADS DUE TO CURRENT ACTION
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST THIS PAPER DISCUSSES THE SHAPE, LOADING AND MOTION OF AN OIL BARRIER. RESULTS OF TESTING AGREE WITH MODEL BARRIER DATA TAKEN IN LAB FACILITIES.
KEYW BARRIERS, CURRENT AND WAVE MOTION, RETENTION
CODE 0540F

AUTH BROWN G., JASPER W.
TITL OIL CONTAINMENT DEVICES
PUBL ERDA, BIOLOGICAL AND ENVIRONMENTAL DIVISION, CONTRACT NO E(11-1) 2756, AUG. 1975
ABST DISCUSSES STEPS INVOLVED FOR EFFICIENT USE OF AN OIL CONTAINMENT DEVICE.
KEYW CONTAINMENT, BARRIER, CHARACTERISTICS OF A SPILL.
CODE 2954F

AUTH BROWN G.A., JASPER W., BONDELL R., ATKINS T., HARVEY E., WILSON R.P.
TITL FINAL REPORT, THE SPREADING, RETENTION AND CLEANUP

OF OIL SPILLS
PUBL ERDA, URI, REPORT NO. E (11-1) 2756, MAY 1976
ABST THIS STUDY REVIEWS AND ASSESSES THE TECHNOLOGICAL STATE OF THE ART OF OIL SPILL SPREADING, RETENTION AND CLEANUP AND PROPOSES RESEARCH NEEDED IN THIS AREA.
KEYW SPREADING, RETENTION, CLEANUP
CODE 2956F

AUTH BROWN G.A., LARRABEE R.M.
TITL SOME COMMENTS ON THE BARRIER TOWING LOAD DATA FOR THE USCG OIL CONTAINMENT SYSTEM
PUBL DEPT. OF OCEAN ENGINEERING, URI, NOV. 1973
ABST INFORMATION REVIEWED FROM MULLER REPORT WHICH IS CONCERNED WITH THE ANALYSES OF DATA FROM THE USCG LIGHTWEIGHT OIL CONTAINMENT SYSTEM SEA TRIALS.
CODE 6036R

AUTH BROWN L.R.
TITL FATE AND EFFECT OF OIL IN THE ENVIRONMENT OF THE COASTAL GULF OF MEXICO
PUBL MISSISSIPPI ST. UNIV. FOR EPA, SSIE NO. AO-19734-1
CODE 0464R

AUTH BROWN P.E.
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PUBL SENIOR PROJECT
ABST PAPER DISCUSSES DETECTION AND SURVEILLANCE OF OIL SPILLS AND VARIOUS METHODS OF CONTROLLING THE OIL AND LIMITING THE EXTENT OF ITS POLLUTION.
CODE 3075R

AUTH BROWN R.J.
TITL OCEAN CURRENT SENSORS (A BIBLIOGRAPHY WITH ABSTRACTS)
PUBL NTIS PS-79/0001
ABST REPORT FOR 1964-1978. THE BIBLIOGRAPHY CITES RESEARCH COVERING MEASUREMENT TECHNIQUES AND DESIGN OF OCEAN CURRENT SENSORS. THE STUDIES COVER SUCH TOPICS AS EQUIPMENT, COMPARISONS, CALIBRATION TECHNIQUES, MOORING STUDIES, AND ACCURACY EVALUATION. REPORTS ON REMOTE SENSING TECHNIQUES FOR CURRENT MEASUREMENT HAS BEEN EXCLUDED. (CONTAINS 108 ABSTRACTS)
KEYW CALIBRATION TECHNIQUES, REMOTE SENSING, BIBLIOGRAPHY
CODE 7740F

AUTH BRUCH B., MAXWELL R.G.
TITL LOCKHEED OIL SPILL RECOVERY DEVICE
PUBL PHYSICAL REMOVAL
ABST THIS PAPER DISCUSSES TESTS AND ANALYSIS OF AN OIL SPILL RECOVERY DEVICE WITH VARIOUS OILS TO ESTABLISH A METHOD FOR ESTIMATING PERFORMANCE.
KEYW RECOVERY, CONTAINMENT, PERFORMANCE
CODE 0826F

AUTH BRUGGEMAN W.H., FAULKNER L.L.
TITL ACOUSTIC TRANSMISSION OF PIPE WRAPPING SYSTEMS
PUBL ASME PUBL.
ABST A REPORT ON THE PROCEDURES AND ANALYSES OF PIPE WRAPPING SYSTEMS AND SUGGEST THE METHODS OF TEST THAT CAN BE USEFUL FOR DEVELOPING TEST THAT STANDARDS.
CODE 2905R

AUTH BRYAN G.W.
TITL THE EFFECT OF OIL-SPILL REMOVERS (DETERGENTS) ON THE GASTROPOD NUCELLA LAPILLUS ON A ROCKY SHORE AND IN THE LAB.
PUBL J. MARINE BIOLOGICAL ASSOCIATION U.K., VOL 49, NO. 4, 1969
ABST THIS PAPER DISCUSSES RESULTS OF TESTS OF DISPERSANTS ON DOGWHELK.
KEYW DISPERSANTS, TOXICITY, DOGWHELK
CODE 2129F

AUTH BUCKMASTER J.
TITL VISCOUS - GRAVITY SPREADING OF AN OIL SLICK
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CODE 2050R

AUTH BULTMAN J.D., LEONARD J.M.
TITL OCEAN SURFACE FILMS MAY-JUNE 1963
PUBL U.S. NAVAL RESEARCH LABORATORY
ABST THIS PAPER DISCUSSES RESULTS OF A FIELD TRIP TO CARRY OUT OCEANOGRAPHIC EXPERIMENTS DEALING WITH SURFACE CHEMISTRY OF THE SEA.
KEYW ADSORPTION OF SURFACE ACTIVE MATERIALS, SEA/AIR INTERFACE, SURFACE FILMS
CODE 0863F

AUTH BUMPUS D.
TITL A DESCRIPTION OF THE CIRCULATION ON THE CONTINENTAL SHELF OF THE EAST COAST OF THE US.
PUBL PROGRESS IN OCEANOGRAPHY, VOL. 6, 1973
ABST THE INTENT OF THIS REPORT IS TO PROVIDE AN INTERPRETATION OF THE LARGE AMOUNT OF DRIFT BOTTLE AND SEA BED DRIFT.
KEYW DRIFT BOTTLE, SEA BED DRIFT, CIRCULATION
CODE 6052F

AUTH BUMPUS D.F.
TITL REVIEW OF THE PHYSICAL OCEANOGRAPHY OF GEORGES BANK
PUBL INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES RESEARCH BULLETIN NO. 12, 1976
ABST PREVIOUSLY PUBLISHED INFORMATION ON THE BATHYMETRY, ROTATING TIDAL CURRENTS, TEMPERATURE-SALINITY DISTRIBUTION AND GENERAL CIRCULATION OF THE GULF OF MAINE AND GEORGES BANK ARE DISCUSSED. NEW INFORMATION ON SURFACE TEMPERATURE FRONTS IN RELATION TO MONTHLY EKMAN TRANSPORT VECTORS IS PRESENTED. DATA ON THE DISTRIBUTION OF HERRING LARVAE DURING SUCCESSIVE PERIODS DURING THE AUTUMNS OF 1972, 1973 AND 1974 ARE USED.
CODE 7087F

AUTH BURKLIN C.E., CULLEY J.D., OWEN M.L.
TITL BACKGROUND INFORMATION ON HYDROCARBON EMISSIONS FROM MARINE TERMINAL OPERATIONS
PUBL USEPA, OFFICE OF AIR AND WASTE MANAGEMENT, OFFICE OF AIR QUALITY PLANNING AND STANDARDS, EPA 450/3-76-038A, NOV. 1976
ABST THE OBJECTIVES OF THIS PROGRAM ARE TO REPORT EMISSION FACTORS AND TO DEVELOP INFORMATION NECESSARY FOR THE ACCURATE ASSESSMENT OF HYDROCARBON EMISSIONS FROM SHIP LOADING OF GAS AND OIL.
KEYW MARINE TERMINALS, HYDROCARBONS, EMISSIONS
CODE 6507F

AUTH BURWOOD R., SPEERS G.C.
TITL PHOTO-OXIDATION AS A FACTOR IN THE ENVIRONMENT DISPERSAL OF CRUDE OIL
PUBL ESTUARINE AND COASTAL MARINE SCIENCES
CODE 0366R

AUTH BUTLER J.N.
TITL PELAGIC TAR
PUBL SCIENTIFIC AMERICAN, VOL. 232, NO. 6, JUNE 1975
CODE 2049F

AUTH BUTLER J.N., LEVY E.M.
TITL LONG TERM FATE OF PETROLEUM HYDROCARBONS AFTER SPILLS, COMPOSITIONAL CHANGES AND MICROBIAL DEGRADATION
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST SUMMARY AND OVERVIEW OF SESSION I, SYMPOSIUM OF RECOVERY POTENTIAL OF OILED MARINE NORTHERN ENVIRONMENTS HALIFAX, OCTOBER 1977.
KEYW RECOVERY, COLD MARINE ENVIRONMENTS, TANKER ACCIDENTS, EXPLORATION AND PRODUCTION
CODE 2669F

AUTH CADY G.
TITL DETERMINATION OF FLUORINE BY TITRATION WITH TRIPHENYLIN NITRATE AND BY STEAM UNDER VACUUM
PUBL ANALYTICAL CHEMISTRY VOL 48, NO. 4, APRIL 1976
ABST THIS PAPER DISCUSSES THE TESTING FOR DETERMINING FLUORINE.
KEYW FLUORINE ANALYSIS, STEAM UNDER VACUUM, TITRATION WITH TRIPHENYLIN NITRATE
CODE 2553F

AUTH CAIRNS R.
TITL OIL SPILL REPORT
PUBL OIL SPILL REPORT, CORNWALL, BRITTANY, APRIL 1, 1970
ABST THIS ARTICLE CONCERNS THE WRECK OF THE TORREY CANYON AND THE OCEAN EAGLE. IT IS AN ATTEMPT AT AN OBJECTIVE REPORT ON TWO MAJOR OIL SPILLS IN RECENT YEARS, THEIR CAUSES AND EFFECTS, AND WHAT WE HAVE LEARNED ABOUT DEALING WITH SUCH INCIDENTS.
KEYW ACCIDENTS, CAUSES, AND EFFECTS
CODE 3039R

AUTH CALABRESE A., DAVIS H.C.
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PUBL PROC. NATL. SHELLFISH ASSOC., VOL. 57, 1967
CODE 1031R

AUTH CAMPBELL F.J.
TITL STANDARDIZED HARDWARE FOR OIL SPILL CONTAINMENT BOOMS
PUBL NAVAL UNDERWATER SYSTEMS CENTER, JUNE 1974, REPORT NO. N-1343
ABST THIS REPORT DESCRIBES THE DESIGN , DEVELOPMENT AND TESTING OF STANDARDIZED HARDWARE FOR USE WITH EXISTING AND NEW NAVY OIL SPILL CONTAINMENT BOOMS.
KEYW CONTAINMENT, REMOVAL, BOOMS
CODE 0521 F

AUTH CAMPBELL W.J., MARTIN S.
TITL OIL AND ICE IN THE ARCTIC OCEAN POSSIBLE LARGE-SCALE INTERACTION
PUBL SCIENCE, 181(4094):56, 1973
CODE 1102R

AUTH CANEVARI G.
TITL GENERAL DISPERSANT THEORY
PUBL AMERICAN PETROLEUM INSTITUTE
ABST THIS PAPER DISCUSSES THE MECHANISM OF AND BASIS FOR DISPERSING OIL SLICKS
KEYW DISPERSANTS, OIL SLICKS
CODE 1066F

AUTH CANEVARI G.
TITL A REVIEW OF THE UTILITY OF SELF-MIXING DISPERSANTS IN RECENT YEARS

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PUBL  PROCEEDINGS OF THE 1975 CONFERENCE ON PREVENTION
      AND CONTROL OF OIL SPILLS, MARCH 25-27, 1975
ABST  THIS PAPER REVIEWS THE DEVELOPMENT DURING THE PAST
      TWO YEARS OF SELF-MIXING DISPERSANTS TO MINIMIZE
      DAMAGE FROM OIL SPILLS.
KEYW  SELF-MIXING DISPERSANTS, DROPLET SIZE, TOXICITIES
CODE  5114F

AUTH  CANEVARI G.P.
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PUBL  PETROLEUM TIMES, AUG. 1, 1969
CODE  5032N

AUTH  CANEVARI G.P.
TITL  THE CASE FOR OIL SPILL DISPERSANTS
PUBL  SOCIETY OF PETROLEUM ENGINEERS, AIME, NOV. 9-10,
      1970, SPE 3235
ABST  THIS PAPER DEFINES THE OVERALL PROBLEM OF OIL
      SPILLS AND THEN DERIVES THE BASIS FOR THE USE OF
      DISPERSANTS, AS WELL AS THE CONDITIONS THAT
      JUSTIFY THEIR USE.
KEYW  DISPERSANTS, CLEANUP, ENVIRONMENTAL FACTORS
CODE  5045F

AUTH  CANEVARI G.P.
TITL  DEVELOPMENT OF THE "NEXT GENERATION" CHEMICAL
      DISPERSANTS
PUBL  PROCEEDINGS OF THE 1973 CONFERENCE ON PREVENTION
      AND CONTROL OF OIL SPILLS, MARCH 13-15, 1973
ABST  REVIEW OF CURRENT STATUS OF CHEMICAL DISPERSANTS
      IN ORDER TO DEVELOP FUTURE DISPERSANTS.
KEYW  DISPERSANTS, CONTROL TOXICITY
CODE  5043F

AUTH  CANEVARI G.P.
TITL  OIL SPILLS DISPERSANTS - CURRENT STATUS AND FUTURE
      OUTLOOK
PUBL  PROCEEDINGS OF J. CONFERENCE ON PREVENTION AND
      CONTROL OF OIL SPILLS JUNE 71 PG. 263
ABST  THIS PAPER REVIEWS SOME OF THE PAST HISTORY AS
      BACKGROUND IN ORDER TO DERIVE THE PROS AND CONS
      REGARDING THE USE OF DISPERSANTS.
KEYW  DISPERSANTS, EFFECTIVENESS, TOXICITIES
CODE  5069F

AUTH  CANEVARI G.P.
TITL  THE ROLE OF CHEMICAL DISPERSANTS IN OIL CLEANUP
PUBL  OIL ON THE SEA, MIT, MAY 1969 SYMPOSIUM
ABST  PROCEEDINGS OF A SYMPOSIUM ON THE SCIENTIFIC AND
      ENGR. ASPECTS OF OIL POLLUTION OF THE SEA,
      SPONSORED BY MIT AND WOODS HOLE OCEANOGRAPHIC
      INSTITUTE. DISCUSSION OF THE ROLE OF CHEMICAL
      DISPERSANTS IN OIL CLEANUP.
KEYW  LOAD ON TOP, CHEMICAL DISPERSANTS, CONTAINMENT,
      REMOVAL, TREATMENT
CODE  5126F

AUTH  CANEVARI G.P.
TITL  SOME BASIC CONCEPTS REGARDING THE SEPARATION OF
      OIL WATER MIXTURES
PUBL  ASME TRANSACTIONS, 12(3) JULY 1969
CODE  5033R

AUTH  CARO J.C., PONCE P.V., SNIDER W.D.
TITL  TANKSHIP ACCIDENTS AND RESULTING OIL OUTFLOWS:
      1969-1973
PUBL  USCG, OFFICE OF MERCHANT MARINE SAFETY, FOR EPA
      1975 CONFERENCE
ABST  INFORMATION HAS BEEN COLLECTED ON 3,715 WORLD-WIDE
      TANKSHIP ACCIDENTS INVOLVEMENTS DURING THE PERIOD
      1969-1973 FROM LLOYD'S WEEKLY CASUALTY REPORTS AND
      OTHER SOURCES. INFORMATION COLLECTED, ONCE
      ANALYZED, SHOULD BE USEFUL IN EVALUATING MEASURES
      FOR REDUCING ACCIDENTS AND RESULTING OIL OUT
      FLOWS.
KEYW  ACCIDENTS, TANKERS, OIL OUT FLOWS
CODE  0095N

AUTH  CARMICHAEL F.R.
TITL  OFFSHORE DRILLING TECHNOLOGY
PUBL  ENERGY TECHNOLOGY REVIEW NO. 5, OCEAN TECHNOLOGY
      REVIEW NO. 3, NOYES DATA CORP., PARK RIDGE, NJ,
      1975
ABST  THIS BOOK SUPPLIES DETAILED TECHNICAL INFORMATION
      AND ADVANCED TECHNICALLY ORIENTED REVIEW OF
      OFFSHORE DRILLING TECHNIQUES AND APPARATUS.
KEYW  OFFSHORE DRILLING, TECHNIQUES, APPARATUS
CODE  4013G

AUTH  CARPENTER C.E., BUTCHER L.F., HURLEY A.S.
TITL  LABORATORY EXAMINATION OF MATERIALS SUBMITTED FOR
      TREATING THE TORREY CANYON OIL SPILL
PUBL  ADMIRALTY OIL LAB., REPORT NO. 51, JAN. 1969
ABST  A REPORT ON THE VESSEL TORREY CANYON WHICH STRUCK
      THE SEVEN STONES REEF IN 1967.
KEYW  DISPERSANTS, CHEMICALS, TORREY CANYON, CLEANUP
CODE  2607F

AUTH  CARTER H.H., SCHUBEL J.R., WILSON R.E., WOODHEAD
      P.M.
TITL  A RATIONALE FOR EVALUATING THERMALLY INDUCED
      BIOLOGICAL EFFECTS DUE TO A ONCE-THROUGH COOLING
      SYSTEM
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      DEVELOPMENT AUTHORITY, SEPT. 1977
ABST  IN THIS REPORT IT IS SHOWN HOW THE THERMALLY
      INDUCED BIOLOGICAL EFFECTS OF POWER PLANTS WITH
      ONCE THROUGH COOLING SYSTEMS CAN BE EVALUATED IN A
      LOGICAL, SCIENTIFICALLY DEFENSIBLE MANNER.
KEYW  POWER PLANTS, ONCE THROUGH COOLING, EXCESS
      TEMPERATURE, THERMAL DOSE
CODE  2682F

AUTH  CARTHY J.D., ARTHUR D.
TITL  THE BIOLOGICAL EFFECTS OF OIL POLLUTION ON
      LITTORAL COMMUNITIES
PUBL  PROCEEDINGS OF A SYMPOSIUM FEB. 1968
CODE  5002R

AUTH  CASCUIYNE P.
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      WATERS
PUBL  WORLD OIL
CODE  0333R

AUTH  CATOE C.
TITL  THE APPLICABILITY OF REMOTE SENSING TECHNIQUES FOR
      OIL SLICK DETECTION
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      MAY 1-3, 1972
ABST  IN THIS REPORT A COMPREHENSIVE SURVEY OF THE
      STATE-OF THE-ART OF VARIOUS REMOTE SENSING
      TECHNIQUES THAT MAKE USE OF BOTH SPECTRAL AND THE
      SPATIAL DIMENSIONS OF REMOTE SENSING ARE GIVEN.
KEYW  DETECTION, IDENTIFICATION, THICKNESS, MAPPING,
      SENSING TECHNIQUES
CODE  0511F

AUTH  CHAMBERS B.E., WILLIAMS H.D.
TITL  UTILIZATION OF DIVING AND SALVAGE EXPERTISE IN THE
      PREVENTION OF OIL POLLUTION
PUBL  USCG ATLANTIC STRIKE TEAM, FOR EPA 1975 CONFERENCE
KEYW  PREVENTION, DIVING, SALVAGE EXPERTISE
CODE  0121R

AUTH  CHAN G.L.
TITL  A STUDY OF THE EFFECTS OF THE SAN FRANCISCO OIL
      SPILL ON MARINE LIFE PART II RECRUITMENT
PUBL  COLLEGE OF MARINE FOR EPA 1975 CONFERENCE
KEYW  EFFECTS SAN FRANCISCO OIL SPILL, MARINE LIFE,
      RECRUITMENT
CODE  0134AR

AUTH  CHANG M., SANER E.B.
TITL  EVALUATION OF BOAT DEPLOYABLE THIN FILM OIL
      SAMPLERS
PUBL  OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1984,
      MAY 6-8, 1974
ABST  THIS PAPER DISCUSSES THE EVALUATION OF FOUR
      PROTOTYPE THIN FILM OIL SAMPLERS FOR  USE IN
      SAMPLING FOR IDENTIFICATION PURPOSES.
KEYW  DEPLOYMENT, RETRIEVAL, CLEANING
CODE  0854F

AUTH  CHAPLIN A.E.
TITL  THE EFFECTS OF OIL SPILL EMULSIFIERS ON THE
      METABOLISM OF CRUSTACEAN
PUBL  REP. OIL POLLUT. RES. UNIT., FLD. STUD COUN. 1971
CODE  1008N

AUTH  CHARLTON T.J., CUNNINGHAM J.M.
TITL  SPILL PREVENTION: THE SPCC APPROACH
PUBL  EPA, FOR EPA 1975 CONFERENCE
ABST  THE OIL SPILL PREVENTION PROGRAM OF THE EPA IS
      DISCUSSED AS IT HAS EVOLVED FROM THE IMPLEMENTING
      LEGISLATION. THE PAPER DISCUSSES EPA PLAN REVIEWS,
      AMENDMENT PROCEDURES, APPEALS ON AMENDMENTS, AND
      PENALTY PROCEDURES AND APPEALS FOR PENALTIES.
KEYW  PREVENTION, LEGISLATION, PENALTIES
CODE  0041N

AUTH  CHARNOCK H.
TITL  WIND STRESS ON A WATER SURFACE
PUBL  UNKNOWN
ABST  THIS REPORT SUMMARIZES THE RESULTS OF TESTS OF
      WIND STRESS ON A WATER SURFACE.
KEYW  WIND PROFILE, AERODYNAMICS, PRECISION ANEMOMETRY
CODE  0823F

AUTH  CHEN E.C., OVERALL J.C.K., PHILLIPS C.R.
TITL  SPREADING OF CRUDE OIL ON AN ICE SURFACE
PUBL  CANADIAN JOURNAL OF CHEMICAL ENGINEERING VOL. 52
CODE  0429R

AUTH  CHUNG J.S.
TITL  THICKNESS VARIATIONS OF AN OIL SPILL ON WAVES
PUBL  CAVITATION AND POLYPHASE FLOW FORUM, 1977
ABST  THIS PAPER DISCUSSES OIL THICKNESS AND ITS
      VARIATION DETERMINING A DESIGN REQUIREMENT FOR THE
      MOTION CHARACTERISTICS OF THE CONTROL EQUIPMENT IN
      WAVES
KEYW  WIND EFFECT, OIL LAYER THICKNESS, SPREADING
CODE  0501F

AUTH  CHUNG J.S., EVUN J.R. CUNNINGHAM C.R.
TITL  DESIGN PARAMETER STUDY OF AN OIL SPILL BOOM
PUBL  CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST  THIS PAPER PRESENTS A DESIGN PARAMETER STUDY OF AN
      OIL SPILL CONTAINMENT BOOM.
KEYW  CONTAINMENT CONTROL, BOOM
CODE  0930F
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AUTH  CHURCHILL R.J.
TITL  PHOTOMICROGRAPH TECHNIQUES FOR CHARACTERIZATION
      AND MONITORING OIL AND WASTE STREAMS
PUBL  PETROLITE CORP. FOR EPA CONFERENCE 1975
KEYW  PHOTOMICROGRAPH TECHNIQUES, CHARACTERIZATION,
      MONITORING, WASTE STREAMS
CODE  0076A

AUTH  CIMBERG R., MANN S., STRAUGHAN D.
TITL  A REINVESTIGATION OF SOUTHERN CALIFORNIA ROCKY
      INTERTIDAL BEACHES THREE AND ONE HALF YEARS AFTER
      THE 1969 SANTA BARBARA OIL SPILL
PUBL  UNIV. OF SO. CAL., 1973 CONF.
ABST  THIS ANALYSIS INDICATES THAT SAND MOVEMENTS AND
      SUBSTRATE STABILITY ARE THE TWO MOST IMPORTANT
      FACTORS AFFECTING THE PRESENCE OF MARITIME
      ORGANISMS ON THESE BEACHES DURING THIS TIME.
CODE  6117F

AUTH  CLARK R.B.
TITL  OILED SEABIRD RESCUE AND CONSERVATION
PUBL  JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST  DISCUSSIONS OF EFFECTIVE TREATMENT METHODS AND
      RECOVERY OF OILED BIRDS.
KEYW  OILED SEABIRD RESCUE, CONSERVATION,
      WATER-REPELLENT PLUMAGE
CODE  2669F

AUTH  CLARK R.C., FINLEY J.S.
TITL  PARAFFIN HYDROCARBON PATTERNS IN PETROLEUM POLLUTED
      MUSSELS
PUBL  MARINE POLLUTION BULLETIN 4(11):172-176
CODE  1051F

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TITL  LONG TERM CHEMICAL AND BIOLOGICAL EFFECTS OF A
      PERSISTANT OIL SPILL FOLLOWING THE GROUNDING OF
      THE GENERAL M.C. MEIGS
PUBL  NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION,
      NATIONAL MARINE FISHERIES SERVICE, WASHINGTON
      STATE DEPT. OF ECOLOGY, FOR EPA 1975 CONFERENCE
KEYW  CHEMICAL AND BIOLOGICAL EFFECTS, GENERAL M.C.
      MEIGS, GROUNDING
CODE  0130R

AUTH  CLARK R.C., PATTEN B.G., DENIKE E.E.
TITL  OBSERVATIONS OF A COLD WATER INTERTIDAL COMMUNITY
      AFTER FIVE YEARS OF A LOW-LEVEL, PERSISTENT OIL
      SPILL FROM THE GENERAL M.C. MEIGS
PUBL  JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST  THIS ARTICLE DISCUSSES THE OBSERVATIONS OF A TIDAL
      COMMUNITY AFTER AN OIL SPILL.
KEYW  HYDROCARBONS, PETROLEUM CONTAMINATION BIOLOGICAL
      EFFECTS
CODE  2669F

AUTH  CLYNE R.W.
TITL  MECHANICAL RETRIEVAL OF WASTE OIL AND SOLIDS FROM
      WATER
PUBL  EDENS EQUIPMENT COMPANY, MAY 6, 1968
ABST  THIS PAPER DISCUSSES THE APPLICATION OF ROTATING
      CYLINDERS FOR THE RECOVERY OF OIL  SPILLS FROM
      INLAND WATERWAYS AND PROTECTED HARBORS, AND FOR
      THE RETRIEVAL OF WASTE OILS FROM WASTE WATER. IT
      ALSO DISCUSSES THE GENERAL DESIGN DETAILS OF
      PERMANENT FIRE-RETARDENT OIL RETENTION FLOATING
      BOOMS FOR MARINE AND INDUSTRIAL APPLICATION.
CODE  3011A

AUTH  COCCETTI G.F.
TITL  IN SITU STUDIES OF THE SEASONAL SUCCESSIONAL
      TRAJECTORIES OF TRANSPLANTED AND EXPERIMENTAL
      DIATOM ASSEMBLAGES
PUBL  A MASTERS THESIS SUBMITTED TO THE DEPT. OF BIOLOGY
      OF THE CITY OF NEW YORK IN PARTIAL FULFILLMENT FOR
      A MASTERS OF ARTS DEGREE
ABST  THIS PAPER DISCUSSES INVESTIGATIONS FOCUSED ON
      INTERPRETING THE SIGNIFICANCE OF ALTERATIONS IN
      COMMUNITY STRUCTURE.
KEYW  DIVERSITY, RESILIENCE STABILITY, PERSISTANCE OF
      COMMUNITIES
CODE  0587F

AUTH  COCHRAN R.A., FRASER J.P.
TITL  COMPUTER SIMULATION OF OFFSHORE OIL SPILL CLEANUP
      OPERATIONS
PUBL  OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2199,
      MAY 5-8, 1975
ABST  THIS PAPER DESCRIBES A POWERFUL TOOL FOR USE IN
      SELECTION AND DESIGN OF OIL SPILL CONTROL
      EQUIPMENT. RESULTS OF A SAMPLE CASE ARE SHOWN
      WHICH INDICATES THE TRENDS WHICH MIGHT BE EXPECTED
      FROM VARIATIONS IN THE NUMBER OF SKIMMERS USED,
      THEIR ABILITY TO OPERATE TO DIFFERENT MAXIMUM WAVE
      HEIGHTS OTHER SKIMMER PERFORMANCE CHARACTERISTICS,
      LENGTH OF TIME SPENT ON THE JOB AND SIZE OF SPILL.
KEYW  COMPUTER SIMULATION, RECOVERY, SKIMMERS
CODE  0963F

AUTH  COCHRAN R.A., HANNEY G.A.
TITL  COMPUTER SIMULATION OF OFFSHORE OIL-SPILL CLEANUP
      OPERATIONS
PUBL  CONFERENCE ON PREVENTION AND CONTROL OF OIL
      POLLUTION
ABST  A COMPUTER SIMULATION PROGRAM HAS BEEN DEVELOPED
      TO AID IN THE EVALUATION OF THE OIL-SPILL
      CONTINGENCY PLANS FOR OFFSHORE OPERATIONS. USING
      THIS PROGRAM, THE PERFORMANCE OF OIL-SPILL
      RECOVERY EQUIPMENT CAN BE SIMULATED AS A FUNCTION
      OF OIL-SPILL SIZE, SPILL LOCATION AND WEATHER.
KEYW  RECOVERY, WEATHER CONDITIONS, SIZE OF SPILL,
      CLEANUP, SPILL LOCATION
CODE  8051F

AUTH  COCHRAN R.A., SCOTT P.R.
TITL  THE GROWTH OF OIL SLICKS AND THEIR CONTROL BY
      SURFACE CHEMICAL AGENTS
PUBL  JOURNAL OF PETROLEUM TECHNOLOGY, JULY 1971
ABST  A CALCULATION METHOD FOR PREDICTING THE RATE OF A
      SLICK AT WHICH AN OIL SLICK WILL SPREAD ON WATER
      CAN ALSO BE USED TO PREDICT THE BEHAVIOR OF A
      SLICK THAT HAS BEEN TREATED WITH A SURFACE
      CHEMICAL COLLECTING AGENT.
KEYW  GROWTHRATE, CLEANUP, PREDICT BEHAVIOR, DISPERSANTS
CODE  2515F

AUTH  COLBURN W.E.
TITL  FINAL REPORT, THE ACQUISITION AND ANALYSIS OF WAVE
      DATA RECORDED AT PT. CONCEPTION, CA.
PUBL  USCG, DEPT. OF TRANSPORTATION, REPORT NO.
      DOT-CG-33962-A-2, SEPT. 1973
ABST  THIS REPORT CONCERNS THE DESIGN, FABRICATION, AND
      OPERATION OF A WAVE MEASUREMENT SYSTEM.
KEYW  OCEAN WAVE DATA, WAVE MEASUREMENT SYSTEM, WAVE
      ANALYSIS
CODE  08654F

AUTH  COLBURN W.E., MIDDLETON F.H., LEBLANC L.R.
TITL  FINAL REPORT, ACQUISITION AND ANALYSIS OF OCEAN
      WAVE DATA RECORDED ON A SPAR BUOY MOUNTED DIGITAL
      CASSETTE RECORDER
PUBL  USCG, DEPT OF TRANSPORTATION REPORT NO.
      CG-D-78-75, MARCH 1974
ABST  THIS REPORT CONCERNS THE DESIGN, FABRICATION, AND
      OPERATION OF A WAVE MEASUREMENT SYSTEM.
KEYW  OCEAN WAVE DATA, WAVE MEASUREMENT SYSTEM, WAVE
      ANALYSIS
CODE  08650F

AUTH  COLE H.A.
TITL  MOVEMENT OF OIL SLICKS INCLUDING PREDICTION
PUBL  MINISTRY OF AGRICULTURE, SSIE NO. GDW-575
CODE  0352R

AUTH  COLE T.J.
TITL  PRELIMINARY ECOLOGICAL-GENETIC COMPARISON BETWEEN
      UNPERTURBED AND OIL IMPACTED URUSALPINX CINEREA
      (PROSOBRANCHIA: GASTROPODA) POPULATIONS: NOBSKA
      POINT (WOODS HOLE) AND WILD HARBOR (WEST
      FALMOUTH), MASSACHUSETTS
PUBL  JOURNAL OF THE FISHERIES, VOL. 35 NO. 5, MAY 1978
ABST  DISCUSSION OF THE INTERDIGITATION OF ECOLOGY AND
      GENETICS.
KEYW  ELECTROPHORESIS, GENETICS, OILED POPULATION
CODE  2669F

AUTH  COLWELL R.R., MILLS A.L., WALKER J.D.,
      GARCIA-TELLO P., CAMPOS-P. V.
TITL  MICROBIAL ECOLOGY STUDIES OF THE METULA SPILL IN
      THE STRAITS OF MAGELLAN
PUBL  JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST  A STUDY OF A MASSIVE SPILL IN A COLD REGION ON A
      LONG TERM BASIS.
KEYW  PETROLEUM DEGRADATION, MICROBIAL DEGRADATION,
      METULA
CODE  2669F

AUTH  CONNER W.G., ALKON P. U.
TITL  PROCEEDINGS OF THE NATIONAL RESPONSE TEAM OIL
      SCIENTIFIC RESPONSE WORKSHOP, NEW ENGLAND FINAL
      REPORT
PUBL  METREK DIVISION OF THE MITRE CORP.
ABST  WORKSHOP ON OIL SPILL: ECOLOGICAL DAMAGE ASSESSMENT
      HELD AT HARTFORD, CONN. AUGUST 28-31, 1977.  THIS
      DOCUMENT PRESENTS THE FINAL RESULTS OF THE
      ABOVE-NAMED WORKSHOP.  THE PRINCIPAL AIM OF THE
      WORKSHOP WAS TO IDENTIFY SCIENTIFIC NEEDS AND
      CAPABILITIES TO BE INCORPORATED INTO A REGIONAL
      RESPONSE PLAN FOR ASSESSING THE ECOLOGICAL DAMAGE
      DUE TO MAJOR OIL SPILLS.
KEYW  OIL POLLUTION, OIL SPILLS, PETROLEUM SPILLS,
      DAMAGE ASSESSMENT
CODE  7711F

AUTH  CONNORS D.N., KESTER D.R.
TITL  EFFECT OF MAJOR ION VARIATIONS IN THE MARINE
      ENVIRONMENT ON THE SPECIFIC GRAVITY - CONDUCTIVITY
      - CHLORINITY - SALINITY RELATIONSHIP
PUBL  MARINE CHEMISTRY, VOL. 2, 1974
ABST  PARTIAL EQUIVALENT CONDUCTANCES AND PARTIAL
      EQUIVALENT VOLUMES OF THE MAJOR CONSTITUENTS IN
      SEAWATER WERE USED TO EVALUATE THE SPECIFIC
      GRAVITY - CONDUCTIVITY - CHLORINITY - SALINITY
      RELATIONSHIPS IN THE MARINE ENVIRONMENT.
KEYW  SALINITY, MIXING, GRAVITY, CONDUCTIVITY,
      CHLORINITY
CODE  7669F

AUTH  CONOMOS T.J.
TITL  MOVEMENT OF SPILLED OIL IN SAN FRANCISCO BAY AS
      PREDICTED BY ESTUARINE NONTIDAL DRIFT
PUBL  PROC. OF SYMPOSIUM AND WORKSHOP, US. NATIONAL
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BUREAU OF STANDARDS MARINE POLLUTION MONITORING, 1974
CODE 2048R

AUTH COOK F.D., WESTLAKE D.W.
TITL BIODEGRADIBILITY OF NORTHERN CRUDE OILS
PUBL ENVIRONMENTAL SOCIAL COMMITTEE, NORTHERN PIPELINE DEVELOPMENT REPORT NO. 7320
CODE 5003R

AUTH COOK F.D., WESTLAKE C.
TITL MICROBIOLOGICAL DEGRADATION OF NORTHERN CRUDE OILS
PUBL ENVIRONMENTAL COMMITTEE NORTHERN PIPELINE TASK FORCE ON NORTHERN OIL DEVELOPMENT REPORT NO. 74-1
CODE 5004R

AUTH COOK G.S.
TITL NON-TIDAL CIRCULATION IN RI SOUND DRIFT BOTTLE AND SEA BED DRIFTER EXPERIMENTS (1962-1963)
PUBL NAVAL UNDERWATER WEAPONS RESEARCH AND ENGINEERING STATION, NEWPORT, RI, TM NO. 369, MAY 1966
ABST THE FEATURES OF THE DRIFT PATTERNS ARE DISCUSSED IN THE LIGHT OF RIVER EFFLUENT, ADVECTION, AND METEOROLOGICAL EFFECTS.
KEYW NON-TIDAL CIRCULATION, SEASONAL VARIATIONS, SURFACE DRIFT
CODE 7685F

AUTH COOKE R.T.
TITL OIL TRANSPORTATION BY SEA
PUBL OIL IN THE SEA, PLENUM PRESS, 1969
ABST THIS IS GULF OIL'S APPROACH TO SUPERTANKER AND TERMINALS IN THE SEA AND IT DEALS WITH THE ADVANTAGE OF THIS SYSTEM OF TRANSPORTATION.
KEYW SUPERTANKERS, TERMINALS, TRANSPORTATION
CODE 3037R

AUTH COOPER B.S.
TITL LAND DERIVED POLLUTANT HYDROCARBON
PUBL MARINE POLLUTION BULLETIN, 5(1):15-16
CODE 1050A

AUTH COOPER C.K., PEARCE B.R.
TITL A THREE-DIMENSIONAL NUMERICAL MODEL TO CALCULATE CURRENTS IN COASTAL WATERS UTILIZING A DEPTH VARYING VERTICAL EDDY VISCOSITY
PUBL MASSACHUSETTS INSTITUTE OF TECHNOLOGY RALPH M. PARSONS LABORATORY
ABST A 3-D NUMERICAL MODEL IS PRESENTED WHICH IS SIMILAR TO 3-D GALERKIN MODELS RECENTLY DEVELOPED BY VARIOUS INVESTIGATORS. THESE PREVIOUS MODELS REQUIRE REASONABLE COMPUTER TIME AND STORAGE REQUIREMENTS , AN ADVANTAGE NOT SHARED BY 3-D MODELS BASED ON OTHER NUMERICAL SCHEMES.
KEYW CIRCULATION MODELLING, GALERKIN TECHNIQUE, 3-D MODEL.
CODE 7714 F

AUTH COOPER R.A.
TITL DEEPWATER PORTS: HOW DO WE GET THERE FROM HERE?
PUBL UNKNOWN
ABST THIS PAPER DISCUSSES THE CONCERN FOR DEEPWATER PORTS.
KEYW DEEPWATER PORTS, TRADE PATTERNS, INSTITUTIONS
CODE 7160F

AUTH CORMACK D. NICHOLS J.A.
TITL FEASIBILITY STUDY OF AERIAL APPLICATION OF OIL DISPERSANT CONCENTRATES FOR OIL SPILL CLEARANCE
PUBL CROWN COPYRIGHT 1977, ISBN 0 85624 107 5, LR 257(OP)
ABST THIS REPORT DESCRIBES EXPERIMENTS UNDERTAKEN TO ASSESS THE FEASIBILITY OF APPLYING DISPERSANT CONCENTRATES FROM AIRCRAFT TO DISPERSE OIL SLICKS AT SEA
KEYW DISPERSANTS, AIRCRAFT, TECHNIQUES, OPERATIONAL FACTORS
CODE 7194F

AUTH CORMACK D., JEFFERY P.G.
TITL AN OIL POLLUTION CONTROL OFFICER TRAINING COURSE
PUBL CONFERENCE ON PREVENTION AND CONTROL OF OIL POLLUTION
ABST TOPICS INCLUDED IN THIS REPORT ARE OF NATURE AND SOURCE OF OIL SPILLS, BEACH PROTECTION AND CLEANING AND THE RECOVERY OF OIL FROM WATER SURFACES.
KEYW CLEANUP, RECOVERY, PROTECTION
CODE 2014F

AUTH CORMACK D., NICHOLS J.
TITL THE CONCENTRATIONS OF OIL IN SEA WATER RESULTING FROM NATURAL AND CHEMICAL INDUCED DISPERSION OF OIL SLICKS
PUBL 1977 OIL SPILL CONFERENCE
ABST RESULTS ARE PRESENTED ON THE FACTORS RELATING TO THE DISSIPATION OF OIL SPILLS AT SEA INCLUDING EMULSION FORMATION, SPREADING, AND NATURAL DISPERSION INTO THE WATER COLUMN.
KEYW DISSIPATION, EMULSION, FORMATION, SPREADING
CODE 1235F

AUTH CORMACK D., NICHOLS J.A.
TITL A SYSTEM FOR THE APPLICATION OF DISPERSANTS TO THE PROBLEMS OF OIL SPILL CLEARANCE
PUBL WARREN SPRING LABORATORY
ABST THIS PAPER DESCRIBES, BY WAY OF INTRODUCTION ONLY, THE U.K. RESPONSE CAPABILITY FOR OIL SPILL CLEARANCE AND OUTLINES THE REASONS FOR CHOOSING A DISPERSANT APPROACH. THE PAPER THEN CONCENTRATES ON THE DETAILS OF THE SYSTEM USED TO RENDER THE DISPERSANT APPROACH OPERATIONAL.
KEYW DISPERSANTS, SPRAYING, AGITATION, TOXICITY
CODE 7133F

AUTH CORNER E.D.S., SOUTHWARD A.J., SOUTHWARD E.C.
TITL TOXICITY OF OIL SPILL REMOVERS TO MARINE LIFE: AN ASSESSMENT USING THE INTERTIDAL BARNACLE ELMINIUS MODESTUS
PUBL J. MARINE BIOL. ASSOC. U.K., 48:29-47
CODE 1085A

AUTH CORNILLON P., SPAULDING M., REED M.
TITL THE PHYSICAL BEHAVIOR OF OIL IN THE MARINE ENVIRONMENT
PUBL DEPT. OF OCEAN ENGINEERING, UNIV. OF RHODE ISLAND
ABST THIS PAPER IS INTENDED AS AN ASSESSMENT OF THE PRESENT STATUS OF OIL SPILL MODELING. THE FIRST SECTION IS DEVOTED TO AN ORGANIZATION OF OIL SPILL MODELS RELATIVE TO THEIR INTENDED APPLICATIONS. THIS IS FOLLOWED BY A DESCRIPTION OF THE URI OIL SPILL FISHERIES INTERACTION MODEL AND ITS APPLICATION TO A SIMULATED GEORGES BANK OIL SPILL. AN EVALUATION OF THE STATE OF KNOWLEDGE REGARDING FUNDAMENTAL OIL SPILL PROCESS & THE RELATIVE IMPORTANCE OF EACH PROCESS IN TERMS OF POTENTIAL ENVIRONMENTAL IMPACT. PRESENTED AT THE WORKSHOP ON THE PHYSICAL BEHAVIOR OF OIL IN THE MARINE ENVIRONMENT, AT PRINCETON, NEW JERSEY, 1979.
KEYW OIL SPILL MODELING, FISHERIES INTERACTION MODEL, CLEAN UP, DAMAGE ASSESSMENT, RISK ANALYSIS, DETECTION
CODE 7725F

AUTH COUSENS J.D.
TITL VAPOR-LIQUID EQUILIBRIUM OF HYDROCARBONS IN SEAWATER
PUBL PROC. OF A CONF. ON OIL AND THE CANADIAN ENVIRONMENT, UNIV. OF TORONTO, MAY 1973
CODE 2070A

AUTH COWELL E.B.
TITL ECOLOGICAL EFFECTS OF OIL POLLUTION ON LITTORAL COMMUNITIES
PUBL INSTITUTE OF PETROLEUM, LONDON, 1971
ABST THIS BOOK STUDIES THE EFFECT OF OIL POLLUTION ON SALT MARSHES AND ZOOLOGICAL EFFECTS ON SHORE COMMUNITIES. THERE ARE MANY STATISTICS, BUT THEY DEAL MAINLY WITH BIOLOGICAL CONSIDERATIONS AND ARE SOMEWHAT OUTDATED.
CODE 3086P

AUTH COWELL E.B., COX G.V., DUNNET G.M.
TITL APPLICATION OF ECOSYSTEM ANALYSIS TO OIL SPILL IMPACT
PUBL 1979 OIL SPILL CONFERENCE
ABST ECOLOGICAL PRINCIPLES IN SELECTION OF OIL SPILL CLEAN-UP DEVICES, SETTING CLEAN-UP PRIORITIES AND EVALUATION OF CLEAN-UP TECHNIQUES; AND STRESSES THEIR PROPER APPLICATION TO MINIMIZE ECOLOGICAL DAMAGE AND TO PROPERLY EVALUATE THAT DAMAGE.
KEYW OILSPILL, CLEAN-UP, ECOSYSTEM
CODE 7755F

AUTH COX B.A., ANDERSON J., PARKER J.C.
TITL AN EXPERIMENTAL OIL SPILL: THE DISTRIBUTION OF AROMATIC HYDROCARBONS IN THE WATER, SEDIMENT AND ANIMAL TISSUES WITHIN A SHRIMP POND
PUBL CONFERENCE ON PREVENTION AND CONTROL OF OIL POLLUTION
ABST AN EXPERIMENTAL SPILL TO TEST CHANGES IN WATER, SEDIMENTS, AND TISSUES OF MARINE ORGANISMS AFTER THE SPILL. DATA COMPILED IN THIS STUDY WERE COMPARED TO FINDINGS OF VARIOUS FIELD AND LABORATORY INVESTIGATIONS.
KEYW DIESEL FUEL, MORTALITIES, SEDIMENTS
CODE 0504F

AUTH CRAIK A.D.
TITL A WAVE-INTERACTION MODEL FOR THE GENERATION OF WINDROWS
PUBL J. FLUID MECHANICS, VOL. 41, PART 4, 1970
ABST INTERACTIONS OF SUITABLE PAIRS OF GRAVITY WAVES IN A SHEAR FLOW ARE FOUND TO GIVE USE TO A PERIODIC OR NEARLY PERIODIC SECONDARY MOTION.
KEYW GRAVITY WAVES, LANGMUIR VORTICES, WINDROWS
CODE 6312F

AUTH CRAPP G.B.
TITL THE BIOLOGICAL EFFECTS OF MARINE OIL POLLUTION AND SHORE CLEANSING
PUBL FIELD STUDIES COUNCIL OIL POLLUTION RESEARCH UNIT ANNUAL REPORT 1969
CODE 5005R

AUTH CRETNEY W.J., WONG C.S., GREEN D.R., BAWDEN C.A.
TITL LONG TERM FATE OF A HEAVY FUEL OIL IN A SPILL CONTAMINATED B.C. COASTAL BAY
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST ON JAN. 24, 1973, THE FREIGHTER IRISH STARDUST RAN AGROUND BETWEEN THE NORTHERN END OF VANCOUVER ISLAND AND THE MAINLAND OF BRITISH COLUMBIA ON

WADDINGTON REEF IN BROUGHTON STRAIT. THE ACCIDENT CAUSED THE RELEASE OF ABOUT 200 TONS OF 1000 SECOND FUEL OIL. THIS REPORT DOCUMENTS THE FATE OF THE OIL STRANDED THERE.
KEYW PETROLEUM, FATE, ENVIRONMENT, GAS CHROMATOGRAPHY
CODE 2664F

AUTH CROCKER A.D., CRONSHAW J.
TITL THE EFFECT OF A CRUDE OIL ON INTESTINAL ABSORPTION IN DUCKLINGS
PUBL ENVIRONMENTAL POLLUTION JOURNAL, NOV. 1974
ABST THIS PAPER DISCUSSES TEST RESULTS OF CRUDE OIL IN DUCKS.
KEYW MUCOSAL TRANSFER RATES, DEHYDRATION
CODE 2123 F

AUTH CROSS R., ROBERTS A., CUNNINGHAM J., KATZ G.
TITL OIL SPILL CONTROL MANUAL FOR FIRE DEPARTMENTS
PUBL US EPA, TECHNOLOGY SERIES EPA-R2-73-117 FEB. 1973
CODE 0460R

AUTH CROSS R.H.
TITL SMALL VACUUM OIL SKIMMING SYSTEM
PUBL PROJECT 15080FVP, FEB. 1973
CODE 6085R

AUTH CROSS R.H., CUNNINGHAM J.J.
TITL OIL BOOMS FOR EMERGENCY HARBOR USE
PUBL JOURNAL OF WATERWAYS, HARBORS AND COASTAL EGR DIVISION, ASCE, VOL. 99, WW 1, 1973
CODE 0729R

AUTH CROSS R.H., HOULT D.P.
TITL COLLECTION OF OIL SLICKS
PUBL ASCE NATIONAL MEETING ON TRANSPORTATION ENGINEERING, JULY 13-17, 1970
ABST MATHEMATICAL DERIVATIONS AND CALCULATIONS ARE USED TO DESCRIBE THE EFFECTIVENESS OF OIL SLICK SKIMMERS.
CODE 3047F

AUTH CROSS R.H., HOULT D.P.
TITL OIL BOOMS IN TIDAL CURRENTS
PUBL JOURNAL OF WATERWAYS, HARBORS, AND COASTAL EGR. DIVISION, ASCE, VOL. 98, WW2, 1972
CODE 0730R

AUTH CROSWELL W.F., PARKER R.N., KOPIA L.P.
TITL REPORT OF JAN. 31 - FEB. 1, 1978 MEETING, AD HOC COMMITTEE ON SPACE MONITORING OF OIL SPILLS
PUBL LANGLEY RESEARCH CENTER, JUNE 16, 1978
ABST MEETING WAS CONVENED TO DISCUSS USER REQUIREMENTS, CURRENT INVESTIGATIONS AND CAPABILITIES, FUTURE PLANS AND PROBLEM AREAS ATTENDANT TO OIL SPILL DETECTION AND CONTROL. THE RESULTS OF THE MEETING ARE CONTAINED IN THIS REPORT.
KEYW OIL SPILLS, WASTE DISPOSAL, SENSORS, MODELING
CODE 7691F

AUTH CROWLEY K.
TITL ARROW NAVSHIP 0994-006-1010
PUBL DEPT. OF THE NAVY, NAVAL SHIP SYSTEMS COMMAND
ABST THE RECOVERY OF BUNKER C FUEL OIL FROM THE SUNKEN TANKER SS ARROW AND CONCURRENT MEASURES ARE DISCUSSED.
KEYW RECOVERY, OIL TRANSFER BARGE, CLEANUP, SS ARROW
CODE 6131F

AUTH CRUMP-WIESNER H.J., JENNINGS A.L.
TITL PROPERTIES AND EFFECTS OF NON-PETROLEUM OILS
PUBL EPA FOR EPA 1975 CONVENTION
ABST DEALS WITH SPILLS OF NON-PETROLEUM OIL IN AN AQUATIC ENVIRONMENT APPROX. 5 PERCENT OF SPILLS ARE NON-PETROLEUM BUT LITTLE OR NO WORK HAS BEEN DONE WITH THEM.
KEYW NON-PETROLEUM SPILLS, PROPERTIES AND EFFECTS
CODE 0073R

AUTH CSANADY G.T.
TITL TURBULENT DIFFUSION IN THE ENVIRONMENT
PUBL GEOPHYSICS AND ASTROPHYSICS
ABST AVAILABLE AT UNH LIBRARY
KEYW DIFFUSION
CODE 6500F

AUTH CUNDELL A.M., TRAXLER R.W.
TITL HYDROCARBON-DEGRADING BACTERIA ASSOCIATED WITH ARCTIC OIL SEEPS
PUBL DEPT. OF PLANT PATHOLOGY-ENTOMOLOGY, URI FOR AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES, 1974
ABST 15 HYDROCARBON-DEGRADING BACTERIA WERE ISOLATED BY ENRICHMENT CULTURE FROM AN AGED ASPHATIC FLOW NEAR A NATURAL OIL SEEP, CAPE SIMPSON ALASKA. THE ENRICHMENT SUBSTANCES WERE NO. 1 AND NO. 6 FUEL OILS AND NAPHTHALENE. THE BACTERIA WHICH REPRESENTED A RANGE OF GENERAL GREW AT THE EXPENSE OF ALIPHATIC AROMATIC AND NAPHTHALENE HYDROCARBONS. THE GROWTH TEMP. OF THE ORGANISMS SUGGEST THAT THE ISOLATES WERE FACULTATIVE PSYCHROPHILIC BACTERIA.
CODE 6122R

AUTH CUNNINGHAM G.R., EVON J., CHUNG J.S.
TITL THE DESIGN OF AN EFFECTIVE POLLUTION CONTAINMENT BARRIER FOR THE OPEN SEA
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1610, MAY 1-3, 1972
ABST THIS PAPER DESCRIBES THE DEVELOPMENT AND TESTING OF THE BOTTOM TENSION BOOM
KEYW BOTTOM TENSION BOOM, CONTAINMENT, MOTION
CODE 0503F

AUTH CUNNINGHAM J.J.
TITL A RAPIDLY DEPLOYABLE OIL CONTAINMENT BOOM FOR EMERGENCY HARBOR USE
PUBL GOVERNMENT REPORTS ANNOUNCEMENTS
CODE 0310R

AUTH CUTLER W.G., DAVIS R.C.
TITL DETERGENCY THEORY AND TEST METHODS PART 1
PUBL MARCEL DECKER INC., SURFACTANT SCIENCE SERIES, VOL. 5, 1972
ABST THIS VOLUME, IN 2 PARTS, PRESENTS A COMPILATION OF TEST METHODS IN USE TODAY, AS WELL AS A THOROUGH EXAMINATION OF THE THEORETICAL BASIS OF THESE TESTS.
KEYW TEST METHODS, DETERGENCY, TOXICOLOGY
CODE 7008E

AUTH CYWIN A.
TITL FEDERAL RESEARCH AND DEVELOPMENT PROGRAM FOR OIL SPILLS
PUBL UNKNOWN
ABST DISCUSSES RESEARCH AND DEVELOPMENT PROGRAMS FOR PREVENTING OIL SPILLS.
KEYW CLEANUP, CONTROL, PREVENTION
CODE 0864F

AUTH DAILEY J.J., CASSIDY P.E., YAGER B.J.
TITL BEACH PROTECTION BY A DEGRADABLE, SPRAYED FILM
PUBL TRACOR INC., FOR EPA 1975 CONFERENCE
ABST THE FEASIBILITY OF BEACH PROTECTION AGAINST OFF-SHORE OIL SPILLS BY MEANS OF A SPRAYED-ON POLYMERIC FILM IS REPORTED SUCCESSFUL. ONLY PROBLEM IS UNDER LAB CONDITIONS, FILM IS QUITE SLOW TO DEGRADE.
KEYW PROTECTION, DEGRADABLE, SPRAYED FILM, POLYMERICA FILM
CODE 0128F

AUTH DAVIES J.T., DRISCOLL P.
TITL EDDIES AT FREE SURFACES, SIMULATED BY PULSES OF WATER
PUBL IND. ENG. CHEMICAL FUNDAMENTALS, VOL. 13, NO. 2, 1974
ABST STUDIES OF PULSES OF WATER COLORED WITH PERMANGANATE ARE PHOTOGRAPHED AS THEY ARE PROJECTED UPWARD TOWARD A HORIZONTAL FREE SURFACE.
KEYW PULSES, HORIZONTAL FREE SURFACE, ZONES OF DAMPED TURBULENCE
CODE 6310F

AUTH DAVIS C.E., ARC A.E., SEARASITIS J.J., HUDSON H.L.
TITL MULTIELEMENT TRUE BOILING POINT GAS CHROMATOGRAPH FOR MONITORING OIL POLLUTION
PUBL SHELL DEVELOPMENT CO. FOR EPA 1975 CONFERENCE
KEYW MULTIELEMENT TRUE BOILING POINT, GAS CHROMATOGRAPH, MONITORING
CODE 0080F

AUTH DAWSON G.W., SCHUCKROW A.J., SWIFT W.H.
TITL CONTROL OF SPILLAGE OF HAZARDOUS POLLUTING SUBSTANCES
PUBL FEDERAL WATER QUALITY OFFICE, DOI, NOV. 1, 1970, PROGRAM NO. 1509, CONTRACT NO. 14-12-866
ABST AN EVALUATION OF THE WATER QUALITY ASPECTS GERMANE TO THE SPILLAGE OF HAZARDOUS POLLUTING SUBSTANCES IS DEVELOPED.
KEYW HAZARDOUS POLLUTING SUBSTANCES, CHEMICALS, ENFORCEMENT, RECOVERY
CODE 4025B

AUTH DEAN R.C.
TITL DEVELOPMENT OF A MOBILE SYSTEM FOR CLEANING OIL CONTAMINATED BEACHES
PUBL EPA, REPORT-R2-73-233
CODE 0483R

AUTH DEDERA D.
TITL THE DISASTERS THAT DIDNT
PUBL EXXON USA THIRD QUARTER, 1977
ABST THIS REPORT DISCUSSES THE EFFECTS OF A SPILL ON THE ENVIRONMENT.
KEYW DISASTERS, ENVIRONMENTAL EFFECT
CODE 1226F

AUTH DELACOUR J., DEBYSER J.
TITL FLEXODRILLING USED FOR DEEP-WATER SEABED RECONNAISSANCE
PUBL OCEAN INDUSTRY, VOL. 5, NO. 7, JULY 1970
ABST ARTICLE DEALS WITH A LOW COST FLEXOLINE METHOD WHICH PERMITS EASY TRIPPING, AND COMPLETE REMOTE CONTROL OF DRILLING AND CORING.
CODE 3042R

AUTH DENNINGTON V.N., GEORGE J.J., WYBORN C.H.E.
TITL THE EFFECTS OF OILS ON GROWTH OF FRESHWATER PHYTOPLANKTON
PUBL ENVIRONMENTAL POLLUTION VOL. 8, NO. 3, APRIL 1973
ABST IN VIEW OF THE ECOLOGICAL SIGNIFICANCE OF FRESHWATER PHYTOPLANKTON AS PRIMARY PRODUCERS IN THE AQUATIC ENVIRONMENT, SURPRISINGLY LITTLE IS

KNOWN OF THEIR TOLERANCE TO OIL POLLUTION.
CODE 3046H

AUTH DENNIS D.
TITL EFFECTIVELY RECOVERING OIL SPILLS TO GROUNDWATER
PUBL UNKNOWN
ABST THIS ARTICLE REVIEWS THREE METHODS FOR RECOVERING GROUNDWATER OIL SPILLS.
KEYW RECOVERY WELLS, RECOVERY TRENCH, CRUCK RECOVERY SYSTEM
CODE 6056F

AUTH DENNIS J.V.
TITL OIL POLLUTION SURVEY OF THE U.S. ATLANTIC COAST
PUBL API, DIVISION OF TRANSPORTATION, MAY 15, 1959
ABST SPECIAL REFERENCE IS MADE TO THE SOUTHEAST FLORIDA COAST CONDITIONS AT THIS TIME.
KEYW SURVEY, ATLANTIC COAST, SOUTHEAST FLORIDA COAST
CODE 0041H

AUTH DENNIS S.J.
TITL UNITED STATES COAST GUARD HIGH SEAS OIL CONTAINMENT SYSTEM (HSOCS)
PUBL CONFERENCE ON PREVENTION AND CONTROL OF OIL POLLUTION
ABST A DETAILED TECHNICAL DESCRIPTION OF THE HIGH SEAS OIL CONTAINMENT SYSTEM IS PRESENTED.
KEYW CONTAINMENT, BARRIERS, MOORINGS, HANDLING, AIRDELIVERY EQUIPMENT
CODE 0524F

AUTH DER J., BRUNNER D.
TITL AN OFFSHORE MECHANIZED SORBENT OIL RECOVERY SYSTEM USING VESSELS OF OPPORTUNITY
PUBL CIVIL ENGINEERING LAB., NAVAL CONSTRUCTION BATTALION CENTER, PORT HUENEME, CA., REPORT NO. N-1476 54-OCI, MARCH 1977
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KEYW RECOVERY, ABSORBERS, SORBENTS
CODE 0876F

AUTH DER J.J. , GHORMLEY E.
TITL OIL CONTAMINATED BEACH CLEANUP
PUBL CIVIL ENGINEERING LAB., 65-110, NAVAL UNDERWATER SYSTEMS CENTER, NAVAL SHIP SYSTEMS COMMAND, N-1337, APR. 1974
ABST THE MOST EFFECTIVE BEACH CLEANUP PROCEDURES AND EQUIPMENT HAVE BEEN IDENTIFIED AND TABULATED IN TERMS OF SELECTED BEACH CLASSIFICATION.
KEYW ENVIRONMENTAL RESTORATION, OIL CONTAINMENT SYSTEMS, RECOVERY, CLEANUP
CODE 2910F

AUTH DER J.J., GRAHAM D.J.
TITL QUANTITATIVE EVALUATION OF MECHANICAL OIL SPILL CLEANUP DEVICES
PUBL APPLIED CONTROL TECHNOLOGY
ABST A SYSTEMATIC QUANTITATIVE METHOD HAS BEEN DEVELOPED WHICH CAN BE USED FOR PRELIMINARY SCREENING, FINAL EVALUATION AND SELECTION OF CANDIDATE OIL REMOVAL DEVICES.
KEYW RECOVERY, COST STUDIES, RECOVERY EQUIPMENT
CODE 0815F

AUTH DESHIMAN G.
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CODE 10364A

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AUTH DEVANNEY J.W.
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PUBL PROPOSAL TO NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, MARCH 1974
CODE 2061H

AUTH DEVANNEY J.W., SIMPSON H., WEISLER Y.
TITL THE MIT SINGLE SPECIES FISHERY SIMULATOR: APPLICATION TO THE GEORGES BANK YELLOWTAIL
PUBL MIT SEA GRANT PROGRAM REPORT NO. MITSG-77-21 DEC. 1977
ABST THIS STUDY HAS TWO SETS OF GOALS: 1. THE DEVELOPMENT AND DOCUMENTATION OF A FISHERIES SIMULATOR AND 2. THE APPLICATION OF THIS MODEL TO THE GEORGES BANK YELLOWTAIL FISHERY.
KEYW FISHERIES SIMULATOR, STOCK-RECRUITMENT FEEDBACK SYSTEM, GEORGES BANK YELLOWTAIL FISHERY
CODE 2684F

AUTH DEVANNEY J.W., STEWART R.J.
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ABST ESTIMATES BY STATISTICAL ANALYSIS ARE GENERATED OF THE PROBABILITIES OF SPILLAGE BY THE NUMBER AND SIZE OF INDIVIDUAL SPILLS.
CODE 3116A

AUTH DEWITT F.A., MELVIN P.
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ABST SUMMARIES AND BIBLIOGRAPHIC LITERATURE CITATIONS CURRENT STATUS OF SOME OF THE RESEARCH PROJECTS AS LISTED IN REPORTS I AND II.
KEYW DETECTION, CONTROL, PREVENTION
CODE 4035B

AUTH DH R.
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ABST STATISTICS ON OILS RUN THROUGH SIEVES - NO PAPER OR CONCLUSION INCLUDED
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AUTH DICK J., FELDMAN A.
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KEYW REMOVAL, SINKING AGENT, OIL LAYER THICKNESS
CODE 7152F

AUTH DICKEY T.R., LUCKRITZ R.T.
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PUBL USCG
CODE 6504H

AUTH DICKS B.
TITL SOME EFFECTS OF KUWAIT CRUDE OIL ON THE LIMPET PATELLA VULGATA
PUBL ENVIRONMENTAL POLLUTION, 5(3):219-225
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AUTH DIEDERICHSEN J., HALL A.R.
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ABST EXPERIMENTS WERE CONDUCTED ON 175 TONS OF OIL TO DETERMINE BURNING CHARACTERISTICS.
CODE 6098F

AUTH DIEDERICHSEN J., HALL A.R., HINDE P.T.
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ABST THE EFFECT OF THE SIZE AND POSITION OF VENTING APPERTURES ON THE BURNING RATE OF CRUDE OIL IN MODEL TANKS HAS BEEN DETERMINED. ONE SIDE APPERTURE AND ONE LID APPERTURE IN ALL TESTS.
CODE 6107H

AUTH DILTEHLE D.A., TINGLE A.C.
TITL A NUMERICAL STUDY OF MESOSCALE TRANSPORT OF AIR POLLUTANTS IN SEA-BREEZE CIRCULATIONS
PUBL UNKNOWN
ABST IN THIS STUDY A NUMERICAL MODEL IS USED TO EXAMINE THE DEVELOPMENT OF MESOSCALE AIRBORNE POLLUTANT DISTRIBUTIONS.
KEYW POLLUTANT DISTRIBUTIONS, SEA-BREEZE CIRCULATIONS, LAKE/SEA BREEZE FLOWS
CODE 1236F

AUTH DIETZ D.N.
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PUBL JOURNAL OF PETROLEUM TECHNOLOGY, 25:1045-1046
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AUTH DIETZ R.S., LAFOND E.
TITL NATURAL SLICKS ON THE OCEAN
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ABST THIS PAPER SUMMARIZES A FEW OBSERVATIONS CONCERNING THE DISTRIBUTION AND ORIGIN OF NATURAL SLICKS.
KEYW NATURAL SLICKS, DISTRIBUTION, ORIGIN
CODE 2653F

AUTH DISALVO L.H., GAVIL H.E.
TITL HYDROCARBONS ASSOCIATED WITH SUSPENDED PARTICULATE MATTER IN SAN FRANCISCO BAY WATERS
PUBL NAVAL BIOMEDICAL RESEARCH LAB., FOR EPA 1975 CONFERENCE
KEYW HYDROCARBONS, SUSPENDED PARTICULATE MATTER, SAN FRANCISCO BAY
CODE 0089A

AUTH DOE, KENNETH G., HARRIS G.W., WELLS P.G.
TITL A SELECTED BIBLIOGRAPHY ON OIL SPILL DISPERSANTS
PUBL ENVIRONMENTAL PROTECTION AGENCY (ATLANTIC), FISHERIES AND ENVIRONMENT CANADA.
ABST A SELECTED AND INDEXED BIBLIOGRAPHY ON THE CHEMISTRY, BIOLOGICAL EFFECTS, USE AND

EFFECTIVENESS OF OIL SPILL DISPERSANTS IS PRESENTED. IT CONTAINS 304 REFERENCES, COMPILED ALPHABETICALLY AND INDEXED BY AUTHOR AND KEYWORD TO ALLOW RAPID ACCESS.
KEYW BIBLIOGRAPHY, DISPERSANTS, DISPERSING, OIL, POLLUTION,SURFACTANTS, TOXICOLOGY, WATER POLLUTION.
CODE 7713 F

AUTH DOLAN F.X., BOWERSOX, J.P.
TITL DEVELOPMENT OF MOBILE SYSTEM FOR CLEANING OIL CONTAMINATED BEACHES.
PUBL PROJECT NO 15080FIG
ABST THE SYSTEM INVOLVES WASHING OF THE SAND IN A HIGH ENERGY JET-CONTAINER WASHER AND SEPARATION OF THE CLEANED SAND FROM THE WASHING FLUID IN A CONVENTIONAL SOLID-LIQUID CYCLONE.
CODE 6089R

AUTH DORRLER J.S.
TITL LIMITED OIL SPILLS IN HARBOR AREAS
PUBL UNKNOWN
ABST THIS PAPER INVESTIGATES THE ACTUAL PROBLEMS WHICH CONTRIBUTE TO THE HIGH COST OF CLEANING UP AFTER AN OIL SPILL.
KEYW CLEAN UP, REMOVAL, PROBLEMS
CODE 0518F

AUTH DORRLER J.S., AYERS R., WOOTEN G.
TITL HIGH CURRENT CONTROL OF FLOATING OIL
PUBL CONFERENCE ON PREVENTION AND CONTROL OF OIL POLLUTION
ABST THIS PAPER DISCUSSES THE DESIGN, DEVELOPMENT AND DEMONSTRATION OF A STREAMLINED BOOM UTILIZING HYDROFOIL CONCEPTS.
KEYW BARRIERS, CONTROL, CONTAINMENT
CODE 0543F

AUTH DOUMA J.H.
TITL CONTROL OF OIL SPILLAGE BY BOOMS
PUBL US CORPS OF ENG, DEPT. OF THE ARMY, 1967
CODE 0742F

AUTH DOWDELL R.B., WILSON R.P., CHEN Y.L., TEYSSANDIER R.
TITL FINAL REPORT, ORIFICE METER RESEARCH, THEORETICAL STUDY OF FLOW THROUGH CONCENTRIC ORIFICES
PUBL PIPELINE RESEARCH COMMITTEE FOR AMERICA GAS ASSOCIATION, PR-60-50, SEPT. 1, 1972
ABST THE OBJECTIVE OF THE PROJECT WAS TO CREATE A THEORETICAL MODEL OF THE FLOW THROUGH ORIFICES WITH THE ULTIMATE GOAL OF IMPROVING THE MEASUREMENT ACCURACY OF GAS FLOW WHEN USING ORIFICES.
KEYW FLOW PATTERNS, DISCHARGE COEFFICIENTS, CONCENTRIC ORIFICES
CODE 4036B

AUTH DRAGGER M., COOLEY H.J.
TITL OIL CONTAINMENT [illegible]
PUBL BUCUR CORP. FOR EPA NO. 68-03-0205, SSIE NO. GMA-1035
CODE 0464F

AUTH DRAKE R.
TITL ENERGY: TECHNOLOGY FOR SELF-SUFFICIENCY
PUBL COMBUSTION ENGINEERING, INC.
CODE 2961R

AUTH DRAXLER R.R.
TITL A DIFFUSION-DEPOSITION SCHEME FOR USE WITHIN THE ARL TRAJECTORY MODEL
PUBL AIR RESOURCES LABORATORIES, DEC. 1976
ABST A FINITE DIFFERENCE METHOD FOR VERTICAL DIFFUSION AND DEPOSITION HAS BEEN DEVELOPED AND INCORPORATED INTO THE EXISTING ARL TRAJECTORY MODEL. THE FINITE DIFFERENCE MULTI-BOX MODEL PERMITS TEMPORAL VARIATIONS OF VERTICAL DIFFUSIVITY PROFILES AND DEPOSITION PARAMETERS. THE MULTI-BOX IS PRESENTED INCLUDING SOME EXAMPLES OF ITS APPLICATION TO LAGRANGIAN TRAJECTORIES WITH RESPECT TO DRY DEPOSITION AND DIURNAL STABILITY CHANGES.
KEYW FINITE DIFFERENCE METHOD, VERTICAL DIFFUSION, ARL TRAJECTORY
CODE 6505F

AUTH DUBOVIK A.S.
TITL PHOTOGRAPHIC RECORDING OF HIGH SPEED PROCESSES
PUBL CLEARINGHOUSE FOR FEDERAL SCIENTIFIC & TECHNICAL INFORMATION
ABST DESCRIBES METHODS OF THE PHOTOGRAPHIC RECORDING OF HIGH SPEED PROCESSES AS WELL AS HIGH SPEED PHOTOGRAPHIC APPARATUS. THESE METHODS ARE PRESENTLY USED IN THE STUDY OF MANY NEW AREAS OF PHYSICS & TECHNOLOGY. THIS MONOGRAPH IS CONCERNED WITH ALL THE BASIC PROBLEMS OF THE PHOTOGRAPHIC RECORDING OF HIGH SPEED PROCESSES: THE THEORY & METHODS OF THE COMPUTATION OF APPARATUS, THE SELECTION OF AN APPARATUS FOR THE SOLUTION OF A GIVEN PROBLEM, SPECIAL METHODS OF STUDYING THE PHYSICAL PARAMETERS OF HIGH SPEED PROCESSES, ETC.
KEYW OPTICAL SYSTEMS, OPERATING PRINCIPLES, PROPAGATION OF SHOCK WAVES
CODE 7001F

AUTH DUCE R.A.
TITL ATMOSPHERIC POLLUTANT TRANSPORT AND DEPOSITION ON THE SEA SURFACE
PUBL URI, SCHOOL OF OCEANOGRAPHY
CODE 0337R

AUTH DUCE R.A., QUINN J.G., OLNEY C.E.
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PUBL SCIENCE 176
CODE 0338R

AUTH DUDLEY G.
TITL THE INCIDENCE AND TREATMENT OF OIL POLLUTION IN OIL PORTS
PUBL UNKNOWN
ABST SUMMARY AND UPDATE OF PREVIOUS PAPERS PRESENTED BY THE AUTHOR ON THE SUBJECT OF INCIDENCE AND TREATMENT OF OIL POLLUTION IN OIL PORTS.
KEYW TERMINALS, TANKERS, OIL PORTS
CODE 7161F

AUTH DUDLEY K.J., HAVIP R.P.
TITL MANY VARIABLES GO INTO PLANNING DEEPWATER TERMINAL
PUBL OIL AND GAS JOURNAL
CODE 0478R

AUTH DUERDEN P.C.
TITL SPILL IN PORTUGAL A REPORT OF THE JAKOB MAERSK INCIDENT
PUBL ENVIRONMENTAL EMERGENCY BRANCH EPS CANADA, REPORT NO. EPS-8-EE-76-1, SEPT. 1975
ABST THIS REPORT DEALS WITH THE SPILL OF OIL FROM THE DANISH TANKER, JAKOB MAERSK WHICH GROUNDED ON THE COAST OF NORTHERN PORTUGAL IN LATE JAN. 1975
KEYW CLEANUP, BEHAVIOR AND EFFECTS OF OIL, TANKER, JAKOB MAERSK
CODE 7143F

AUTH DUERR C.
TITL HOW DID URI GET INVOLVED IN THIS MESS?
PUBL URI ALUMNI BULLETIN, VOL. LVII, NO. 8, SPRING 1977
ABST WHEN THE LIBERIAN TANKER ARGO MERCHANT LOST HER OIL TO THE SEA OFF NANTUCKET ISLAND IN DEC., URI'S OCEAN SCIENTISTS WENT TO WORK.
KEYW ARGO MERCHANT, ENVIRONMENTAL EMERGENCY, IMPACT
CODE 7066F

AUTH DUKE K.M., DAVIS M.E., DENNIS A.J.
TITL ENVIRONMENTAL ASSESSMENT BIOLOGICAL TESTS FOR PILOT STUDIES - IERL-RTP PROCEDURES MANUAL: LEVEL 1
PUBL EPA OFFICE OF RESEARCH AND DEVELOPMENT, EHE623, APRIL 1977, EPA 600/7-77-043
ABST THIS MANUAL GIVES LEVEL 1 BIOLOGICAL TESTING PROCEDURES FOR PERSONNEL EXPERIENCED IN CONDUCTING BIOASSAYS ON SAMPLES FROM INDUSTRIAL AND ENERGY PRODUCING PROCESSES.
KEYW BIOASSAY, SAMPLING, ANALYZING
CODE 7160F

AUTH DUNBAR M.J.
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PUBL ARCTIC 26(3):179-185, 1973
CODE 3054R

AUTH DUNN C.L., HALE L.Z.(COORDINATED BY)
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PUBL URI COASTAL RESOURCES CENTER MARINE TECHNICAL REPORT 70, 1979 BIBLIOGRAPHY
ABST VOLUME 1 - SIX CROSS REFERENCED SECTIONS - DOCUMENT LISTING, AUTHOR INDEX, CORPORATE INDEX, GEOGRAPHICAL LISTING MAP LISTING, NARRAGANSETT BAY SAMPLING, STATIONS LISTING ON MARINE ENVIRONMENT OF RI AND NEARBY WATERS VOLUME 2 - THE BAY BIB IS DESIGNED SO THAT ALL THE INFORMATION NECESSARY TO OBTAIN A COPY OF A PUBLICATION CAN BE QUICKLY AND EASILY FOUND WITH WHATEVER FACT A RESEARCHER BEGINS.
KEYW MARINE BIBLIOGRAPHY
CODE 7744R

AUTH DUNN W.A., TULLIER P.M.
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PUBL OPERATIONS RESEARCH INC. USCG, AUG. 1974
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CODE 6106F

AUTH DYE L.
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CODE 3065R

AUTH EAMES, M.
TITL STEADY-STATE THEORY OF TOWING CABLES
PUBL QUARTERLY TRANSACTIONS OF THE ROYAL INSTITUTION OF NAVAL ARCHITECTS, APRIL 1968, VOL. 110, NO. 2
ABST THIS PAPER SETS A BASE FOR DEVELOPMENT OF A TOWING CABLE BY PRESENTING THE THEORY OF TOWING.
KEYW HYDRODYNAMICS, TOWED BODY CHARACTERISTICS, CABLE

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      CHARACTERISTICS
CODE  0806F

AUTH  EASTON R.
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PUBL  DELACORTE PRESS, NEW YORK 1972
ABST  THIS IS A COMPLETE REPORT OF THE SANTA BARBARA OIL
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CODE  3081R

AUTH  EDDY, METCALF, INC.
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      BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN
      AREA
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ABST  THIS REPORT SUMMARIZES RESULTS OF STUDY ON
      COMBATTING POLLUTION IN THE EASTERN MASSACHUSETTS
      METROPOLITAN AREA.
KEYW  WATER ORIENTED, LAND DISPOSAL, INDUSTRIAL WASTE
CODE  6522F

AUTH  EDGERTON A.T., MEEKS D., WILLIAMS D.
TITL  MICROWAVE EMISSIONS CHARACTERISTICS OF OIL SLICKS
PUBL  JOINT CONFERENCE ON SENSING OF ENVIRONMENT
      POLLUTANTS, NOV. 1971
CODE  0400K

AUTH  EDGERTON A.T., TREXLER D.T.
TITL  FINAL REPORT, RADIOMETRIC DETECTION OF OIL SLICKS
PUBL  USCG, APPLIED TECHNOLOGY DIVISION, JAN. 1970, NO.
      SD1335-1
ABST  A STUDY HAS BEEN PERFORMED TO ASSESS THE
      FEASIBILITY TO USE MICROWAVE RADIOMETRY FOR
      DETECTION OF OIL POLLUTION.
KEYW  DETECTION, SURVEILLANCE, MICROWAVES, RADIOMETRY
CODE  2062F

AUTH  EDWARDS M.
TITL  ROLE OF THE FEDERAL GOVERNMENT IN CONTROLLING OIL
      POLLUTION AT SEA
PUBL  OIL ON THE SEA, PLENUM PRESS, 1969
ABST  THIS ARTICLE EXAMINES SOME  OF THE PROBLEMS AND
      TOUCHES BRIEFLY UPON EXISTING AUTHORITIES IN
      CONTROLLING OIL POLLUTION OF THE SEA. IT ALSO
      LOOKS AT PENDING CONGRESSIONAL ACTION.
CODE  3038K

AUTH  EIDAM C., FITZPATRICK E., CONLON J.
TITL  THE CASCO BAY OIL SPILL: PROBLEMS OF CLEANUP AND
      DISPOSAL
PUBL  EPA, REGION I, DIVISION OF SURVEILLANCE AND
      ANALYSIS FOR 1975 CONFERENCE
ABST  STUDY OF A LACK OF LOCALLY AVAILABLE EQUIPMENT
      LOGISTICS INVOLVED IN MOVING MEN AND EQUIPMENT TO
      NUMEROUS ISLANDS WHICH WERE AFFECTED BY THE SPILL,
      AND DISPOSAL OF LARGE AMOUNTS OF OIL SOAKED DEBRIS
      PRESENTING UNIQUE PROBLEMS TO ON-SCENE PERSONNEL.
KEYW  CLEANUP, DISPOSAL, CASCO BAY, OIL SOAKED DEBRIS
CODE  0096P

AUTH  EISLER R.
TITL  SOME EFFECTS OF A SYNTHETIC DETERGENT ON THE
      ESTUARINE FISH
PUBL  AMERICAN FISH SOCIETY, 94:26-31
CODE  1080K

AUTH  EISLER R.
TITL  TOXIC, SUBLETHAL AND LATENT EFFECTS OF PETROLEUM
      ON RED SEA MACROFAUNA
PUBL  USEPA, NATIONAL MARINE WATER QUALITY LAB.,
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KEYW  TOXICITY, SUBLETHAL AND LATENT EFFECTS, RED SEA
      MACROFAUNA
CODE  0145R

AUTH  ELDERING H.G.
TITL  OIL SPILL SURVEILLANCE SYSTEMS
PUBL  EPA
CODE  0433H

AUTH  ENRIGHT R.J.
TITL  STEEL OR CONCRETE PLATFORMS FOR THE NORTH SEA - OR
      NEITHER?
PUBL  THE OIL AND GAS JOURNAL, JUNE 30, 1975
ABST  DISCUSSION OF THE PROS AND CONS OF STEEL VS.
      CONCRETE PLATFORM FOR OIL DRILLING.
KEYW  PLATFORMS, NORTH SEA, CONCRETE, STEEL
CODE  5094F

AUTH  ENVIRONMENTAL RESOURCE LTD.
TITL  CLEANING AND CONDITIONING AGENTS: THEIR IMPACT ON
      THE ENVIRONMENT IN THE EEC
PUBL  GRAHAM AND TROTMAN LIMITED
ABST  THIS REPORT EXAMINES THE QUANTITY OF CLEANING AND
      CONDITIONING PRODUCTS USED IN THE COMMUNITY AND
      THE NATURE OF THEIR CONSTITUENTS. IT REVIEWS THE
      EVIDENCE ON THE EFFECTS ON THE ENVIRONMENT OF THE
      FOLLOWING: SURFACTANTS, PHOSPHATES AND OTHER
      DETERGENT BUILDERS, BLEACHING AGENTS, FLUORESCENT
      WHITENING AGENTS, ABRASIVES, ALCOHOL AND
      HYDROTROPES PERFUMES AND DYES, ETC.
KEYW  SURFACTANTS, DETERGENTS, ENVIRONMENTAL IMPACT
CODE  3696F

AUTH  FALLAH M., STARK A.
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      SEA
PUBL  OCEAN ENGINEERING VOL. 3, 1976
ABST  OIL SPILLED AT SEA SPREADS INTO AN IRREGULAR OIL
      MASS. WAVES AND SEA TURBULENCE BEAT PORTIONS OF
      THE OIL MASS INTO PARTICLES AND DRIVE THEM TO
      SUBSURFACE DEPTHS. THIS PROCESS IS CALLED
      DISPERSION AND IS DISCUSSED HERE.
KEYW  DISPERSION, TURBULENT FLUCTUATIONS, WAVE ACTION
CODE  6564F

AUTH  FALLAH M.H., STARK R.M.
TITL  MOVEMENT OF SPILLED OIL AT SEA
PUBL  MARINE TECHNOLOGY SOCIETY JOURNAL, VOL. 10, NO. 1,
      JAN. 1976
ABST  THIS PAPER PROVIDES AN OVERVIEW OF SOME IMPORTANT
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KEYW  SPREADING, DRIFT, DIFFUSION, DISSIPATION
CODE  6581F

AUTH  FALLAH-ARAGHI M.
TITL  RANDOM MODULES OF SPILLED OIL MOVEMENT
PUBL  UNIVERSITY MICROFILMS INTERNATIONAL, ANN ARBOR,
      MICH.
ABST  THIS DISSERTATION FOCUSES UPON MODELING THE
      DOMINANT MODES OF MOVEMENT OF SPILLED OIL IN AN
      UNCONTROLLED ENVIRONMENT. REVIEWING THE STATE OF
      THE ART, IT IS CONCLUDED THAT A CAUSAL ANALYSIS OF
      THE RANDOM MOVEMENT OF SPILLED OIL IS BEYOND THE
      SHORT TERM REACH. A SEMI-EMPIRICAL MODELING
      APPROACH WITH PROVISION FOR DESCRIBING TACTICAL
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CODE  2096P

AUTH  FANTASIA J., INGRAO H.
TITL  THE DEVELOPMENT OF AN EXPERIMENTAL AIRBORNE LASER
      OIL SPILL REMOTE SENSING SYSTEM
PUBL  DETECTION AND MONITORING OF SPILLS
ABST  THE DEVELOPMENT AND LAB TESTS RESULTS OF THE
      EXPERIMENTAL SYSTEM ARE DESCRIBED.
KEYW  DETECTION, CLASSIFICATION, QUANTIFICATION
CODE  0851F

AUTH  FARLOW J.S. FREESTONE F.J.
TITL  OPERATION OF NEW EPA FACILITY PERMITS TEST OF
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PUBL  OIL AND GAS JOURNAL, JUNE 30, 1975
ABST  A REPORT ON THE OPERATION OF A NEW OIL AND
      HAZARDOUS MATERIALS SIMULATED ENVIRONMENTAL TEST
      TANK THAT IS AVAILABLE ON A COST SHARING BASIS, TO
      BOTH PRIVATE AND GOVERNMENT USERS TO CONDUCT TESTS
      AND TO DEVELOP FULL SIZE DEVICES AND TECHNIQUES
      FOR CONTROL OF OIL AND HAZARDOUS MATERIALS SPILLED
      IN INLAND AND COASTAL WATERS.
KEYW  CLEANUP, WAVE AND TOW SPEED, OIL AND HAZARDOUS
      MATERIALS SIMULATED ENVIRONMENTAL TEST TANK
CODE  2907F

AUTH  FARLOW J.S., FREESTONE F.J.
TITL  USEPA'S TEST FACILITY OHMSETT: THE FIRST SIX
      MONTHS
PUBL  CONFERENCE ON PREVENTION AND CONTROL OF OIL
      POLLUTION
ABST  A REPORT OF THE FIRST SIX MONTHS OF TEST TANK
      OPERATION AND A DISCUSSION OF THE FEASIBILITY OF
      THE FACILITY'S SERVING THE PUBLIC AND PRIVATE
      USERS IS PRESENTED.
KEYW  CLEANUP, BIOLOGICAL IMPACT, PREVENTION
CODE  0527F

AUTH  FARRELL C.
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      HY7 PROC. PAPER 6823, JULY 1973
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AUTH  FARRINGTON J.W., MEDEIROS G.V.
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      PETROLEUM HYDROCARBONS IN MARINE ORGANISMS
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KEYW  ANALYSIS, MARINE ORGANISMS, HYDROCARBONS
CODE  0083H

AUTH  FAY J., MACKENZIE J.
TITL  COLD CARGO
PUBL  ENVIRONMENT, VOL. 14, NO. 9, NOV. 1972
ABST  IMPORTATION OF LIQUIFIED NATURAL GAS MAY HELP MEET
      RISING ENERGY NEEDS IN THE US BUT MAY CREATE NEW
      SAFETY HAZARDS. ARTICLE INCLUDES STATISTICS ON
      IMPORTATION QUANTITIES OF NATURAL GAS AND
      PROPERTIES OF NATURAL GAS SPILLS.
CODE  3095K

AUTH  FAY J.A.
TITL  OIL SPILLS: THE NEED FOR LAW AND SCIENCE
PUBL  TECHNOLOGY REVIEW, VOL. 72, NO. 3, JAN. 1970
ABST  THE CONTROL OF MARINE OIL POLLUTION IS HAMPERED BY
      INADEQUATE RESEARCH AND BY ECONOMIC CONSTRAINTS.
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AUTH  ERLING BRATBERG
TITL  THE BRAVO BLOW OUT
PUBL  INSTITUTE OF MARINE RESEARCH, SER. B, NO. 5, MAY
      1977
ABST  A REPORT ON MARINE RESEARCH ACTIVITIES APRIL 23 TO
      MAY 5, 1977 INCLUDING SOME PRELIMINARY RESULTS.
KEYW  PLATFORM BLOWOUT, DISCHARGES, TOXICITIES
CODE  6504F

AUTH  ESTES J.E., GOLOMB B.
TITL  OIL SPILLS: METHOD FOR MEASURING THEIR EXTENT ON
      THE SEA SURFACE
PUBL  SCIENCE, VOL. 165, AUG. 1970
ABST  THIS PAPER DISCUSSES AN ACCURATE SYSTEM DEVELOPED
      TO MEASURE SPILLS.
KEYW  AREA AFFECTED, DEGREE OF CONCENTRATION, QUANTITY
      OF POLLUTANTS
CODE  2101F

AUTH  ESTES J.E., THAMAN R.R., SENGER L.W., MIKOLAJ P.G.
TITL  VOLUMETRIC DETERMINATION OF MARINE OIL SPILLS
      USING COORDINATED AIRBORNE AND SURFACE SAMPLING
      DATA
PUBL  DETECTION AND MONITORING OF SPILLS
ABST  THIS PAPER DISCUSSES A SYSTEM FOR ESTIMATING THE
      VOLUME OF OIL LOSS RESULTING FROM OIL POLLUTION
      INCIDENTS.
KEYW  DETECTION, MEASUREMENT, MONITORING
CODE  0840F

AUTH  EVANS J.T.
TITL  PNEUMATIC AND SIMILAR BREAKWATERS
PUBL  DOCKS AND BRITISH TRANSPORT COMMISSION, WATERWAYS
      RESEARCH STATION JUNE 1955
ABST  THE SURFACE CURRENTS SET-UP BY AIR INJECTION, AND
      THE DISTRIBUTION OF THE WATER VELOCITY WITHIN THE
      CURRENTS, CAN BE MATCHED BY CURRENTS SET UP BY
      WATER JETS AND THAT THE TWO CURRENTS SO MATCHED
      HAVE ALMOST THE SAME WAVE-DAMPING EFFECTS WHETHER
      THEY ARE SET UP BY WATER JETS OR AIR. IT IS FOUND
      THAT WAVES OF SMALL AMPLITUDE ARE STOPPED IN THE
      WAY PREDICTED THEORETICALLY.
KEYW  SURFACE CURRENTS, WATER VELOCITY, WATER JETS.
CODE  3019F

AUTH  EWING G.
TITL  SLICKS, SURFACE FILMS, AND INTERNAL WAVES
PUBL  JOURNAL OF MARINE RESEARCH, VOL IX, NO. 3, 1950
ABST  THIS PAPER DISCUSSES THEORIES AND TESTS OF THE
      RELATION OF SLICKS TO WAVE MOTION.
KEYW  RIPPLE-DAMPING, COMPACTION, WIND STRESS
CODE  6327F
      BUT PROPERLY DESIGNED LEGISLATION COULD BE MUCH TO
      DISCOURAGE THE POLLUTER.
CODE  3043F

AUTH  FAY J.A.
TITL  PHYSICAL PROCESSES IN THE SPREAD OF OIL ON A WATER
      SURFACE
PUBL  PHYSICAL PROCESSES
ABST  THIS PAPER REVIEWS OUR CURRENT UNDERSTANDING OF
      THE PHYSICAL PROCESSES WHICH INITIALLY COULD
      ULTIMATELY TERMINATE THE SPREAD OF OIL ON THE
      SURFACE OF WATER.
KEYW  PHYSICAL PROCESSES, SPREADING, WATER SURFACE
CODE  0506F

AUTH  FAY J.A.
TITL  THE SPREAD OF OIL SLICKS ON A CALM SEA
PUBL  OIL ON THE SEA, PLENUM PRESS, 1969
ABST  THIS ARTICLE DEALS MATHEMATICALLY WITH OIL SLICK
      SPREADING.
KEYW  MATHEMATICAL, SPREADING
CODE  3034F

AUTH  FELDMAN M.H.
TITL  PETROLEUM WEATHERING: SOME PATHWAYS, FATE AND
      DISPOSITION ON MARINE WATERS.
PUBL  NATIONAL ENVIRONMENT RESEARCH CENTER, OFFICE OF
      RESEARCH AND DEVELOPMENT, PROGRAM NO. 1BA025,
      SEPT. 1973
ABST  THREE MECHANISMS OF WEATHERING OF OIL POLLUTION ON
      MARINE WATERS ARE DISCUSSED. PHOTOLYSIS,
      INTERACTION WITH TRACE MATERIALS AND SEDIMENTATION
      WITH PARTICULATE MATERIALS ARE CONSIDERED AS
      COMPETITIVE TO OTHER FATE OF PETROLEUM MECHANISMS
      AND AS HAVING POSSIBLE ECOLOGICAL IMPORTANCE.
KEYW  WEATHERING, FATE, DISPOSITION, PHOTOLYSIS, TRACE
      MATERIALS, SEDIMENTATION
CODE  6130F

AUTH  FELDMAN M.H.
TITL  THE 50 MILE BALLAST OIL DUMPING PROHIBITED ZONE
      OFF ALASKA RECONSIDERED IN THE LIGHT OF AVAILABLE
      DATA GLEANED FROM SIGNIFICANT INCIDENTS
PUBL  US DEPT. OF INTERIOR, FWQA, OCT. 1970
ABST  DISCUSSION OF PETROLEUM POLLUTION IN THE ALASKAN
      ENVIRONMENT INFORMATION DEFICIENCIES FOR ANALYSIS
      OF THE ALASKAN SITUATION DISCUSSION OF THE 50 MILE
      PROHIBITED ZONE AND REFERENCES.
CODE  6012A

AUTH  FERNANDES J.M.
TITL  ENERGY CONSERVATION AND THE POTENTIAL ROLE OF
      WASTE
PUBL  US/JAPAN CONSERVATION SEMINAR, FEB. 4-5, 1976
ABST  THIS PAPER WILL TOUCH ON THE ENERGY CRISIS DISCUSS
      THE AVAILABILITY OF FUEL CONSIDER SOME OF THE TRADE
      OFFS AND LEAD INTO THE POSITION WASTE COULD TAKE
      IN A PROGRAM OF FUEL CONSERVATION.
CODE  2963F

AUTH  FERRAN B.
TITL  OUTBOARD'S INEFFICIENCY IS A POLLUTION FACTOR
PUBL  NATIONAL FISHERMAN, APRIL 1970
ABST  THE POLLUTION EFFECTS OF OUTBOARD MOTORS, THEIR
      SPILLAGE RATES AND WASTAGE ARE DISCUSSED.
CODE  3044R

AUTH  FINCH L., BLACKLAW J.
TITL  OIL SPILL TREATING AGENTS
PUBL  API, CONTRACT NO. 212800000, PROJECT OS-6, NO.
      4150, REVISED 1972
ABST  TO UPGRADE INFORMATION REGARDING AVAILABLE OIL
      SPILL TREATING AGENTS.
KEYW  TREATING AGENTS, WAREHOUSED MATERIALS, PRODUCTION
      RATES, READY REFERENCE
CODE  40394 B

AUTH  FINGAS M., ROSS C.W.
TITL  OIL SPILL BIBLIOGRAPHY MARCH, 1975 TO DEC. 1976
PUBL  RESEARCH AND DEVELOPMENT DIVISION, ENVIRONMENTAL
      EMERGENCY BRANCH, DEPT. OF FISHERIES AND
      ENVIRONMENT, EPA-3-EC-77-10, FEB. 1977
ABST  PERTAINING TO THE FIELD OF OIL SPILLS, THIS
      BIBLIOGRAPHY REPRESENTS A LISTING OF VARIOUS
      LITERATURE EITHER WRITTEN OR PUBLISHED DURING THE
      PERIOD OF MARCH 1975 TO DEC. 1976.
KEYW  BIBLIOGRAPHY, RESEARCH
CODE  7151F

AUTH  FINGER S., YU T.S.
TITL  ANALYTICAL EXAMINATION OF OIL/WATER SEPARATION BY
      COALESCENCE
PUBL  CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST  THE PHYSICAL SEPARATION PROCESS OF COALESCENCE HAS
      BEEN STUDIED ANALYTICALLY UNDER CONTROLLED
      CONDITIONS IN REGARD TO THE SEPARATION OF OIL FROM
      OILY WATER MIXTURES.
KEYW  COALESCENCE, SEPARATION, CLEANUP
CODE  5117F

AUTH  FIOCCO R.J., RIELLEY V.B.
TITL  SLOP TANK DESIGN FOR IMPROVED LOAD ON TOP.
PUBL  EXXON RESEARCH AND ENGINEERING CO.
ABST  THIS INVESTIGATION PROVIDES A BASES FOR FUTURE
      LARGE SCALE OR SHIPBOARD STUDIES TO IMPROVE THE
      PERFORMANCE OF SLOP TANKS ON EXISTING TANKERS AS

      WELL AS ON FUTURE TANKERS.
KEYW  SLOP TANKS, LOAD ON TOP, TANKERS
CODE  8043A

AUTH  FISCHER P., STEVENSON A.
TITL  NATURAL HYDROCARBON SEEPS ALONG THE NORTHERN SHELF
      OFF THE SANTA BARBARA BASIN, CALIFORNIA
PUBL  OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1738,
      APR. 29-MAY 2, 1973
ABST  THIS PAPER DISCUSSES THE STUDY OF SEEPS ALONG
      FLOOR OF OCEAN.
KEYW  SUB-BOTTOM PROFILER SYSTEM, HYDROCARBON SEEPS,
      SEDIMENTS
CODE  0849F

AUTH  FORNS J.M.
TITL  METHOD DEVELOPMENT AND INITIAL EVALUATIONS OF
      LARVAL LOBSTER EXPOSURE TO SOUTH LOUISIA-  CRUDE
      OIL
PUBL  API, FEB. 20, 1976
ABST  THIS PAPER DISCUSSES THE RESULTS OF TESTS OF
      LOBSTER LARVAE TO OIL.
KEYW  LARVAL LOBSTER EXPOSURE, TOXICITY, LOUISIANA CRUDE
CODE  2555F

AUTH  FORRESTER W.D.
TITL  DISTRIBUTION OF SUSPENDED OIL PARTICLES FOLLOWING
      THE GROUNDING OF THE TANKER ARROW
PUBL  JOURNAL OF MARINE RESEARCH VOL. 29-2
ABST  THIS PAPER DISCUSSES THE ORIGIN OF THE PARTICLES.
      THEIR DISTRIBUTION IN SIZE AND DEPTH AND TRANSFER.
KEYW  FOOD CHAINS, DISPERSION, CIRCULATION
CODE  6545F

AUTH  FOSSBERG R.A.
TITL  FLEXIBLE OIL BOOM
PUBL  OFFICIAL GAZETTE OF THE US PATENT OFFICE, VOL.
      929, NO. 2
ABST  DESCRIBES A NEW BOOM PRODUCED.
CODE  3115A

AUTH  FOULK, M.R., ZILLIOUX E.J., GARCIA J.A.
TITL  USING ARTEMIA TO ASSAY OIL DISPERSANT TOXICITIES
PUBL  WATER POLLUT. CONTROL FED. JOURNAL,
      45(11):2389-2391
CODE  1971R

AUTH  FOWLER J.R.
TITL  MATHEMATICAL MODEL OF THE TEXAS A&M LOW TENSION
      OIL CONTAINMENT BARRIER
PUBL  PHD THESIS A&M UNIVERSITY
CODE  3044AR
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AUTH FOWLER J.R., BAILEY E.I.
TITL DYNAMIC RESPONSE OF SURFACE-MOUNTED VERTICAL BARRIER TO WAVE ACTION BY ANALOG AND DIGITAL SIMULATION
PUBL JOURNAL OF ENG. FOR INDUSTRY, FEB. 1974
ABST A TWO-DIMENSIONAL THEORETICAL MODEL REPRESENTING THE DYNAMICS OF AN OIL CONTAINMENT BARRIER WAS SOLVED ON ANALOG AND DIGITAL COMPUTERS.
KEYW MECHANICAL BARRIERS, CONTAINMENT, RESPONSES TO WAVES
CODE 0834F

AUTH FRANCIS J.R.
TITL WIND STRESS ON A WATER SURFACE
PUBL UNKNOWN
ABST THIS REPORT SUMMARIZES THE ATTEMPTS AT MEASUREMENT OF TANGENTIAL STRESS OF WIND ON WATER SURFACES.
KEYW WINDSTRESS, WINDSPEED, DRAG, TANGENTIAL STRESS
CODE 0867F

AUTH FRANK R.L.
TITL OIL POLLUTION CONTROL ON THE BUFFALO RIVER
PUBL UNKNOWN
ABST THIS PAPER DISCUSSES THE TWO MAIN SYSTEMS DEVELOPED: THE UPPER RIVER SYSTEM AND THE LOWER RIVER SYSTEM. THE BASIC DESIGN OF THE AIR BARRIER IS DISCUSSED ALONG WITH THE RESULTS OF LAB. AND FIELD TESTS.
KEYW CONTROL, AIR BARRIERS, OIL RETRIEVAL, CHEMICAL USE
CODE 0519F

AUTH FRANK, U.
TITL IDENTIFICATION OF PETROLEUM OILS BY FLOURESENCE SPECTROSCOPY
PUBL INDUSTRIAL WASTE TREATMENT LAB., EPA, 1975 CONFERENCE
KEYW IDENTIFICATION, FLUORESCENCE SPECTROSCOPY
CODE 0079H

AUTH FRANKENFELD J.W.
TITL FACTORS GOVERNING THE FATE OF OIL AT SEA: VARIATION IN THE AMOUNTS AND TYPES OF DISSOLVED OR DISPERSED MATERIALS DURING THE WEATHERING PROCESS
PUBL ESSO RESEARCH AND ENGINEERING CO., 1973 JOINT CONFERENCE
KEYW FATE, TYPES, DISSOLVED, DISPERSED, WEATHERING PROCESS
CODE 0268F

AUTH FRANKENFELD J.W.
TITL IDENTIFICATION OF WEATHERED OIL FILMS FOUND IN THE MARINE ENVIRONMENT
PUBL EXXON
CODE 0341H

AUTH FRANKENFELD J.W.
TITL WEATHERING OF OIL AT SEA
PUBL NTIS AD-787705, ESSO RESEARCH AND ENGINEERING CO., 9/73
ABST A STUDY WAS CONDUCTED TO TRACE THE FATE OF PETROLEUM PRODUCTS DISCHARGED IN THE MARINE ENVIRONMENT AND TO DETERMINE THE MAGNITUDE OF THE MORE IMPORTANT VARIABLES ON THE PHYSICAL AND CHEMICAL CHANGES WHICH OCCUR.
CODE 3114F

AUTH FREESTONE F.J., ANDERSON R.A., TRENTACOSTE N.P.
TITL U.S. EPA RESEARCH IN HIGH-SPEED DEVICES FOR THE RECOVERY OF THIN-FILM OIL SPILLS
PUBL EPA, TETRADYNE CORP., SCIENCE APPLICATIONS INC., FOR EPA 1975 CONFERENCE
ABST MATERIAL IS PRESENTED ON THE RATIONALE FOR DEVELOPING THE DEVICES FOR THE TESTING TECHNOLOGY USED AND THE TEST RESULTS FOR EACH OF TWO DEVICES.
KEYW DEVELOPMENT, THIN-FILM OIL SPILLS, RECOVERY
CODE 0127F

AUTH FREESTONE F.J., TOOBKIN R.D.
TITL REVIEW OF USEPA RESEARCH IN OIL-WATER SEPARATION TECHNOLOGY
PUBL USEPA FOR EPA 1975 CONFERENCE
ABST THE USEPA HAS SPONSORED TWO SEPARATE RESEARCH CONTRACTS IN THE FIELD OF WATER-OIL SEPARATION FOR THE FISCAL YEAR 1974. THE RATIONALE FOR DEVELOPMENT OF EACH OF THESE DEVICES ALONG WITH DETAILED INFORMATION CONCERNING TEST RESULTS IS PRESENTED.
KEYW RESEARCH, OIL-WATER SEPARATION
CODE 0131F

AUTH FREY R.F.M.
TITL DEVELOPMENT OF HERMAPHRODITE BREAKWATER UNITS UTILIZING HYDROFOILS IN SPECIFIC ARRANGEMENTS
PUBL URI MARINE TECHNICAL REPORT SERIES NO. 24
CODE 0370H

AUTH FRYE J.
TITL SOMETHING IS BEING DONE ABOUT OIL
PUBL BOATING ZIFF DAVIS PUBL. APRIL 1968
ABST A DISCUSSION OF LEGISLATION PASSED TO CURTAIL VIOLATORS OF POLLUTION LAWS AS PERTAINS TO OIL SPILL AND SOME METHODS OF DETECTION AND REMEDIAL ACTION.
CODE 6004P

AUTH FRYE J.
TITL SPOT 8.5 MILES OFF DELAWARE EYED FOR SUPERPORT
PUBL NATIONAL FISHERMAN, OCT. 1972
ABST ARTICLE ON HOW MAN MADE ISLAND COULD FULFILL PUBLIC AND ENVIRONMENTAL NEEDS. POLLUTION PREVENTION MEASURES ARE LISTED.
KEYW SUPERPORT, MAN MADE ISLAND, ENVIRONMENTAL NEEDS, POLLUTION PREVENTION
CODE 0025H

AUTH GALES L.E., BUSS J.A., BLEDSOE L.J.
TITL SIMULATION CONCEPTS FOR FISHERY SYSTEMS
PUBL WASHINGTON SEA GRANT REPRINT NO. WSG-TA 77-5. REPRINTED FROM: JOURNAL OF THE FISHERIES RESEARCH BOARD OF CANADA, VOL. 34, NO. 12, P. 2374-2380, 1977
ABST PRESENTS AN ADVANCED COMPUTER TECHNIQUE (LINKED LISTS) WHICH PERMITS THE INCLUSION OF COMPLEX TIME SIMULATIONS AND DATA STRUCTURE IN FISHERY MODELS WITH LITTLE ADDITIONAL EFFORT. EXAMPLES OF APPLICATION TO COMPLEX INFORMATION ARRAYS AND AN AGE-STRUCTURED MODEL ARE INCLUDED.
KEYW FISHERIES, POPULATION, COMPUTER PROGRAMS, MODELS
CODE 7747F

AUTH GALVIN C.J.
TITL WAVE-HEIGHT PREDICTION FOR WAVE GENERATORS IN SHALLOW WATER
PUBL US ARMY CORPS OF ENGINEERS, TECHNICAL MEMORANDUM NO. 4, MARCH 1964
ABST THIS PAPER DISCUSSES TESTING OF A METHOD OF WAVE HEIGHT PREDICTION.
CODE 3040H

AUTH GANDHI D.S.
TITL SHIPOWNERS, MARINERS AND THE NEW LAW OF THE SEA
PUBL FAIRPLAY PUBLICATION LTD.
ABST THIS REPORT DISCUSSES THE EFFECTS OF TECHNICAL LEGAL AND POLITICAL CONSTRAINTS UPON THE TRADITIONAL USERS OF THE WORLDS OCEANS.
KEYW SHIPOWNERS, MARINERS, POLITICAL CONSTRAINTS
CODE 2004F

AUTH GARDNER G.R., YEVICH P.P., ROGERSON P.F.
TITL MORPHOLOGICAL ANOMALITIES IN ADULT OYSTER, SCALLOP, AND ATLANTIC SILVERSIDES EXPOSED TO WASTE MOTOR OILS
PUBL USEPA, NATIONAL MARINE WATER QUALITY LAB., FOR EPA 1975 CONFERENCE
KEYW MORPHOLOGICAL ANOMALITIES, OYSTER, SCALLOP, ATLANTIC SILVERSIDES, WASTE MOTOR OILS
CODE 0137H

AUTH GARRETT W., SMAGIN V.
TITL DETERMINATION OF THE ATMOSPHERIC CONTRIBUTION OF PETROLEUM HYDROCARBONS TO THE OCEANS
PUBL WORLD METEOROLOGICAL ORGANIZATION, ISBN 92-63-10440-9, WMO NO. 440, 1976
ABST THIS REPORT REVIEWS THE EXISTING KNOWLEDGE CONCERNING PETROLEUM HYDROCARBONS IN THE MARINE ATMOSPHERE AND PROCEDURES BY WHICH THEIR FLUX FROM THE AIR TO SEA MAY BE DETERMINED.
KEYW ATMOSPHERIC POLLUTION, CONCENTRATION, TRANSPORT
CODE 7602F

AUTH GARRETT W.D.
TITL CONFINEMENT AND CONTROL OF OIL POLLUTION ON WATER WITH MONOMOLECULAR SURFACE FILMS
PUBL UNKNOWN
ABST UNDER FAVORABLE CONDITIONS MONOMOLECULAR SURFACE FILMS CAN BE USED TO GUIDE, CONFINE AND CONDENSE PETROLEUM SPILLS ON WATER.
KEYW PREVENTION, CONTAINMENT, RECOVERY
CODE 0523F

AUTH GARRETT W.D.
TITL IMPACT OF PETROLEUM SPILLS ON THE CHEMICAL AND PHYSICAL PROPERTIES OF THE AIR/SEA INTERFACE
PUBL NAVAL RESEARCH LAB., DEPT. OF THE NAVY, PROJECT NO. RR 131-03-41-5507, FEB.16, 1972
ABST WEATHERING DISPERSION AIR/SEA DYNAMICS ULTIMATELY DEGRADE THE SPILL TO TARLIKE LUMPS AND/OR STABLE WATER-IN-OIL EMULSIONS, BOTH WHICH HAVE LONG LIFE TIMES IN THE SEA. ALTHOUGH AN OIL SLICK CAN DAMP ITS ENVIRONMENT BY SLOWING PROCESSES AT THE AIR/SEA INTERFACE AND RESISTING INTERACTIONS BETWEEN THE OCEAN AND ATMOSPHERE, A WORLDWIDE OCEAN SURFACE FILM CAPABLE OF GLOBAL IMPACTS IS UNLIKELY.
KEYW WEATHERING DISPERSION, DEGRADATION, EMULSION
CODE 6096F

AUTH GEORGE J. DAVID
TITL THE EFFECTS OF POLLUTION BY OIL AND OIL-DISPERSANTS ON THE COMMON INTERTIDAL POLYCHAETES, CIRRIFORMIA TENTACULATA AND CIRRATULUS CIRRATUS
PUBL JOURNAL OF APP. ECOL., VOL. 8, NO. 2, AUG. 1971 PP411-420
ABST THIS PAPER DISCUSSES TEST RESULTS OF DISPERSANTS ON POLYCHAETES.
KEYW DISPERSANTS, TOXICITY, POLYCHAETES
CODE 2130F

AUTH GEORGE J.C.
TITL SUBLETHAL EFFECTS ON LIVING ORGANISMS
PUBL MARINE POLLUTION BULL.

CODE 1047R

AUTH GERMAN J.M.
TITL U.S. COAST GUARD ARCTIC OIL POLLUTION PROGRAM
PUBL OFFICE OF RESEARCH AND DEVELOPMENT, USCG. FOR EPA CONFERENCE 1975
ABST PAPER INCLUDES: THE ARCTIC POLLUTION RESPONSE PROGRAM, FIELD EXPERIMENTS, HARDWARE EVALUATION TEST, CONTAINMENT DEVICES, RECOVERY DEVICE, PERSONNEL AND SUPPORT EQUIPMENT PERFORMANCE.
KEYW ARCTIC POLLUTION, CONTAINMENT, RECOVERY
CODE 0103R

AUTH GEYER R.A., SWEET W.E.
TITL NATURAL HYDROCARBON SEEPAGE IN THE GULF OF MEXICO
PUBL TRANSACTIONS GULF COAST ASSOCIATION OF GEOLOGICAL SOCIETIES, 23RD ANNUAL CONVENTION, OCT. 24-26, 1973
CODE 0339F

AUTH GIBBS C.F.
TITL A NEW APPROACH TO THE MEASUREMENT OF RATE OF OXIDATION OF CRUDE OIL IN SEAWATER SYSTEMS
PUBL CHEMOSPHERE NO. 3, 1972
CODE 2079R

AUTH GIBSON A.
TITL NON-TOXIC DISPERSANT COMBATS OIL SPILLS
PUBL WORLD PETROLEUM, 40(4)
CODE 2125R

AUTH GILBERT R.O.
TITL ON THE ESTIMATION OF SPATIAL PATTERN FOR ENVIRONMENTAL CONTAMINANTS
PUBL STATISTICS SECTION, SYSTEMS DEPT., PACIFIC NORTHWEST LABORATORIES, BATTELLE MEMORIAL INSTITUTE, AUG. 1976
ABST IN THIS PAPER THE PERFORMANCE OF AN ITERATIVE PROCEDURE FOR ESTIMATING THE GRID VALUES TO DETERMINE SPATIAL PATTERN OR GEOGRAPHICAL DISTRIBUTION OF ENVIRONMENTAL CONTAMINANTS IS EXAMINED.
KEYW SPATIAL PATTERN, GEOGRAPHICAL DISTRIBUTION, ENVIRONMENTAL CONTAMINANTS
CODE 1210F

AUTH GILFILLAN E.S., VANDERMEULEN J.H.
TITL ALTERATIONS IN GROWTH AND PHYSIOLOGY OF SOFT-SHELLED CLAMS, MYA ARENARIA, CHRONICALLY OILED WITH BUNKER C FROM CHEDABUCTO BAY, NOVA SCOTIA, 1970-76
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST DATA ON CARBON FLUX AND SHELL AND TISSUE GROWTH, AND ON POPULATION STRUCTURE AND RECRUITMENT OF M. ARENARIA FROM CHRONICALLY OILED SEDIMENTS 6 AND 7 YEAR POSTSPILL. RESULTS ARE DISCUSSED IN TERMS OF POPULATION RECOVERY POTENTIAL DURING CHRONIC OIL EXPOSURE.
KEYW PHYSIOLOGY, GROWTH, CARBON FLUX, RECRUITMENT
CODE 2664F

AUTH GILMORE G.A., SMITH D.D., RICE A.H., SHENTON E.H., MOSER W.H.
TITL FINAL REPORT, SYSTEMS STUDY OF OIL SPILL CLEANUP PROCEDURES, VOL. 1, ANALYSIS OF OIL SPILLS AND CONTROL MATERIALS
PUBL DILLINGHAM CORP., COMMITTEE FOR AIR AND WATER CONSERVATION API, FEB. 1970
ABST THE INTENT OF THIS STUDY WAS TO PROVIDE MEMBERS OF THE PETROLEUM INDUSTRY WITH AN INDEPENDENT EXAMINATION OF THE MEANS CURRENTLY AVAILABLE FOR CONTROLLING SPILLS.
KEYW CLEAN UP, CONTROL, ROUGH WATER
CODE 2564F

AUTH GKY AND ASSOCIATES
TITL FINAL REPORT - MAJOR OIL SPILLS FROM TANKERS AND BARGES AND OTHER VESSELS IN US WATERS/ANALYSIS OF RECENT TRENDS AND PATTERNS
PUBL US DEPT. OF COMMERCE, COUNCIL ON ENVIRONMENTAL QUALITY, PB 268 515, 1976-1977, EC 7AC235
ABST AN INVESTIGATION OF OIL SPILLS DURING THE WINTER 1976-1977 AND COMPARISON WITH OTHER SPILLS SINCE 1969.
KEYW TANKERS, BARGES, VESSELS, TRENDS
CODE 7157F

AUTH GLAESER J.L.
TITL A DISCUSSION OF THE FUTURE OIL SPILL PROBLEM IN THE ARCTIC
PUBL PHYSICAL-BIOLOGICAL EFFECTS
ABST THIS PAPER DEFINES THE CAUSES AND EFFECTS OF THE POTENTIAL ARCTIC PROBLEM BY PRESENTING SOME OF THE EXISTING INFORMATION ON THE TOPIC.
KEYW DISPERSION, EVAPORATION, SOLUTION, ABSORPTION, BIODEGRADATION, ULTRA-VIOLET OXIDATION
CODE 0576F

AUTH GLAESER J.L.
TITL AN EFFECTIVE OIL SPILL CONTAINMENT RECOVERY SYSTEM FOR HIGH SEAS USE
PUBL APPLIED CONTROL TECHNOLOGY
ABST THE DEVELOPMENT AND TESTING OF A NEW OPERATIONAL OIL SPILL CONTAINMENT RECOVERY SYSTEM IS DISCUSSED.
KEYW CONTAINMENT, RECOVERY, BOOM AND SKIMMER
CODE 0810F

AUTH GLAESER J.L., VANCE G.P.
TITL A STUDY OF THE BEHAVIOR OF OIL SPILLS IN THE ARCTIC
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1551, MAY 1-3, 1972
ABST THIS PAPER DISCUSSES THE LONG RANGE RESEARCH EFFORT TO STUDY OIL POLLUTION IN THE ARCTIC.
KEYW SPREADING RATES, INTERACTION OF OIL AND ICE, AGING EFFECTS, BURNING AND NATURAL ABSORBENTS
CODE 0581F

AUTH GLENN W.
TITL OIL POLLUTION OF RIVERS, METHODS OF ANALYSIS
PUBL DEPT. OF ENVIRONMENT, SSIE NO. WDG-527
CODE 0488F

AUTH GOLDFARB C., BROWN C.W.
TITL COLLECTION OF GAS CHROMATOGRAPHIC FRACTION ON ACTIVATED CHARCOAL AND IDENTIFICATION BY INFRARED SPECTROSCOPY
PUBL APPLIED SPECTROSCOPY VOL. 33 NO. 2, 1979
ABST A NOVEL METHOD FOR COLLECTING GAS CHROMATOGRAPHIC FRACTIONS ON COMMERCIALLY AVAILABLE TUBES OF ACTIVATED CHARCOAL HAS BEEN DEVELOPED AND TESTED ON A NUMBER OF ORGANIC MIXTURES.
KEYW GAS CHROMATOGRAPHY, FRACTIONS, SEPARATION
CODE 7632F

AUTH GOLDFARB, C.
TITL COLLECTION AND ANALYSIS OF TREATED AND UNTREATED OIL SPILL VAPORS
PUBL A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CHEMISTRY, URI, APRIL 1976
ABST THIS PAPER DISCUSSES THE CHEMICAL TREATMENT OF OIL SPILLS INVOLVING THE USE OF DISPERSANTS.
KEYW DISPERSANTS, CHEMICAL TREATMENT
CODE 7673F

AUTH GOLDMAN J., BUJNOCH J.
TITL FORECASTING AND HINDCASTING THE MAXIMUM COMBINED SEA IN STORMS
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1832, APR. 29-MAY 2, 1973
ABST THIS PAPER DISCUSSES THE IMPORTANCE OF DETAILED WIND INFORMATION FOR BOTH FORECASTING AND HINDCASTING.
KEYW FORECASTING/HINDCASTING, WIND, WAVES, SWELLS
CODE 0047F

AUTH GOLDSMITH R., HOSSIAN S.
TITL OIL WATER SEPARATION BY ULTRAFILTRATION
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST THE OBJECT OF THIS REPORT IS TO DEVELOP TECHNOLOGY TO TREAT OIL DISCHARGES. TESTING OF METHOD, MEMBRANE ULTRAFILTRATION, IS SHOWN.
KEYW DISCHARGES, TREATMENT, MEMBRANE ULTRAFILTRATION
CODE 5110F

AUTH GOLDSTEIN M., MILLER P.
TITL FINAL REPORT, NUMERICAL MODEL FOR PREDICTION OF SURFACE CURRENTS IN THE OCEAN
PUBL USCG, DEPT. OF TRANSPORTATION, NOVA-60056-A, MAY 1974
ABST AN ENSEMBLE OF 136 OBSERVATIONS OF SURFACE CURRENTS ON THE WESTERN FLORIDA SHELF NEAR 82 DEGREES 30 FEET WEST, 25 DEGREES 30 FEET NORTH IS REPORTED.
KEYW SURFACE CURRENT, PREDICTION, FLORIDA SHELF
CODE 2944F

AUTH GOOCH P.W.
TITL FLUIDIC VELOCITY SENSOR FOR GASEOUS EFFLUENTS
PUBL ASME PUB.
ABST THIS PAPER DESCRIBES THE FLUIDIC VELOCITY SENSOR THE PURPOSE OF THE PAPER IS TO DESCRIBE THE SUBSEQUENT DEVELOPMENT OF THIS SENSOR AND ITS APPLICATIONS IN INDUSTRY FOR MEASUREMENTS OF THE TYPE REFERRED TO, IF ITS CHARACTERISTICS ARE USED IN A SUITABLE MANNER.
CODE 2900A

AUTH GOODIER J.L., STEVENS J.T., BEARY W.V., MCMAHAN, J.R., MZAGLLIN S.V.
TITL SPILL PREVENTION TECHNIQUES FOR HAZARDOUS POLLUTION SUBSTANCES
PUBL EPA CONTRACT NO. 14-12-527
ABST STUDY DESIGNED TO INVESTIGATE THE PREVENTION OF HAZARDOUS MATERIAL SPILLS, AND TO DETERMINE METHODS THAT WOULD PREVENT SUCH SPILLS FROM ENTERING A PUBLIC WATER COURSE.
KEYW PREVENTION, HAZARDOUS MATERIALS, PUBLIC WATER COURSE
CODE 0056R

AUTH GOODIER L.J.
TITL FUTURE GUIDELINES FOR US DEEPWATER PORT DEVELOPMENT
PUBL UNKNOWN
ABST THIS PAPER DISCUSSES EXISTING US FACILITIES, ENVIRONMENTAL IMPACT, SITE SELECTION, CARGO HANDLING FACILITIES.
KEYW MARINE TRANSPORT, LARGE BULK CARRIER, DEEPWATER PORT

CODE 7140F

AUTH GOODRICH F.C.
TITL MEASUREMENT AND MOLECULAR INTERPRETATION OF SURFACE SHEAR VISCOSITY
PUBL CLARKSON COLLEGE OF TECHNOLOGY FOR US NATIONAL SCIENCE FOUNDATION
CODE 0344H

AUTH GOODRICH F.C., ALLEN L.A., POSKANZER A.
TITL A NEW SURFACE VISCOMETER OF HIGH SENSITIVITY I THEORY
PUBL PREPRINT FROM F.C. GOODRICH
CODE 0345F

AUTH GOOS G., HARTMANIS J.
TITL ECI CONFERENCE 1976
PUBL PROCEEDINGS OF THE FIRST CONFERENCE OF THE EUROPEAN COOPERATION IN INFORMATICS
CODE 3513AF

AUTH GORDON A., GERARD R.
TITL WIND DRIFT SURFACE CURRENTS AND SPREAD OF CONTAMINANTS IN SHELF WATERS
PUBL DEPT. OF TRANSPORTATION, USCG.
ABST THE RESULTS OF THE EXPERIMENTS INDICATE THE PRESENCE OF STRONG VERTICAL AND LATERAL SHEAR WITHIN THE UPPER FEW METERS OF THE WATER.
KEYW VERTICAL AND LATERAL SHEAR, WIND DRIFT, SPREAD OF CONTAMINATNTS
CODE 2542A

AUTH GORDON A.L., GERARD R.D.
TITL FINAL REPORT - WIND DRIFT SURFACE CURRENTS AND SPREAD OF CONTAINMENT IN SHELF WATERS
PUBL USCG AD 783 107
CODE 0395F

AUTH GORDON D.C., DALE J., KEIZER P.D.
TITL IMPORTANCE OF SEDIMENT WORKING BY THE DEPOSIT-FEEDING POLYCHAETE ARENICOLA MARINA ON THE WEATHERING RATE OF SEDIMENT-BOUND OIL
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST THE INTERACTIONS BETWEEN THE POLYCHAETE ARENICOLA MARINA A COMMON DEPOSIT FEEDER IN SANDY INTERTIDAL AREAS, AND SEDIMENT CONTAMINATED WITH THE FRESH API REFERENCE OILS AND WEATHER BUNKER C OIL REMAINING FROM THE 1970 ARROW SPILL ARE INVESTIGATED IN LABORATORY EXPERIMENTS.
KEYW SEDIMENT, POLYCHAETE, WEATHERING RATE
CODE 2669F

AUTH GORDON R. SPAULDING M.
TITL BIBLIOGRAPHY OF NUMERICAL MODELS FOR TIDAL RIVERS, ESTUARIES AND COASTAL WATERS
PUBL URI, MARINE TECHNICAL REPORT NO. 32, OCEAN ENGINEERING NOA SEA GRANT, 1974
ABST THIS PUBLICATION INCLUDES A DOCUMENT LISTING, A SELECTED REVIEW AND FOUR INDICES: KEY WORD IN CONTEXT INDEX, AUTHOR INDEX, CORPORATE INDEX AND INVERTED INDEX.
KEYW BIBLIOGRAPHY, DOCUMENT LISTING, INDICES
CODE 2929F

AUTH GOREN S.L.
TITL REMOVAL OF OIL FROM AQUEOUS WASTES BY FILTRATION
PUBL CAL. RESOURCES CENTER
ABST THE EFFECTS OF ELECTROLYTE TYPE AND CONCENTRATION ON THE SEPARATION OF OIL IN WATER DISPERSANTS WAS EXAMINED EXPERIMENTALLY.
CODE 6097A

AUTH GOULD J.R.
TITL PROBLEMS OF POLLUTION OF THE SEA
PUBL HAZARDS OF MARITIME TRANSIT, BALLINGER PUBLISHING CO., 1973
ABST INCLUDES A BRIEF DISCUSSION ON OIL INSURANCE PROGRAMS FOR TANKERS AND A LISTING OF API PROJECTS ON OIL SPILL RESEARCH.
CODE 3107A

AUTH GRAEBEL W., PHELPS V.
TITL FAST CURRENT OIL CONTROL STUDY
PUBL USCG, DEPT. OF TRANSPORTATION, REPORT NO. CG-D-84-75, INTERIM REPORT, AUG. 1974
ABST A VORTEX RECOVERY DEVICE WAS CONCEIVED AND TESTED WHICH SHOWED ONLY VERY SMALL LOSS RATES AT ALL SPEEDS. RATE OF RECOVERY OF A SLICK INCREASED WITH CURRENT SPEED.
KEYW BARRIERS, FAST CURRENT OIL BEHAVIOR, HERDING, RATES OF RECOVERY
CODE 6055F

AUTH GRAHAM D.J.
TITL FIELD EVALUATION OF OPEN SEA OIL SPILL RECOVERY EQUIPMENT
PUBL NAVAL UNDERWATER SYSTEMS CENTER, TECHNICAL NOTE NO. N-1330, FEB. 1974
ABST DEPLOYMENT TEST OF TWO TYPES OF OIL CONTAINMENT BOOMS AND TWO OIL SKIMMERS WERE CONDUCTED.
KEYW OIL RECOVERY, DEPLOYMENT, OIL CONTAINMENT BOOMS, OIL SKIMMERS
CODE 0809F

AUTH GRAHAM D.J.
TITL MULTICOMPONENT EVALUATION TEST OF HARBOR OIL SPILL RECOVERY SYSTEM
PUBL TECHNICAL NOTE N-1293, NAVAL CIVIL ENGINEERING LAB., JUNE
CODE 0422B

AUTH GRAHAM D.J., SOMERS L.
TITL EVALUATION TEST OF A SMALL HARBOR OIL SPILL RETRIEVAL SYSTEM
PUBL HARDING POLLUTION CONTROL CORP., AD 782567, JULY 1975
ABST DISCUSSION ON A SMALL TWO MAN SKIMMER.
CODE 3113B

AUTH GRAHL-NIELSEN O., STAVELAND J.T., WILHELMSEN S.
TITL AROMATIC HYDROCARBONS IN BENTHIC ORGANISMS FROM COASTAL AREAS POLLUTED BY IRANIAN CRUDE OIL
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST THIS INVESTIGATION WAS BEGUN ONE MONTH AFTER A SPILL OF 2000 TONS OF IRANIAN CRUDE OIL POLLUTED SHORES ALONG THE WEST COAST ON NORWAY IN FEB. 1976. IT IS BASED ON MASSFRAGMENTOGRAPHIC ANALYSIS OF NAPTHALENE, METHYL, DIMETHYL AND TRIMETHYLNAPTHALENES, PHENANTHRENE, METHYL AND DIMETHYLPHENANTHRENE, DIBENZOTHIOPHENE, METHYL AND DIMETHYL AND TRIMETHYLDIBENZOTHIOPHENES.
KEYW BENTHIC ORGANISMS, NAPHTHALENES, MASS FRAGMENTOGRAPHY
CODE 2669F

AUTH GRAY J.S.
TITL PROGRAMME TO ASSESS THE ECOLOGICAL EFFECTS OF OIL SPILLS IN COASTAL AREAS OF NORWAY
PUBL NORWEGIAN MARINE POLLUTION RESEARCH AND MONITORING PROGRAMME (FOH)
ABST THE PROGRAM DESCRIBED HERE IS DESIGNED TO ACHIEVE A QUANTITATIVE ASSESSMENT OF THE EFFECTS OF OIL ON SHALLOW WATER BIOTA AND COVERS THE WHOLE OF THE NORWEGIAN COAST.
KEYW OIL SPILL, CONTINGENCY, CHEMICAL ANALYSIS
CODE 7742F

AUTH GRAY W.O.
TITL THE 1973 IMCO CONVENTION A TANKER OPERATORS VIEWPOINT
PUBL EXXON CORP.
ABST THE ESSENTIAL PROVISIONS OF THE CONVENTION IS REVIEWED STRESSING THE TECHNOLOGY ELEMENTS RELATING TO OIL TANKERS. QUESTIONS OF RECEPTION FACILITIES ASHORE IS CONSIDERED.
KEYW TECHNOLOGY, OIL TANKERS, RECEPTION FACILITIES
CODE 0071A

AUTH GREEN F.
TITL EPAS VIEW OF PROJECTED OIL DRILLING ON THE CONTINENTAL SHELF
PUBL SEA TECHNOLOGY, OCT. 1976
ABST THIS PAPER DISCUSSES FUTURE DRILLING OFFSHORE.
KEYW OFFSHORE DRILLING, COASTAL ZONE
CODE 2552F

AUTH GREGG M.
TITL THE MICROSTRUCTURE OF THE OCEAN
PUBL UNKNOWN
ABST THE TEMPERATURE AND SALTINESS OF SEAWATER CAN NOW BE MAPPED. SUCH MAPPINGS ARE NEEDED TO LEARN HOW THE SEA IS SO EFFECTIVELY STIRRED BY WINDS AND TIDES.
KEYW SAMPLING, TEMPERATURE, SALINITY, MAPPINGS
CODE 6303F

AUTH GRIBBON E., LOGAN J.W.R.
TITL OIL DISPERSANT TOXICITY
PUBL MARINE POLLUTION BULLETIN, 4(6)190-93, 1973
CODE 3126A

AUTH GRIFFIN L.F., CALDER J.A.
TITL TOXIC EFFECT OF WATER--SOLUBLE FRACTIONS OF CRUDE, REFINED AND WEATHERED OILS ON THE GROWTH OF A MARINE BACTERIUM
PUBL APPLIED AND ENVIRONMENTAL MICROBIOLOGY, MAY 1977
ABST THIS STUDY DEMONSTRATES THE TOXICITY OF THE WSF'S OF SEVERAL OILS, INCLUDING CRUDE, REFINED AND WEATHERED, ON THE MOTILE MARINE BACTERIUM SERRATIA MARINORUBRA; ADDITIONALLY, IT WAS FOUND THAT CHANGES IN TOXICITY WERE RELATED TO CHANGES IN ORGANIC NUTRIENT CONCENTRATION.
KEYW TOXICITY, WATER-SOLUBLE FRACTIONS, MARINE BACTERIA
CODE 7207F

AUTH GRIFFIN P.J.
TITL RESPONSE OF A NATURAL POPULATION OF MARINE HETEROTROPHIC BACTERIA TO A CRUDE OIL AND A DISPERSANT
PUBL MASTER'S THESIS IN MICROBIOLOGY UNIVERSITY OF RHODE ISLAND
ABST MESO-SCALE (ENVIRONMENTALLY EXPOSED TESTING SYSTEM) AND LABORATORY SYSTEMS WERE EXAMINED USING VIABLE PLATE COUNT, MOST PROBABLE NUMBER, AND REPLICA PLATING TECHNIQUES TO DETERMINE THE EFFECTS OF KUWAIT CRUDE OIL AND/OR COREXIT 9527 ON BACTERIAL POPULATIONS.
KEYW DISPERSANT, MESO-SCALE SYSTEM, BACTERIAL
CODE 7767F

AUTH GRIFFITH D.
TITL INVESTIGATION INTO THE TOXICITY OF COREXIT - A NEW

OIL DISPERSANT
PUBL DEP. AGRIC. FISH. FISHERY LEAFLET, 6.
CODE 1088R

AUTH GRISCOM C.A., TIPPIE V.K.
TITL RHODE ISLAND AND OFFSHORE OIL: DIGEST OF A WORKSHOP
PUBL DIV. OF MARINE RESOURCES, URI, SPT. 22-24, 1976
ABST A DIGEST OF INFORMATION EXCHANGED DURING A WORKSHOP ON RHODE ISLAND AND THE OFFSHORE PETROLEUM INDUSTRY.
KEYW OFFSHORE EXPLORATION, TRANSPORTATION, LEASE AND SALES
CODE 6511F

AUTH GRIZZLE P.L., COLEMAN H.J.
TITL GLC ANALYSIS OF N-PARAFFIN DISTRIBUTION IN CRUDE OILS AND TOPPED CRUDE OILS FOR OIL IDENTIFICATION
PUBL USERDA, BERC/RI-77/12, OCT. 1977
ABST THIS PAPER DISCUSSES THE ANALYSIS AND EVALUATION OF PARAFINS OBTAINED IN OIL SAMPLES FOR THEIR IMPORTANCE IN OIL IDENTIFICATION.
KEYW PARAFINS, OIL SAMPLES, OIL IDENTIFICATION
CODE 7119F

AUTH GUARD H.E., DISALVO L., HUNTER L.
TITL IDENTIFICATION AND POTENTIAL BIOLOGICAL EFFECTS OF THE MAJOR COMPONENTS IN THE SEAWATER TRACT OF A BUNKER FUEL
PUBL BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY, VOL. 14, NO. 4, 1975
ABST THIS IS A REPORT ON THE COMPOSITION OF SEAWATER EXTRACT OF A BUNKER FUEL.
KEYW SEAWATER EXTRACT, BUNKER FUEL, SEAWATER SOLUBLE FRACTION
CODE 2570F

AUTH GUERIN M.R.
TITL ENERGY SOURCES OF POLYCYCLIC AROMATIC HYDROCARBONS
PUBL OAK RIDGE NATIONAL LAB., EPA, AND US ERDA
ABST THIS PAPER DISCUSSES THE ENERGY SOURCES OF POLYCYCLIC AROMATIC HYDROCARBONS.
KEYW POLYCYCLIC AROMATIC HYDROCARBONS, COMBUSTION, COAL, OIL SHALE, CONCLUSIONS
CODE 2679F

AUTH GUNTZ G.
TITL RESTORATION OF BEACHES CONTAMINATED BY OIL
PUBL CONTRACT NO 14-47-804, RESEARCH AND MONITORING EPA SEPT. 1977
CODE 6071F

AUTH GUNTHER M.
TITL THEORETICAL AND EXPERIMENTAL EVALUATION OF OIL CONTROL DEVICES
PUBL PHYSICAL REMOVAL
ABST THIS PAPER DESCRIBES THE FIRST PHASES OF A PROGRAM AIMED AT PROVIDING A MEANS FOR EVALUATION OF EXISTING OIL CONTAINMENT DEVICES AND FOR IMPROVING BASIC DESIGN.
KEYW CONTAINMENT, CONTROL, DESIGN IMPROVEMENT
CODE 0804F

AUTH HABERCOM G.E.
TITL SUPERTANKER AND SUPER PORTS: A BIBLIOGRAPHY WITH ABSTRACTS
PUBL REPORT FOR 1974 SUPERSEDES REPORT DATED OCT. 1973
CODE 0393R

AUTH HALE L.A.
TITL HYDRODYNAMIC EFFECTS OF AN OIL SLICK MECHANICAL CONTROL DEVICES
PUBL TEXAS A & M RESEARCH FOUNDATION AD 779226 FEB. 1974
ABST THE OBJECTIVE OF THIS STUDY WAS TO INVESTIGATE THE BEHAVIOR OF AN OIL SLICK UNDER THE INFLUENCE OF VARIOUS MECHANICAL CONTROL DEVICES.
CODE 6094AR

AUTH HALE M.E., KUGLER B.A.
TITL THE ACOUSTIC PERFORMANCE OF PIPE LAGGING SYSTEMS
PUBL ASME PUBL.
ABST THIS PAPER PRESENTS SOME EXPERIMENTS RESULTS FOR TYPICAL PIPE LAGGING CONFIGURATION. COMMENTS ARE ALSO MADE REGARDING CERTAIN PROBLEMS THAT EXIST IN SOME PERFORMACE CHARACTERISTIC DATA REPORTED IN THE LITERATURE AND BY MATERIAL MANUFACTURERS.
CODE 2904R

AUTH HALSTEAD B.W.
TITL MARINE POLLUTION AND PHARMACEUTICAL SCIENTIST
PUBL AMERICAN JOURNAL OF PHARMICEUTICAL EDUCATION
CODE 1044R

AUTH HAMPSON G.R., MOUL E.T.
TITL NO. 2 FUEL OIL SPILL IN BOURNE, MASSACHUSETTS: IMMEDIATE ASSESSMENT OF THE EFFECTS ON MARINE INVERTEBRATES AND A 3 YEAR STUDY OF GROWTH AND RECOVERY OF A SALT MARSH
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST THIS PAPER DISCUSSES THE IMMEDIATE ASSESSMENT OF A SPILL AND A LONG TERM ASSESSMENT ON THE EFFECT ON MARINE LIFE.
KEYW SALT MARSH, EROSION, ALGAE, MARSH GRASS, INTERSTITIAL FAUNA, MARINE INVERTEBRATES
CODE 2669F

AUTH HANCOCK J.A., JENSEN D.
TITL WATERBORNE DEBRIS IN MARINE POLLUTION INCIDENTS
PUBL BATTELLE, COLUMBUS LABS, USCG, ENVIRONMENTAL AND TRANSPORTATION TECHNOLOGY DIV. FOR EPA 1975 CONFERENCE
ABST CURRENT DEBRIS HANDLING PRACTICES ARE DESCRIBED ALONG WITH THE GENERAL HANDLING REQUIREMENTS NECESSARY FOR SPILL CLEANUP CONTINGENCY PLANNING. EFFECTS OF DEBRIS ON POLLUTION RESPONSE EQUIPMENT ARE CONSIDERED.
KEYW CLEANUP, DEBRIS, CONTINGENCY
CODE 0097R

AUTH HANDLEY G.W.
TITL THE ROLE OF THE MARINE INSURANCE INDUSTRY IN THE EMERGING REGIME OF THE OCEANS
PUBL THE LAW OF THE SEA: BALLINGER PUBLISHING CO. 1974
ABST THIS ARTICLE DEALS WITH THE FINANCIAL, LEGAL AND PHYSICAL PROBLEMS IN INSURING SUPERTANKERS AND THEIR CARGOES. IT ALSO LISTS THE PRINCIPAL PHYSICAL CONCERNS AS OF UNDERWRITERS TODAY.
CODE 3102H

AUTH HANN R.W.
TITL VLCC METULA OIL SPILL
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 4111.15.1, DEC. 1974
CODE 0787R

AUTH HANN R.W., JAMES W.P.
TITL ENVIRONMENTAL ASPECTS OF A TEXAS SUPERPORT
PUBL UNKNOWN
ABST THE OBJECTIVE OF THIS STUDY IS TO EVALUATE THE ENVIRONMENTAL IMPACT OF A SUPERPORT OFF THE TEXAS COAST. BOTH THE NONOIL SPILL IMPACT OF CONSTRUCTION AND OF OPERATION AND THE OIL SPILL IMPACT ON THE COASTAL ENVIRONMENT ARE INCLUDED IN THIS PROJECT.
KEYW SUPERPORT ENVIRONMENTAL ASPECT, CONSTRUCTION AND OPERATION
CODE 7195F

AUTH HANNAN P., PATOUILLET C.
TITL EFFECTS OF POLLUTANTS ON THE GROWTH OF ALGAE
PUBL REPORT OF NRL PROGRESS, FEB. 1972
ABST THIS PAPER DISCUSSES THE STUDY UNDERTAKEN TO DETERMINE THE EFFECTS OF POLLUTANTS ON GROWTH RATES OF ALGAE.
KEYW GROWTH RATES, TOXICANTS, NUTRIENT CONCENTRATIONS
CODE 2136F

AUTH HANSEN J.R.
TITL LIGHTWEIGHT OIL CONTAINMENT SYSTEM LOW TENSION BARRIER SYSTEM
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. 714102/A/001, 1971
CODE 2005F

AUTH HANSON J.A., KOCHIS D.M.
TITL OAKLAND ESTUARY OIL SPILL CLEANUP: A REVIEW OF A MAJOR OIL SPILL CLEANUP IN A TRASH-LADEN ESTUARY EMPHASIZING SMALL BOAT HARBOR CLEANUP.
PUBL SHELL OIL CO., FOR EPA 1975 CONFERENCE
ABST THE REPORT INCLUDES A DAY BY DAY REVIEW OF THE CLEANUP EXPERIENCE AND AN EVALUATION OF PROCEDURES, EMPHASIZING PROBLEMS ENCOUNTERED IN CLEANUP OF OIL IN TRASH-LADEN WATERS.
KEYW CLEANUP, PROCEDURES, TRASH-LADEN WATERS
CODE 0044F

AUTH HARDY R.W.
TITL WATER RESOURCES RESEARCH COORDINATION IN NEW ENGLAND
PUBL RI WATER RESOURCES CENTER FOR N.E. COUNCIL OF WATER CENTER DIRECTORS, JAN. 1973
ABST THIS REPORT INVESTIGATES THE POTENTIALS AND FEASIBILITY OF COORDINATING WATER RESOURCE RESEARCH ON A NEW ENGLAND WIDE SCALE AND DERIVES THEREFROM GUIDING PRINCIPLES FOR OTHER MULTI-STATE REGIONS.
KEYW WATER RESEARCH COORDINATION, REGIONAL WATER RESEARCH, COORDINATION OF WATER RESOURCES
CODE 6580F

AUTH HARGRAVE B.T., NEWCOMBE C.
TITL CRAWLING AND RESPIRATION AS INDICES OF SUBLETHAL EFFECTS OF OIL AND A DISPERSANT ON AN INTERTIDAL SNAIL "LITTORINA LITTOREA"
PUBL JOURNAL OF FISHERIES RESEARCH BOARD OF CANADA, VOL. 31, NO. 12, 1973
ABST THIS PAPER DISCUSSES THE RESULTS OF TESTS ON SNAILS OF OIL AND DISPERSANTS.
KEYW DISPERSANTS, TOXICITY, BEHAVIORAL TRAITS
CODE 2142F

AUTH HARGRAVE B.T., PHILLIPS G.A.
TITL ESTIMATES OF OIL IN AQUATIC SEDIMENTS BY FLUORESCENCE SPECTROSCOPY
PUBL ENVIRONMENTAL POLLUTION, VOL. 8, NO. 3, APRIL 1975
ABST ESTIMATES OF OIL IN AQUATIC SEDIMENTS BY FLUORESCENCE SPECTROSCOPY EXTRACTED FROM ALIPHATIC SUBSTANCES IN VARIOUS SEDIMENTS, DISCUSSION ON EXTRACTION PROCEDURES.
CODE 3097R

AUTH HARRISON E.

TITL BIOINDICATORS OF POLLUTION
PUBL NTIS
ABST A BIBLIOGRAPHY WITH ABSTRACTS
CODE 6590N

AUTH HARRISON E.
TITL THE BIOLOGICAL EFFECTS OF OIL SPILLS
PUBL NTIS
ABST A BIBLIOGRAPHY WITH ABSTRACTS
CODE 6589N

AUTH HARRISON W.
TITL ENVIRONMENTAL IMPACT OF OIL SPILLS OFF GRAND BAHAMA AND SOUTHERN GREAT ABACO ISLANDS, BAHAMAS
PUBL DEPT. OF GEOGRAPHY, UNIV. OF TORONTO, 1973
CODE 2047R

AUTH HARRISON W.
TITL FATE OF SPECIFIC HYDROCARBONS IN EXPERIMENTAL RELEASES OF CRUDE OIL TREATED BY A DISPERSANT
PUBL API, WATER RESOURCES RESEARCH PROGRAM, ARGONNE NATIONAL LABORATORY, ENERGY AND ENVIRONMENTAL SYSTEMS DIV., FEB. 1977, P-77054
ABST A PRECISE DESCRIPTION OF THE TEMPORAL AND SPATIAL CHANGES IN CONCENTRATION OF VARIOUS COMPONENTS OF A DISPERSANT-TREATED CRUDE OIL SPILL IS REQUIRED FOR PROPER ASSESSMENT OF THE EFFICACY AND ENVIRONMENTAL IMPACT OF THE DISPERSANT ROLE OF OIL SPILL TREATMENT.
KEYW DISPERSANTS, CONCENTRATION, TEMPORAL-SPATIAL CHANGES
CODE 6567F

AUTH HARVEY A., STOKES V.
TITL EVALUATION OF A UNIQUE CENTRIFUGE FOR SEPARATION OF OIL FROM SHIP DISCHARGE WATER
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST THIS PAPER DESCRIBES AN EVALUATION OF SEPARATOR PERFORMANCE AS A FUNCTION OF THE DROP SIZE CONTENT OF THE OIL DISPERSION AND A RATIONAL ASSESSMENT OF THE DESIGN METHOD AND ITS APPLICATION TO THE DEVELOPMENT OF FUTURE PROTOTYPES.
KEYW CENTRIFUGATION, SEPARATING EMULSIONS, PURIFICATION
CODE 5116F

AUTH HARWOOD M.
TITL THE RISING TIDE OF OIL SPILLS
PUBL THE NEW YORK TIMES MAGAZINE, APRIL 9, 1978
ABST THE LESSON OF THE AMOCO CADIZ DISASTER OFF BRITTANY IS THAT CLEANUP TECHNOLOGY HAS NOT CAUGHT UP WITH THE AGE OF THE SUPERTANKER.
KEYW CLEANUP TECHNOLOGY, DISPERSANTS, BOOMS, SUPERTANKERS
CODE 2685F

AUTH HARDY L.P.
TITL AMERICAN PETROLEUM INSTITUTES WORK ON OIL SPILL PREVENTION, CONTAINMENT, AND CLEANUP
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1749, APRIL 29-MAY2,1973
ABST THIS PAPER PROVIDES A REPORT OF TRIALS ON "NEW CONCEPT" METHODS FOR OIL SPILL RECOVERY UNDER ADVERSE CONDITIONS.
KEYW PREVENTION, CONTAINMENT, CLEANUP
CODE 0832F

AUTH HAY A.
TITL OIL AND THE SEA - THE ECOLOGICAL IMPLICATIONS OF A CONTROVERSIAL INVASION
PUBL MARINE TECH. SOCIETY JOURNAL, VOL. 8, NO. 8, JAN. 1974
ABST THIS PAPER DISCUSSES THE RESULTS OF FINDINGS BY AN OIL SPILL RESEARCH TEAM.
KEYW EVAPORATION, DISPERSION, BIODEGRADATION
CODE 2100F

AUTH HAY R.G.
TITL THE STATUS OF OILED WILDLIFE: RESEARCH AND PLANNING
PUBL AMERICAN PETROLEUM INSTITUTE FOR EPA 1975 CONFERENCE
KEYW OILED WILDLIFE
CODE 0101H

AUTH HAYDY L.P.
TITL API'S WORK ON OIL SPILL PREV. CONTAINMENT AND CLEANUP
PUBL OFFSHORE TECHNOLOGY CONFERENCE, OTC 1794
CODE 0665H

AUTH HAZEL C.R.
TITL EVALUATING OIL SPILL CLEANUP AGENTS DEVELOPMENT OF TESTING PROCEDURES AND CRITERIA
PUBL CALIFORNIA WATER RESOURCES CONTROL BOARD, PAPER NO. 34, JULY 1970
CODE 5006R

AUTH HAZEL C.R., KOPPERDAHL F., MORGAN W. THOMSEN W.
TITL EVALUATING OIL SPILL CLEANUP AGENTS DEVELOPMENT OF TESTING PROCEDURES AND CRITERIA
PUBL RESOURCES CONTROL BOARD, PUBL. NO. 43, 1971
CODE 5064R

AUTH HEALY R.J.
TITL AN ECONOMIC OF MARINE RISK ALLOCATION, ECONOMIC IMPACTS OF NEW REGULATIONS AND THE EXTENSION OF COASTAL STATE JURISDICTION
PUBL THE HAZARDS OF MARINE TRANSIT
ABST DISCUSSES THE HISTORY AND SIGNIFICANCE OF MARINE INSURANCE.
CODE 3109R

AUTH HEINRICH J.A., RASBERRY S.D.
TITL FINAL REPORT, ACTIVITIES OF THE NBS SPECTROCHEMICAL ANALYSIS SECTION JULY 1970 TO JUNE 1971
PUBL NBS TECHNICAL NOTE NO. 582
ABST SPECTROCHEMICAL RESEARCH ACTIVITIES, IMPROVEMENTS IN EQUIPMENT AND APPLICATIONS, ESPECIALLY TO THE CERTIFICATION OF NBS STANDARD REFERENCE MATERIALS, ARE SUMMARIZED. LISTINGS ARE GIVEN FOR 8 PUBLICATIONS AND 25 TALKS BY MEMBERS OF THE SECTION DURING THE YEAR.
KEYW ELECTRON PROBE, MICROANALYSIS, SPECTROCHEMICAL ANALYSIS
CODE 2945F

AUTH HELLEBUST J.A., SNEATH B., GERGIS M., HUTCHISON T., HANNA B.
TITL EXPERIMENTAL CRUDE OIL SPILLS ON A SMALL SUBARCTIC LAKE IN THE MACKENZIE VALLEY, N.W.T.: EFFECTS OF PHYTOPLANKTON, PERIPHYTON AND ATTACHED AQUATIC VEGETATION
PUBL CONFERENCE ON THE PREVENTION AND CONTROL OF OIL POLLUTION
ABST DISCUSSES EXPERIMENTAL RESULTS OF OIL ON PLANT LIFE IN THE SUBARCTIC LAKES.
KEYW ENVIRONMENTAL EFFECT, SUBARCTIC LAKES, PHYTOPLANKTON, PERIPHYTON, VEGETATION
CODE 0862F

AUTH HELLMAN H.
TITL AGING OF CRUDE PETROLEUM ON WATER
PUBL ERDOEL AND KOHLE-ERDGAS- PETROCHEMIE
CODE 0388P

AUTH HELLMAN H.
TITL THE BEHAVIOR OF CRUDE OIL ON WATER SURFACES AS INDICATED BY THE TEMPORAL CHANGES IN FLOW CHARACTERISTICS
PUBL ERDOL KOHLE ERDGAS PETROCHEM, VOL. 24, 1971
CODE 2045F

AUTH HELLMAN H.
TITL COMBATTING OIL WITH COREXIT 7664, A LARGE SCALE TEST IN THE NORTH SEA
PUBL HANSA, 102,(16), 1965
CODE 5025H

AUTH HELLMAN H.
TITL SPREADING OF MINERAL OIL ON THE WATER SURFACE
PUBL NEUE DELIWA Z, VOL. 5, 1974
CODE 2035H

AUTH HELLMAN H., BRUNS F.
TITL MODEL TESTS FOR THE FORMATION OF WATER IN OIL EMULSIONS AND THEIR IMPORTANCE IN FIGHTING OIL SPILLS AT SEA
PUBL TENSIDE 7, VOL. 1, 1970
CODE 5031H

AUTH HENAGER C., WALKUP P.C., BLACKLAW J.R., SMITH J.D.
TITL STUDY OF EQUIPMENT AND METHODS FOR REMOVING OR DISPERSING OIL FROM OPEN WATER
PUBL PHYSICAL REMOVAL
ABST THIS PAPER REPORTS ON A COST EFFECTIVENESS ANALYSIS PERFORMED FOR EQUIPMENT MATERIALS AND TECHNIQUES APPLICABLE TO THE REMOVAL OR DISPERSAL OF SPILLED OIL ON OPEN WATER.
KEYW REMOVAL, DISPERSAL, ENVIRONMENTAL IMPACT
CODE 0825F

AUTH HENAGER C.H., SMITH J.D.
TITL RECOVERY OF FLOATING OIL
PUBL CONTRACT NO. 68-01-0070, PROJECT 15080HEC, SPT. 1972
ABST CONCEPT EVALUATION, RECOVERY OF FLOATING OIL USING POLYURETHANE FOAM SORBENT
CODE 6067H

AUTH HESS K., WHITE F.M.
TITL MODELING THE DISPERSAL OF A MARKED FLUID IN NARRAGANSETT BAY
PUBL OCEAN ENGINEERING, NOAA SEA GRANT, MARINE TECHNICAL REPORT NO. 38, URI
ABST THIS REPORT SUMMARIZES SOME OF THE WORK CARRIED OUT AT THE UNIV. OF RI IN ITS SEA GRANT PROGRAM FOR MODELING AND UPDATES PART OF THE ENGINEERING EFFORT IN THIS DISCIPLINE.
KEYW ESTUARINE MODELING, NUMERICAL MODEL, CONVECTIVE/DIFFUSIVE EQUATION OF MASS CONSERVATION
CODE 2930F

AUTH HESS K.W., WHITE F.M.
TITL A NUMERICAL MODEL OF NARRAGANSETT BAY
PUBL URI, MARINE TECHNICAL REPORT NO. 20
ABST THE NUMERICAL MODEL WAS DEVELOPED TO PROVIDE INFORMATION CONCERNING THE TIDAL DYNAMICS OF THE BAY AND THE ACCOMPANYING CURRENTS AND FLOWS.
KEYW NUMERICAL MODEL, FLOW RATES, TIDAL DYNAMICS
CODE 0018R

AUTH HICKEL W.
TITL OIL POLLUTERS
PUBL TIME, VOL. 95, NO. 15, APRIL 13, 1970
ABST INTERIOR SECRETARY WALTER J. HICKEL IS OUTRAGED BECAUSE RECENT INVESTIGATIONS BY THE US GEOLOGICAL SURVEY OF OUR OIL AND GAS LEASES IN THE GULF OF MEXICO HAVE PRODUCED EVIDENCE OF MANY SERIOUS VIOLATIONS OF INTERIOR DEPARTMENT REGULATIONS.
CODE 3057A

AUTH HILLYARD H.E.
TITL RECOVERY OF WASTE OIL USING FLOATING-TYPE SKIMMERS
PUBL IRON AND STEEL ENGINEER, AUG. 1968
ABST LUBRICANT LEAKAGE AND SPILLAGE THAT FINDS ITS WAY INTO THE PLANT SEWERS IS RECOVERED BY MEANS OF A LOGOON WITH FLOATING TYPE SKIMMERS. THE WASTE IS EVENTUALLY USED AS A FUEL AT THE PLANT BOILER HOUSE. THUS, A SATISFACTORY AND ECONOMICAL MEANS OF DISPOSAL IS PROVIDED IN ADDITION TO THE POLLUTION ABATEMENT ASPECT.
KEYW RECOVERY, LEAKS, FLOATING-TYPE SKIMMER
CODE 3000A

AUTH HINZE J.O.
TITL FUNDAMENTALS OF THE HYDRODYNAMIC MECHANISM OF SPLITTING IN DISPERSION PROCESSES
PUBL A.I.CH.E. JOURNAL VOL. 1, NO. 3
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CODE 6305M

AUTH HIRANO F., SAKAI T.
TITL EVAPORATION OF PETROLEUM OIL FILMS
PUBL JUNKATSU, 10(8):557-585
CODE 2091A

AUTH HODGSON R.D., MCINTYRE R.V.
TITL MARITIME COMMERCE IN SELECTED AREAS OF HIGH CONCENTRATION
PUBL HAZARDS OF MARITIME TRANSIT, BALLINGER PUBLISHING CO., 1973
ABST DISCUSSES THE PRINCIPLE ROUTES FOR OCEAN SHIPPING, LISTS THE GEOGRAPHIC FACTORS WHICH DETERMINE THE ROUTES, AND DEFINES THE MAJOR STRAITS.
CODE 3105A

AUTH HOFFMAN D., MILES M.
TITL ANALYSIS OF A STRATIFIED SAMPLE OF OCEAN WAVE RECORDS AT STATION "INDIA"
PUBL THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, T + R BULLETIN 1-35, MAY 1976
ABST RESULTS ARE PRESENTED OF AN EXTENSIVE STRATIFIED RANDOM SAMPLING OF SPECTRA OBTAINED BY ANALYSIS OF WAVE RECORDS AT STATION INDIA.
KEYW SPECTRA ANALYSIS, WIND SPEEDS, SEASONAL VARIATION
CODE 2609F

AUTH HOFFMAN E.
TITL REPORTS OF THE ARGO MERCHANT OIL SPILL
PUBL URI, GRADUATE SCHOOL OF OCEANOGRAPHY
ABST SERIES OF REPORTS SENT TO NOAA TO BE INCLUDED WITH DATA FROM ALL THE OTHER AGENCIES AND INSTITUTIONS INVOLVED WITH THE ARGO MERCHANT OIL SPILL.
KEYW SEABED DRIFTERS, SEDIMENTS,MARINE BIOLOGY
CODE 6174F

AUTH HOLLINGER J.P.
TITL THE DETERMINATION OF OIL SLICK THICKNESS BY MEANS OF MULTIFREQUENCY PASSIVE MICROWAVE TECHNIQUE
PUBL NAVAL RESEARCH LAB., AD 771 376, JUNE 1973
ABST THIS INTERIM REPORT DISCUSSES THE TECHNIQUE FOR REMOTE DETERMINATION OF THE THICKNESS AND VOLUME OF SEA SURFACE OIL SPILLS USING MULTIFREQUENCY MICROWAVE RADIOMETRY.
KEYW THICKNESS AND VOLUME OF OIL, MULTIFREQUENCY MICROWAVE, RADIOMETRY
CODE 7208F

AUTH HOLLINGER J.P.
TITL MEASUREMENTS OF THE DISTRIBUTION AND VOLUME OF SEA SURFACE OIL SPILLS USING MULTIFREQUENCY MICROWAVE RADIOMETRY
PUBL USCG, NAVAL RESEARCH LAB., REPORT NO. 7512, MAY 1973
ABST MULTIFREQUENCY PASSIVE MICROWAVE MEASUREMENTS FROM AIRCRAFT HAVE BEEN MADE OF EIGHT CONTROLLED MARINE OIL SPILLS.
KEYW MICROWAVE RADIOMETRY, MULTIFREQUENCY PASSIVE MICROWAVE, CONTROLLED MARINE OIL SPILLS
CODE 2680F

AUTH HOLLINGER J.P., MENNELLA R.A.
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PUBL SCIENCE
CODE 0416A

AUTH HOLME N.A.
TITL EFFECTS OF TORREY CANYON POLLUTION ON MARINE LIFE
PUBL OIL ON THE SEA, PLENUM PRESS, 1969
ABST THE ARTICLE DESCRIBES THE EFFECT OF THE TORREY CANYON ACCIDENT ON THE MARINE LIFE AND DISCUSSES BRIEFLY THE METHODS USED FOR CLEAN UP.
KEYW CLEANUP, TORREY CANYON, ACCIDENT, MARINE LIFE
CODE 3030A

AUTH HOLMES R.W.
TITL SANTA BARBARA OIL SPILL
PUBL OIL ON THE SEA, PLENUM PRESS, 1969
ABST THIS ARTICLE PRESENTS THE FACTS AND OPINIONS CONCERNING THE SANTA BARBARA OIL SPILL AND DISCUSSES THE ATTEMPTS AT CONTAINMENT OF THE SPILL
KEYW CONTAINMENT, SANTA BARBARA OIL SPILL, FACTS AND OPINIONS
CODE 3032A

AUTH HOLT M.
TITL NUMERICAL METHODS IN FLUID DYNAMICS
PUBL SPRINGER VERLAG, NY, 1977
ABST MANY APPLICATION AND SAMPLES OF NUMERICAL SOLUTIONS OF MODEL PROBLEMS ARE PRESENTED.
KEYW NON LINEAR WAVE INTERACTION, GAS DYNAMICS, LOW AND HIGH SPEEDS.
CODE 6133E

AUTH HORNSTEIN B.
TITL THE APPEARANCE AND VISIBILITY OF THIN OIL FILMS ON WATER
PUBL EDISON WATER QUALITY RESEARCH LAB. AUG. 1972
ABST THE REPORT EXAMINES THE INHERENT OPTICAL CHARACTERISTICS AND CORRESPONDING INHERENT VISUAL EFFECTS OF THIN FILMS OF OIL ON WATER.
KEYW OPTICAL PROPERTIES, REFLECTIVITY, VISIBILITY, THIN FILMS
CODE 0293A

AUTH HORVATH R., MORGAN W.L., STEWART S.
TITL FINAL, OPTICAL REMOTE SENSING OF OIL SLICKS
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT, OCT. 1971, PROJECT NO. 724104.2I
ABST THE GOAL OF THIS REPORT IS TO DEVELOP METHODS FOR IMPROVING AND EXTENDING CURRENT AIRBORNE AND SPACEBORNE REMOTE SENSING CAPABILITIES.
KEYW OPTICAL PROPERTIES OF PETROLEUMS, REFLECTANCE, THERMAL, FLUORESCENCE SIGNATURES, OPERATIONAL EQUIPMENT
CODE 0624F

AUTH HOUK D.
TITL THE EFFECTS OF RAIN ON NEAR-SURFACE WATER
PUBL UNIVERSITY MICROFILMS, ANN ARBOR, MICH. A THESIS SUBMITTED TO THE UNIV. OF WISC. FOR THE DOCTORATE OF PHILOSOPHY
ABST THE PHYSICAL EFFECTS OF RAIN ON CALM NEAR-SURFACE FRESHWATER AND SALTWATER EXAMINED EXPERIMENTALLY.
KEYW PHYSICAL EFFECTS, RAIN, CALM NEAR-SURFACE WATER
CODE 7604F

AUTH HOULT D.
TITL EULER-LAGRANGE RELATIONSHIP FOR RANDOM DISPERSIVE WAVES
PUBL THE PHYSICS OF FLUIDS, VOL. 11, NO. 10, OCT. 1968
ABST THE TIME AND LENGTH SCALES OVER WHICH THE PROCESS IS DIFFUSIVE ARE DETERMINED AND A FORMULA FOR THE DIFFUSION COEFFICIENT IS PRESENTED.
KEYW TURBULENT DIFFUSION, DISPERSIVE WAVES, DIFFUSION COEFFICIENT
CODE 0836F

AUTH HOULT D.
TITL OIL SPREADING ON THE SEA
PUBL ANNUAL REVIEW OF FLUID MECHANICS, VOL. 4, 1972
ABST THIS PAPER DISCUSSES THE PROBLEMS OF DETERMINING THE SPREADING OF OIL AND THE ENVIRONMENTAL HAZARDS OF THE SPREADING.
KEYW ENVIRONMENTAL DAMAGE, CONVECTION BY WINDS AND CURRENTS, AREA OF SPREADING
CODE 0577F

AUTH HOULT D.P.
TITL ARCTIC POLLUTION CONTROL PROGRAM OIL DISSIPATION RESEARCH
PUBL MIT FOR USCG, SSIC NO. 62P-47
CODE 0431A

AUTH HOULT D.P.
TITL CONTAINMENT AND COLLECTION DEVICES FOR OIL SLICKS
PUBL M.I.T. FLUID MECHANICS LAB., AUG. 1969
ABST A BRIEF REVIEW OF THE MAIN TYPES OF COLLECTION SYSTEMS IN USE IS GIVEN.
KEYW CONTAINMENT, PHYSICAL BOOMS, PNEUMATIC BOOMS
CODE 0542F

AUTH HOULT D.P.
TITL CONTAINMENT OF OIL SPILLS BY PHYSICAL AND AIR BARRIERS
PUBL STOP POLLUTION
ABST A REVIEW OF THE STATE OF OUR UNDERSTANDING OF BARRIERS TO CONTAIN OIL IS PRESENTED.
CODE 3051A

AUTH HOULT D.P.
TITL THE SPREADING AND CONTAINMENT OF OIL SLICKS
PUBL PAPER NO. 70-754, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, JUNE 1970
ABST SPREAD OF OIL SLICKS IN A ONE-DIMENSIONAL CHANNEL.
CODE 3045A

AUTH HOULT D.P., CROSS R.H., MILGRAM J.H., PULLAR E.G., REYNOLDS H.J.
TITL CONCEPT DEVELOPMENT OF A PROTOTYPE LIGHTWEIGHT OIL CONTAINMENT SYSTEM FOR USE ON THE HIGH SEAS.

PUBL JOHNS-MANVILLE RESEARCH AND ENGINEERING CENTER,
JUNE 1973
ABST A SOLUTION OF THE OIL SPILLAGE CONTAINMENT
PROBLEM.
CODE 6035F

AUTH HOUSTON C.W.
TITL BIOLOGICAL DEGRADATION OF HYDROCARBONS IN WATER
PUBL NTIS REPORT NO. BP 223 438
CODE 0322A

AUTH HOWARD A.M.
TITL EXPERIMENT ON OIL BARRIERS
PUBL URI FOR USCG, SSIE NO. 62-38991-1
CODE 0430A

AUTH HUFFORD G., LISSAUER I.M., WELSH J.P.
TITL FINAL REPORT, MOVEMENT OF SPILLED OIL OVER THE
BEAUFORT SEA-SHELF - A FORECAST
PUBL USCG, DEPT. OF TRANSPORTATION, CG-D-101-76, JUNE
1976
ABST PROJECTION OF THE MOVEMENT OF OIL SLICKS AND THEIR
IMPACT LOCATION ALONG THE NO. ALASKAN COAST ARE
DETERMINED FROM FIFTEEN POTENTIAL OIL DRILLING
SITES. TWO APPROACHES ARE IMPLEMENTED TO DETERMINE
IMPACT ON THE METEOROLOGY AND WATER MOVEMENT IN
THE AREA. THIS SECOND CONSIDERS THE INTERACTIONS
OF THE ENVIRONMENTAL PROCESSES IN FORECASTING THE
POTENTIAL PATHS OF SPILLED OIL AND THEIR IMPACT
LOCATION.
KEYW OIL SPILL MOVEMENT, IMPACT ASSESSMENT,
METEOROLOGY, WATER MOVEMENT
CODE 2562F

AUTH HUFFORD G.L.
TITL BIOLOGICAL RESPONSE TO OIL IN MARINE ENVIRONMENT
PUBL MARCH 1971, TD 5.25: 714121/100
CODE 0054A

AUTH HUGHES P.
TITL A DETERMINATION OF THE RELATION BETWEEN WIND AND
SEA SURFACE DRIFT
PUBL QUARTERLY JOURNAL OF THE ROYAL METEROLOGICAL
SOCIETY, VOL. 82, 1956
ABST THIS REPORT DISCUSSES THE RELATIONSHIP BETWEEN
DRIFT AND GRADIENT WIND.
KEYW DRIFT GRADIENT WIND, SPEED AND DIRECTION
CODE 0069F

AUTH HUNT G., HORTON D., LEVINE J., MAYO D., DONOVAN
D., SHELLEY W., JIANG L., CRANE R., JOHNSON R.
TITL THE EVALUATION AND DEVELOPMENT OF PASSIVE TAGGING
PROCEDURES FOR THE IDENTIFICATION OF CRUDE OIL
SPILLED ON WATER
PUBL STATE OF MAINE DEPT. OF EP, FOR EPA 1975
CONVENTION
ABST A PRELIMINARY REVIEW OF DATA SUCCESSES AND
LIMITATIONS ARE DISCUSSED.
KEYW PASSIVE TAGGING, DEVELOPMENT, IDENTIFICATION
PROCEDURES
CODE 0066AA

AUTH HUNT G.S.
TITL THE FEASIBILITY OF IDENTIFYING MYSTERY OIL SPILLS
PUBL STATE DEPT. OF ENVIRONMENT PROTECTION FOR EPA,
SSIE NO. GMA-1046
CODE 0066A

AUTH HUNT J.P., OAKLEY T.
TITL WATER QUALITY STUDY OF MONTAUK HARBOR, LONG
ISLAND, NY, USING A HYDRAULIC MODEL
PUBL NEW YORK OCEAN SCIENCE LAB., SSIE NO. AL-964
CODE 0054A

AUTH HUTCHINSON T.C., FRELDMAN W.
TITL EFFECTS OF EXPERIMENTAL CRUDE OIL SPILLS ON TAIGA
AND TUNDRA VEGETATION OF THE CANADIAN ARCTIC.
PUBL DEPT. OF BOTONY AND INSTITUTE FOR ENVIRONMENTAL
STUDIES, UNIV. OF TORONTO, CANADA, FOR EPA 1975
CONFERENCE
KEYW EXPERIMENTAL CRUDE OIL SPILLS TAIGA AND TUNDRA
VEGETATION, CANADIAN ARCTIC
CODE 0143A

AUTH HYLAND J.
TITL A REVIEW OF OIL POLLUTING INCIDENTS IN AND AROUND
NEW ENGLAND
PUBL ENVIRONMENTAL RESEARCH LAB., EPA 600/3-77-064,
JUNE 1977, URI.
ABST THE FOLLOWING REPORT OFFERS A COMPREHENSIVE REVIEW
OF OIL POLLUTION INCIDENTS IN AND AROUND NEW
ENGLAND WATERS. THE FIRST SECTION OF THE REPORT
PRESENTS AN ANALYSIS OF ALL OIL DISCHARGE DATA
MAINTAINED BY THE USCG FOR YEARS 1973 - 1975.
KEYW DISCHARGE, NEW ENGLAND AREAS, CAUSES
CODE 7205F

AUTH HYLAND J., ROGERSON P., GARDNER G.
TITL A CONTINUOUS FLOW SYSTEM FOR THE EXPOSURE OF
MARINE ORGANISMS TO OIL
PUBL EPA, PROCEEDINGS OF 1977 OIL SPILL CONFERENCE,
MARCH 1977
ABST A CONTINUOUS FLOW-THROUGH BIOASSAY SYSTEM IS
DESCRIBED FOR EXPOSING MARINE TEST ORGANISMS AND
THEIR VARIOUS LIFE STAGES TO OIL.
KEYW OIL BIOASSAY SYSTEM, CONTINUOUS FLOW, OIL
CONTAMINATION
CODE 6063F

AUTH HYLAND J., SCHNEIDER E.
TITL PETROLEUM HYDROCARBONS AND THEIR EFFECTS ON MARINE
ORGANISMS, POPULATIONS, COMMUNITIES AND ECOSYSTEMS
PUBL E.R.L., NARRAGANSETT, R.I.
ABST ANALYSIS OF AVAILABLE DATA FROM BIOASSAYS
CONDUCTED ON ADULT STAGES OF A WIDE VARIETY OF
MARINE ORGANISMS REVEALS LETHAL EFFECTS FROM
SOLUBLE FRACTION OF PETROLEUM AND PETROLEUM
PRODUCTS IN THE 1 TO 100 PART PER MILLION RANGE
KEYW LETHAL AND SUBLETHAL EFFECTS, ECOLOGICAL EFFECTS,
CONTROL
CODE 1206F

AUTH HYLAND J.L., MELZIAN B.D., GALLOWAY W., ROGERSON
P., MOORE W.S.
TITL A TECHNIQUE FOR THE REMOVAL OF DISSOLVED AND
DISPERSED HYDROCARBONS FROM BIOASSAY EFFLUENTS
PUBL USEPA ENVIRONMENTAL RESEARCH LABORATORY,
NARRAGANSETT, RI
ABST A METHOD IS DESCRIBED FOR THE EFFICIENT REMOVAL OF
PETROLEUM DERIVED HYDROCARBONS FROM THE OIL
CONTAMINATED EFFULENT OF CONTINUOUS FLOW THROUGH
OIL BIOASSAY SYSTEM.
KEYW ENVIRONMENTAL POLLUTANTS, FILTRATION TECHNIQUES,
FLOW THROUGH OIL BIOASSAY SYSTEM
CODE 1208F

AUTH IMBERGE J., FISCHER H.B.
TITL SELECTIVE WITHDRAWAL FROM A STRATIFIED RESERVOIR
PUBL EPA, PROJECT NO. 15040EJZ, DEC. 197_
ABST THEORETICAL AND EXPERIMENTAL FLOW INTO A LARGE
SINK IN A LINEARLY DENSITY STRATIFIED RESERVOIR.
THE PRIMARY FOCUS IS ON PARTITIONING THE FLOW INTO
DISTINCT FLOW REGIMES, AND PREDICTING THE
WITHDRAWAL LAYER THICKNESS AS A FUNCTION OF THE
DISTANCE FROM THE SINK.
KEYW WITHDRAWAL LAYER THICKNESS, SINK, LINEARLY DENSITY
STRATIFIED RESERVOIR
CODE 0047A

AUTH INAMI NOBUO
TITL PREVENTION OF DISCHARGED OIL IN THE SEA
PUBL J. FUEL. SOC. JAP., VOL 51, NO. 541
CODE 1066F

AUTH INSTITUTE OF PETROLEUM
TITL A REVIEW OF MECHANICAL SYSTEMS FOR THE RECOVERY OF
OIL SPILLED ON WATER
PUBL COORDINATING COMMITTEE FOR THE PREVENTION OF SEA
POLLUTION, APRIL, 1974
ABST THIS REPORT REVIEWS AVAILABLE INFORMATION ON THE
TECHNIQUES AND EQUIPMENT INVOLVED IN THE
MECHANICAL RECOVERY OF OIL SPILLED ON THE WATER.
KEYW MECHANICAL RECOVERY, CONTAINMENT, SKIMMING,
TRANSFER, STORAGE, LOGISTICS
CODE 0514F

AUTH JACKSON R.G.
TITL OFFSHORE OIL POLLUTION: LAW AND ENFORCEMENT
PUBL EPA 1975 CONFERENCE
ABST THE CENTRAL PURPOSE OF THIS STUDY IS TO COVER
BROADLY IN NON-TECHNICAL TERMS THE SALIENT ASPECTS
OF LAW AND ENFORCEMENT AS RELATED TO OFFSHORE OIL
POLLUTION SO AS TO ACHIEVE A PRACTICAL OVERALL
PERSPECTIVE.
KEYW LAW AND ENFORCEMNET, OFFSHORE
CODE 0069A

AUTH JAIN S.C.
TITL LIMITATIONS TO LENGTH OF CONTAINED OIL SLICKS
PUBL DISCUSSION MARCH 1974
ABST THIS DISCUSSION SHOWS THAT THE SOLUTIONS FOR THE
SLICK PROFILES AND FOR THE CRITICAL SLICK VOLUME
CAN BE OBTAINED IN CLOSE FORM.
KEYW THERMAL WEDGES, DENSITY DIFFERENCES, SLICK VOLUME
CODE 6571F

AUTH JAMES F.M.
TITL REVIEW OF OIL SPILL CLEANUP TECHNIQUES AND
EXPERIENCES
PUBL GULF OIL CO., MAY 13, 1969
ABST A REVIEW OF EQUIPMENT, MATERIALS, TECHNIQUES AND
PROCEDURES THAT HAVE ACTUALLY BEEN USED AND ARE
BEING USED FOR CLEAN-UP OF OIL SPILLS WHICH OCCUR
IN HARBORS AND INLAND WATERWAYS SPECIFICALLY
CONCERNS THOSE METHODS USED BY GULF OIL CO.
CODE 3002F

AUTH JAMES W.P.
TITL ENVIRONMENTAL ASPECTS OF A SUPERTANKER PORT ON THE
TEXAS GULF COAST
PUBL TEXAS A&M UNIV. SEA GRANT PROGRAM, REPORT NO
TAMU-SG-73-201, DEC. 1972
CODE 2090A

AUTH JAMES W.P., MANN R.W.
TITL ENVIRONMENTAL IMPACT OF A SUPERTANKER PORT
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1734,
MAY, 1973
ABST THIS PAPER DESCRIBES A STUDY OF THE ENVIRONMENTAL
ASPECTS OF AN OFFSHORE SUPERTANKER PORT.
KEYW WIND AND WATER CURRENT, SIZE OF SPILL, SEA
CONDITIONS

CODE 8660F

AUTH JASPER W., KIM T., WILSON M.P.
TITL DROP SIZE DISTRIBUTION IN A TREATED OIL WATER SYSTEM
PUBL ASTM - TECHNICAL PUBLICATION 659,474
ABST AN EXPERIMENTAL STUDY WAS CONDUCTED TO DETERMINE THE DROP SIZE DISTRIBUTIONS IN A DISPERSANT TREATED OIL WATER SYSTEM.
KEYW DISPERSANTS, DROP SIZE, INTERFACIAL AREA
CODE 6594F

AUTH JASPER W.L.
TITL DROP SIZE DISTRIBUTIONS IN A TREATED OIL-WATER SYSTEM
PUBL A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MECHANICAL ENGINEERING
ABST THIS PAPER DISCUSSES DROP SIZE DISTRIBUTIONS IN A TREATED OIL-WATER SYSTEM.
KEYW DROP SIZE DISTRIBUTIONS, TREATED OIL-WATER SYSTEM
CODE 6594AF

AUTH JEFFERIES H.P., JOHNSON W.
TITL PETROLEUM, TEMPERATURE AND TOXICANTS: EXAMPLES OF SUSPECTED RESPONSES BY PLANKTON AND BENTHOS ON THE CONTINENTAL SHELF
PUBL URI, MARINE REPRINT NO. 69, MARINE ADVISORY SERVICE PUBLICATIONS
ABST RESULTS OF TESTING ON PLANKTON AND BENTHOSOF PETROLEUM, TEMPERATURE AND TOXICANTS ARE DISCUSSED.
KEYW PETROLEUM, TEMPERATURE, TOXICANTS, BENTHOS, PLANKTON
CODE 1036P

AUTH JEFFERY P.G.
TITL LARGE-SCALE EXPERIMENTS ON THE SPREADING OF OIL AT SEA AND ITS DISAPPEARANCE BY NATURAL FACTORS
PUBL CONFERENCE ON PREVENTION AND CONTROL OF OIL POLLUTION, 1973
ABST THIS PAPER DESCRIBES THOSE CONSIDERATIONS THAT ARE OF IMPORTANCE IN UNDERSTANDING LARGE-SCALE OIL SPREADING EXPERIMENTS.
CODE 2643A

AUTH JEFFERY P.G., NICHOLS J.A.
TITL DISPERSANTS FOR OIL SPILL CLEAN-UP OPERATIONS AT SEA, ON COASTAL WATERS AND BEACHES
PUBL WARREN SPRING LABORATORY, DEPT. OF TRADE INDUSTRY, LR 193(OP), 1973
ABST THIS PRESENT REPORT REPLACES REPORT NO. LR 162, NOV. 1972. THE FIRST PART OF THIS REPORT PROVIDES GENERAL BACKGROUND INFORMATION AND RECENT IDEAS CONCERNING THE FORMATION, COMPOSITION AND USE OF MATERIALS INTENDED TO DISPERSE OIL. THE FINAL PART LISTS ALL THOSE DISPERSANT MATERIALS THAT HAVE BEEN RECEIVED AT WARREN SPRING LABORATORY.
KEYW DISPERSANTS, CLEANUP, PREVENTION
CODE 2921F

AUTH JENSEN D.S.
TITL U.S. COAST GUARD FAST CURRENT OIL REMOVAL SYSTEM DEVELOPMENT PROGRAM
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2197, MAY 5-8, 1975
ABST FIVE CONCEPTS TO CONTROL AND REMOVE OIL SLICKS IN WATER CURRENT VELOCITIES OF UP TO 10 KNOTS ARE PRESENTED.
KEYW CONTROL, REMOVAL, HEAD WAVE, INTERFACIAL INSTABILITIES
CODE 0532F

AUTH JENSEN D.S., NORTON D.J., LINDENMUTH W., BEACH- R.L.
TITL ENERGY DISSIPATIVE DEVICES TO CONTROL OIL SLICKS IN FAST-CURRENT ENVIRONMENTS
PUBL CONFERENCE ON PREVENTION AND CONTROL OF OIL POLLUTION
ABST A CONCEPT TO CONTROL AND RECOVER OIL SLICKS IN POTENTIAL WATER CURRENT VELOCITIES OF 10 KNOTS IS PRESENTED.
KEYW CONTROL, RECOVERY, REMOVAL
CODE 0526F

AUTH JOBSON A., COOK F.D., WESTLAKE D.W.S.
TITL MICROBIAL UTILIZATION OF CRUDE OIL
PUBL APPL. MICROBIAL 23:1082
CODE 5060F

AUTH JOENSEN A.H.
TITL DANISH SEABIRD DISASTERS IN 1972
PUBL MARINE POLLUTION BULL., 4(8):117-118
CODE 1082F

AUTH JOHANSON E., BIANCHI R., FARRELL J.
TITL THE DESIGN, DEVELOPMENT, TEST AND EVALUATION OF AN OPEN OCEAN OIL RECOVERY SYSTEM FOR USE IN WAVES
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1995, MAY 6-8, 1974
ABST THIS PAPER PRESENTS THE RESULTS OF A PROGRAM, CONDUCTED BY JBF SCIENTIFIC TO ESTABLISH THE REQUIREMENTS FOR AND THEN TO BUILD AND TEST AN OPEN OCEAN OIL RECOVERY SYSTEM FOR OPERATION IN HIGH WAVE ENVIRONMENTS.
KEYW RECOVERY, SKIMMERS, TESTING

CODE 0565F

AUTH JOHNSON J.C., MCAULIFFE C.D., BROWN R.
TITL PHYSICAL AND CHEMICAL BEHAVIOR OF SMALL CRUDE OIL SLICKS ON THE OCEAN .
PUBL JBF SCIENTIFIC CORP.
ABST THIS PAPER DESCRIBES THE RESULTS OF A SERIES OF RESEARCH OIL SPILLS IN THE NORTH ATLANTIC TO DETERMINE THE PHYSICAL AND CHEMICAL BEHAVIOR OF FRESH OILSLICKS.
KEYW RESEARCH OIL SPILLS, TRACKING, DISPERSION
CODE 7350F

AUTH JOHNSON J.W., HWANG H.C.
TITL MIXING AND DISPERSION BY WIND WAVES
PUBL DEPT. OF HEALTH, EDUCATION AND WELFARE, SER. 138, ISSUE 5, GRANT AG5445, UNIVERSITY OF CAL. HYDRC ENGINEERING LAB.
ABST CHARACTER AND NATURE OF ACTION WIND WAVES ON DISPERSION IS DISCUSSED.
KEYW WIND WAVE ACTION, DISPERSION, MIXING
CODE 6600F

AUTH JONES H.R.
TITL POLLUTION CONTROL IN THE PETROLEUM INDUSTRY
PUBL POLLUTION TECHNOLOGY REVIEW NO. 4, NOYES DATA CORP, PARK RIDGE, NJ, 1973
ABST THIS REPORT ATTEMPTS TO CLARIFY THE WAYS AND MEANS OPEN TO THE ALERT PETROLEUM REFINER WHO MUST KEEP HIS POLLUTION WASTES DOWN TO A MINIMUM.
KEYW EFFLUENT WASTES, BIODEGRADABILITY, DISCHARGE
CODE 4012F

AUTH JONES L.W.
TITL USE OF SULFUR FOR COMBATTING OIL SPILLS
PUBL AMOCO PRODUCTION CO., OFFICIAL GAZETTE FOR US PATENT OFFICE, VOL. 927, NO. 5, OCT. 29, 1974
ABST SULFUR IS SPREAD OVER THE SPILLED OIL TO HOLD THE OIL MASS TOGETHER AND PERMIT IT TO BE EASILY REMOVED.
CODE 3133A

AUTH JONES R.G.
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PUBL USCG, BOSTON, MASS.
ABST A LANDFILL WAS DESIGNED AND CONSTRUCTED FOR THE DISPOSAL OF APPROX. 8,500 YARDS OF DEBRIS IN THE CLEANUP OF A MAJOR POLLUTION INCIDENT IN NARRAGANSETT BAY, RI. THE RESULTS TO DATE: NO INCREASE IN THE TOTAL ORGANIC CARBON OR PHENOLIC CONTENT.
KEYW LANDFILL, CLEANUP, DISPOSAL, ORGANIC CARBON, PHENOLIC CONTENT
CODE 0098

AUTH JONES W.T.
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PUBL SOCIETY OF PETROLEUM ENGINEERS OF AIME, NO. SPE 3050, OCT., 4-7, 1970
ABST THIS PAPER DISCUSSES AN EXPERIMENTAL INVESTIGATION OF AIR BARRIERS AS CONTAINMENT DEVICES.
KEYW AIR BARRIERS, CONTAINMENT, SURFACE CURRENTS
CODE 0807F

AUTH JORDON L., BRAGAW L.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1994, MAY 6-8, 1974
ABST THIS PAPER DISCUSSES THE CHARACTERISTICS, VARIOUS EQUIPMENT, AND THE MAKE UP OF THE NATIONAL STRIKE FORCE.
KEYW AIR TRANSFER SYSTEM, BARRIERS, RECOVERY, AIRBORN REMOTE SENSING
CODE 0529F

AUTH JUNGHAS R.C.
TITL MARINE POLLUTION MONITORING
PUBL NBS SPECIAL PUBLICATION 409, 1974
ABST PROCEEDINGS CONTAIN LECTURES REPRESENTING. PERTINENT SCIENTIFIC, ENVIRONMENTAL AND REGULATORY ASPECTS OF PETROLEUM HYDROCARBONS MEASUREMENTS AND SUMMARIES OF VARIOUS DISCUSSIONS AND PAPERS. INCLUDES SPECIFIC RECOMMENDATIONS FOR MARINE PETROLEUM MONITORING.
KEYW MARINE PETROLEUM MONITORING, SCIENTIFIC, ENVIRONMENTAL AND REGULATORY ASPECTS
CODE 2139AH

AUTH KAISER R., JONES D., LARP H.
TITL TROPICAL STORM AGNES, PENNSYLVANIA'S TORREY CANYON
PUBL EPA, 1973 CONF.
ABST LARGEST INLAND OIL SPILL 6-8,000,000 GALLONS OF SLUDGE OIL WAS RELEASED FROM ITS WASTE HOLDING LAGOONS ON JUNE 22, 1972
CODE 6114F

AUTH KAISER R., MISKOLCZY G., CURTIS R.A., COLTON L.R.
TITL THE RECOVERY OF OIL FROM WATER WITH MAGNETIC LIQUIDS
PUBL PHYSICAL REMOVAL
ABST A NOVEL METHOD OF OIL-WATER SEPARATION HAS BEEN DEVELOPED WHICH UTILIZES MAGNETISM TO SEPARATE THE TWO PRELIMINARY RESULTS AND ECONOMIC PROJECTIONS ARE THEN PRESENTED.
KEYW OIL-WATER SEPARATION, MAGNETISM, FERRO-FLUID MISCIBLE

CODE 5114F

AUTH KAISER R.C., VAN CLEAVE H.D.
TITL METHODS AND PROCEDURES FOR PREVENTING OIL POLLUTION FROM ONSHORE AND OFFSHORE FACILITIES
PUBL OIL SPILL PREVENTION
ABST THE ROLE OF DESIGN CRITERIA, PERSONNEL OPERATING PROCEDURES AND HUMAN ERROR IN SPILL PREVENTION ARE DISCUSSED AND FUTURE PRACTICES ARE POSTULATED.
KEYW PREVENTION, ONSHORE, OFFSHORE
CODE 0871F

AUTH KANE J.
TITL RAYLEIGH WAVES AT THE CONTINENTAL MARGIN
PUBL URI, SCIENTIFIC REPORT NO. 6, JUNE 10, 1965
ABST THIS REPORT INTRODUCES AN ELEMENTARY PROCEDURE FOR THE SOLUTION OF PROBLEMS INVOLVING THE DIFFRACTION OF VECTOR FIELDS. IN PARTICULAR, THE REPORT DISCUSSES THE PROPAGATION OF RAYLEIGH WAVES INCIDENT OBLIQUELY UPON THE CONTINENTAL MARGIN.
KEYW RAYLEIGH WAVES, DIFFRACTION OF VECTOR FIELDS, CONTINENTAL MARGIN
CODE 7688F

AUTH KAPLAN A.M.
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PUBL DEVELOPMENTS IN INDUSTRIAL MICROBIOLOGY, VOL. 18, 1977
ABST THIS PAPER DISCUSSES THE IMPORTANCE IN DEVELOPMENT OF MATERIALS BEING THE DETERMINATION OF THEIR BEHAVIOR UNDER STRESS.
KEYW DEGRADATION, ENVIRONMENTAL STRESS, DEVELOPMENT OF MATERIALS
CODE 4576F

AUTH KARELSE M., DELVIGNE G., VREUGDENHIL C.B.
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PUBL DELFT HYDRAULICS LAB.
ABST RESULTS OF THIS STUDY SHOULD GIVE RELATIONS BETWEEN DENSITY GRADIENTS AND THE VERTICAL TRANSFER OF MOMENTUM AND MASS IN THIS TYPE OF FLOWS WHICH COULD BE USED IN A TWO-DIMENSIONAL MATHEMATICAL MODEL.
KEYW MOMENTUM AND MASS TRANSFER, STRATIFIED FLOWS, DENSITY GRADIENTS, VERTICAL TRANSFER
CODE 2573R

AUTH KATO H., PHILLIPS O.
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AUTH KATZ E.
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AUTH KAWAHARA F.
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ABST ANALYTICAL METHODS DEVELOPED RECENTLY AT THE ANALYTICAL QUALITY CONTROL LAB ARE DESCRIBED FOR THE CHARACTERIZATION AND IDENTIFICATION OF HEAVY RESIDUAL FUEL OIL POLLUTANTS FOUND IN SURFACE WATERS.
KEYW IDENTIFICATION OF OIL SPILLED, GAS CHROMATOGRAPHY, INFRARED SPECTROPHOTOMETRY
CODE 1201F

AUTH KAWAHARA F.
TITL TRACE ORGANIC COMPONENTS AS FINGERPRINTS IN GAS CHROMATOGRAPHIC IDENTIFICATION OF SPILLED ASPHALTS
PUBL ENVIRONMENTAL SCIENCE AND TECHNOLOGY, VOL. 10, AUG. 1976
ABST THIS PAPER DISCLOSES THE FIRST SUCCESSFUL APPLICATION OF GAS CHROMATOGRAPHY ELECTRON CAPTURE DETECTION IN THE ANALYSIS OF THE ORGANIC TRACE COMPONENTS PRESENT IN ASPHALTS AND ITS USEFULNESS IN PROVIDING IDENTIFICATION OF ASPHALT POLLUTANTS FOUND IN SURFACE WATERS.
KEYW OIL IDENTIFICATION, GAS CHROMATOGRAPHY, ELECTRON CAPTURE DETECTION
CODE 1202F

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PUBL IND. AND ENG. CHEM. RES. AND DEVEL., VOL. 9, DEC. 1970
ABST NUMEROUS UNIDENTIFIED OIL SAMPLES COLLECTED FROM THE SURFACE WATERS OF THE UNITED STATES WERE ANALYZED BY THE METHOD OF RATIOS OF INFRARED ABSORBANCE USING SIX WAVENUMBERS.
KEYW CHARACTERIZATION, IDENTIFICATION, RATIO VALUES
CODE 1225F

AUTH KAWAHARA F., SANTER J., JULIAN E.
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KEYW IDENTIFICATION, INFRARED SPECTROPHOTOMETRY, CLASSIFICATION SAMPLES
CODE 1203F

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TITL SYSTEMS CHEMICAL ANALYSIS OF PETROLEUM POLLUTANTS
PUBL ANALYTICAL CHEMISTRY, VOL. 48, APR., 1976
ABST THE APPLICATION OF AN ESTABLISHED MATHEMATICAL TREATMENT USEFUL FOR THE CHARACTERIZATION AND IDENTIFICATION OF PETROLEUM POLLUTANTS IS DESCRIBED.
KEYW CHARACTERIZATION, IDENTIFICATION, INFRARED SPECTROPHOTOMETRIC
CODE 1231F

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TITL GAS CHROMATOGRAPHIC ANALYSIS OF MERCAPTANS, PHENOLS, AND ORGANIC ACIDS IN SURFACE WATERS WITH USE OF PENTAFLUOROBENZYL DERIVATIVES
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ABST QUALITATIVE SEPARATION AND QUANTITATIVE DETERMINATION SAMPLING IS DISCUSSED
KEYW DETECTION, IDENTIFICATION, SAMPLING
CODE 1211F

AUTH KEEVIL B., RAMSEIER R.
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PUBL CONFERENCE ON THE PREVENTION AND CONTROL OF OIL POLLUTION
ABST COLD ROOM EXPERIMENTS DESIGNED TO SIMULATE A [illegible] OIL SPILL UNDER ICE IS DEMONSTRATED.
KEYW CLEANUP, BEHAVIOR OF OIL UNDER ICE, COLD ROOM EXPERIMENTS
CODE 0850F

AUTH KEITH V.F., PORRICELLI J.D.
TITL AN ANALYSIS OF OIL OUTFLOW DUE TO TANKER ACCIDENTS
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ABST ANALYSIS OF DATA PERTAINING TO OIL SPILLS ACCORDING CRITERIA OF AMOUNT, LOCATION, ETC.
CODE 3137R

AUTH KEIZER P.D., AHERN T.P., DALE J., VANDERMEULEN J.H.
TITL RESIDUES OF BUNKER C OIL IN CHEDABUCTO BAY, NOVA SCOTIA, 6 YEARS AFTER THE ARROW SPILL
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5 MAY 1978
ABST AN EXTENSIVE SURVEY OF SURFICIAL SEDIMENTS, INTER-TIDAL AND SUBLITTORAL, OF CHEDABUCTO BAY IN JULY 1976
KEYW GAS LIQUID CHROMATOGRAPHY, FLUORESCENCE SPECTROSCOPY, POLYCYCLIC AROMATIC HYDROCARBONS
CODE 2669F

AUTH KENNEDY J.M., WERMUND E.G.
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AUTH KENNEDY J.M., WERMUND E.G.
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PUBL PHOTOGRAMMETRIC ENGINEERING, VOL. 37, DEC. 1971
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AUTH KENNEDY J.R.
TITL HELICOPTER TOW TESTS OF THE USCG'S AIR DELIVERY CONTAINER FOR OIL SPILL CONTAINMENT BARRIER
PUBL US NAVAL COASTAL SYSTEMS LAB., REPORT NO NCSL 198-73
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AUTH KERR R.S.
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PUBL ENVIRONMENTAL PROTECTION TECHNOLOGY SERIES, DEC. 1972
ABST THE PAPER DISCUSSES A STUDY DESIGNED TO DEMONSTRATE THE EFFECTIVENESS AND COST OF THE SOIL CULTIVATION PROCESS FOR DISPOSAL OF OILY WASTE FROM PETROLEUM.
KEYW WASTE DISPOSAL, INDUSTRIAL WASTES TREATMENT, BIODEGRADATION
CODE 0134R

AUTH KETCHEL R.J., EDGERTON A.T.
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PUBL DETECTION AND MONITORING OF SPILLS
ABST DISCUSSION OF DEVELOPMENT, DESIGN AND FLIGHT TEST EVALUATION OF A PROTOTYPE AIRBORNE OIL SURVEILLANCE SYSTEM.
KEYW DETECTION MAPPING, DOCUMENTATION
CODE 0855F

AUTH KHANDEKAR M., MURTY T.S.
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PUBL PROC. OF THE CANADIAN SOCIETY FOR CIVIL ENG. FIRST CANADIAN HYD. CONF., 1973, ALBERTA UNIV. WATER RESOURCES CENTER, PUB. NO.4, 1973
CODE 2034R

AUTH KHMEL'NIK R.I.

TITL THE ESTIMATION OF IMPULSIVE PRESSURES ARISING IN THE IMPACT OF A DROP AGAINST A SOLID SURFACE
PUBL ROYAL AIRCRAFT ESTABLISHMENT, LIBRARY TRANSLATION NO. 1653, AUG. 1972, PROCUREMENT EXECUTIVE MINISTRY OF DEFENCE
ABST IN THIS ESTIMATION OF IMPACT PRESSURES OF A DROP WITH A SOLID SURFACE, THE DEFORMATION OF THE SURFACE OF THE DROP AND THE ONSET OF POST-COLLISIONAL MOTION OF THE LIQUID ARE CONSIDERED. IT IS ALSO SHOWN HOW EXCESSIVE FLATTENING OF THE DROP LEADS TO A REDUCTION OF IMPACT PRESSURES.
KEYW IMPACT PRESSURES, DEFORMATION OF THE SURFACE OF THE DROP, POST-COLLISIONAL MOTION, EXCESSIVE FLATTENING
CODE 7674F

AUTH KIMBAL V.S.
TITL WASTE OIL RECOVERY AND DISPOSAL
PUBL POLLUTION TECHNOLOGY REVIEW NO. 20, NOYES DATA CORP., PARK RIDGE, NJ, 1975
ABST THE TWIN SUBJECTS OF WASTE OIL RECOVERY VERSUS NON POLLUTING DISPOSAL ARE OF HIGH CURRENT INTEREST BOTH FROM THE STANDPOINT OF CONSERVATION OF ENERGY RESOURCES AND THE PROTECTION OF THE ENVIRONMENT.
KEYW RECOVERY, DISPOSAL, CONSERVATION AND PROTECTION
CODE 4011B

AUTH KINNEY P.J., BUTTON D.K., SCHELL D.M.
TITL KINETICS OF DISSIPATION AND BIODEGRADATION OF CRUDE OIL IN ALASKA COOK INLET
PUBL INSTITUTE OF MARINE SCIENCE, UNIVERSITY OF ALASKA, CONTRIBUTION NO. 61
ABST THE RESULTS OF A STUDY TO DEFINE THE MAGNITUDE OF OIL POLLUTION PROBLEMS IN ALASKA COOK INLET ARE REPORTED.
KEYW DISSIPATION, BIODEGRADATION RATES, ALASKAS COOK INLET
CODE 2147F

AUTH KINKMAN R.L.
TITL MODEL TEST OF A 1/12 SCALE OCEAN SYSTEM OIL RETENTION BARRIER
PUBL TECH REPORT NO 1040-1, OCEAN SYSTEMS, INC., 1970
CODE 0740R

AUTH KITTREDGE J.S.
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PUBL GOVERNMENT REPORTS ANNOUNCEMENTS, 73(15):78
CODE 1056R

AUTH KLEMAS V.
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PUBL UNIV. OF DELAWARE
ABST DIFFERENCES IN PROPERTIES OF OIL AND WATER OFFERS A POTENTIAL METHOD FOR DETECTING POLLUTION. SUCCESSFUL DETECTORS CAN DISCRIMINATE AMONG DIFFERENT OIL TYPES AND ARE NOT CONFUSED BY OTHER POLLUTANTS WHICH MAY RESEMBLE OIL.
CODE 3500R

AUTH KLEMAS V., MAURER D., LEATHAM W., KINNER P., TREASURE W.
TITL DYE AND DROGUE STUDIES OF SPOIL DISPOSAL AND OIL DISPERSION
PUBL JOURNAL OF WATER POLLUTION CONTROL FED, VOL 46, NO. 8, AUG. 1974
ABST THIS PAPER DISCUSSES THE RESEARCH OF A STUDY TO DETERMINE EFFECTS OF DREDGING AND OVER BOARD SPOIL DISPOSAL ON BENTHIC INVERTEBRATE COMMUNITIES.
KEYW SAMPLING, DISPERSION, DISPOSAL
CODE 2141F

AUTH KLEMAS V., OTLEY M., WETHE C., ROGER R.
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PUBL NASA, 3D-ERTS-1 SYMP., VOL. 1, SECT. B, P1387-1411
CODE 0409R

AUTH KNAPP R.
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CODE 5026R

AUTH KNAUSS J.A.
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PUBL THE LAW OF THE SEA: THE EMERGING REGIME OF THE OCEANS. BALLINGER PUBLISHING CO. 1974
ABST KNAUSS DISCUSSES THE TIME-DEPENDENT NATURE OF OIL POLLUTION, EXPLAINS THE WAYS POLLUTANTS ENTER THE OCEAN, AND MAKES SOME PREDICTIONS AS TO THE FUTURE OF OIL POLLUTION.
CODE 3103R

AUTH KNIGHT H.
TITL INTERNATIONAL LEGAL PROBLEMS IN THE CONSTRUCTION AND OPERATION OF OFFSHORE DEEP DRAFT PORT FACILITIES
PUBL THE HAZARDS OF MARITIME TRANSIT, BALLINGER PUBLISHING CO., 1973
ABST THE PRINCIPLE OBJECTIVES OF THIS CHAPTER ARE TO IDENTIFY AND DISCUSS INTERNATIONAL LEGAL PROBLEMS INVOLVED IN THIS CONTRUCTION AND OPERATION OF OFFSHORE DEEP DRAFT PORT FACILITIES AND TO PROPOSE A DRAFT TREATY ARTICLE CONCERNING SUCH FACILITIES.
CODE 3108F

AUTH KNUBEL F.
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PUBL OFFICE OF PUBLIC INFORMATION, NEW YORK, COLUMBIA UNIVERSITY
ABST THIS PAPER DISCUSSES THE RESULTS OF TESTS OF OIL AND WATER MIXTURES WITH THE HELP OF DISPERSANTS.
KEYW DISPERSANTS, MONOLAYER FILMS
CODE 2136F

AUTH KOLMOGOROV, A.N.
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PUBL TRANSLATED FROM DOK. AKAD. NAUK 66 1949
ABST STUDIES ON BREAK-UP IN A TURBULENT STREAM OF WATER DROPLETS OF LIQUIDS NOT SOLUBLE IN WATER.
KEYW TURBULENCE PULSATIONS, SIZE REDUCTIONS, PULSATION VELOCITIES
CODE 6034F

AUTH KOLPACK R.
TITL BEHAVIOR OF HYDROCARBONS FROM NATURAL SEEPS AND A WELL BLOWOUT IN SANTA BARBARA CHANNEL CALIFORNIA
PUBL ABSTRACT VOLUME, SECOND NATIONAL COASTAL AND SHALLOW WATER RESEARCH CONFERENCE
ABST THIS REPORT DISCUSSES THE PHYSICAL AND CHEMICAL INFORMATION OBTAINED TO PROVIDE QUANTITATIVE METHODS OF DETERMINING THE BEHAVIOR OF SPILLED OIL.
KEYW DISTRIBUTION, DISSOLUTION, OIL SEEPS
CODE 2035F

AUTH KOLPACK R.
TITL PRIORITIES IN FATE OF OIL SPILL RESEARCH
PUBL 1977 OIL SPILL CONFERENCE
ABST RESEARCH EFFORTS THAT WILL BE REQUIRED TO GAIN A BETTER UNDERSTANDING OF THE FATE OF OIL IN THE OCEAN ARE CATEGORIZED WITH RESPECT TO FIVE MAJOR ENVIRONMENTAL RESERVOIRS.
KEYW INTERACTION, MARINE ENVIRONMENT, SPREADING, MIXING, DISSOLUTION, EMULSIFICATION, DEGRADATION
CODE 1234F

AUTH KOLPACK R.L., MECHALAS B.J., MYERS T.J., PLUTCHAK N.B., EATON E.
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PUBL ENVIRONMENTAL GEOLOGY PROGRAM, API PUBLICATION, NO. 4212
ABST THIS REPORT PRESENTS THE RESULTS OF AN EVALUATION OF THE LITERATURE TO DETERMINE WHAT IS KNOWN ABOUT THE FATE OF OIL RELEASED TO THE WATER ENVIRONMENT
KEYW MASS BALANCE RELATIONSHIPS, OIL SPREAD
CODE 2542F

AUTH KOLPACK R.L.
TITL FATE OF OIL IN A WATER ENVIRONMENT - PHASE II A DYNAMIC MODEL OF THE MASS BALANCE FOR RELEASED OIL, FINAL REPORT MARCH 1977
PUBL DEPARTMENT OF ENVIRONMENTAL AFFAIRS AMERICAN PETROLEUM INSTITUTE
ABST A THREE-DIMENSIONAL DIGITAL COMPUTER SIMULATION MODEL WAS CONSTRUCTED FOR THE PURPOSE OF ORGANIZING THE AVAILABLE INFORMATION FROM OIL SPILL RESEARCH EFFORTS IN ORDER TO DEVISE A MANAGEMENT & SCIENTIFIC TOOL WHICH COULD BE USED TO GAIN A BETTER UNDERSTANDING OF THE FATE OF OIL RELEASED IN ICE FREE MARINE ENVIRONMENTS. RESULTS SHOW THAT THE FATE OF A PARTICULAR OIL SPILL DEPENDS ON A COMBINATION OF FACTORS SUCH AS TYPE OF OIL INVOLVED, VOLUME RELEASED, RESIDENCE TIME IN A GIVEN AREA, & ENVIRONMENTAL CONDITIONS AT THE SITE OF THE SPILL.
KEYW THREE-DIMENSIONAL MODEL, OIL SPILL RESEARCH
CODE 7763F

AUTH KOLPACK, R., PLUTCHAK N.
TITL ELEMENTS OF MASS BALANCE RELATIONSHIPS FOR OIL RELEASED IN THE MARINE ENVIRONMENT
PUBL ENVIRONMENTAL GEOLOGY, UNIV. OF SO. CALIFORNIA
ABST THE COMPOSITION OF OIL RELEASED IN THE MARINE ENVIRONMENT AND THE PROCESS AND PARAMETERS WHICH INFLUENCE THE COMPOSITION, QUANTITY AND SPATIAL DISTRIBUTION OF HYDROCARBONS IN THE ENVIRONMENT ARE THE CONTROLLING FACTOR IN DETERMINING THE FATE OF AN OIL SPILL.
KEYW COMPOSITION, QUANTITY, SPATIAL DISTRIBUTION, FATE
CODE 2634F

AUTH KOLPACK, R.L.
TITL MOVEMENT OF OIL AND WATER IN SANTA BARBARA CHANNEL, CALIFORNIA
PUBL UNIV. OF CALIF., FOR 1969 JOINT CONFERENCE
KEYW MOVEMENT, SANTA BARBARA CHANNEL
CODE 0265R

AUTH KONDO G.
TITL ABOUT THE PROPERTY OF DISPERSING METHOD FOR SPILLED OIL
PUBL PAPER PRESENTED AT THE SECOND INTERNATIONAL OCEAN DEVELOPMENT CONFERENCE, OCT. 1972
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2447, MAY 3-6, 1976
ABST THIS PAPER REVIEWS THE CONSTITUENTS OF PRODUCED WATERS AND THEIR EFFECTS ON BOTH OFFSHORE AND COASTAL MARINE ENVIRONMENTS. INTERPRETATION OF CONSIDERABLE LABORATORY AND FIELD DATA WITH CONCLUSIONS.
KEYW TOXICITY, DILUTION, EVAPORATION, FIELD DATA
CODE 2623F

AUTH KORDYBAN E. CURIE S.
TITL A METHOD FOR MEASURING OIL THICKNESS ON THE SURFACE OF WATER IN THE PRESENCE OF WAVES.
PUBL CAVITATION AND POLYPHASE FLOW FORUM, 1977
ABST THIS PAPER DISCUSSES THE NEED TO UNDERSTAND THE BEHAVIOR OF OIL ON WATER TO DESIGN AN EFFECTIVE RECOVERY DEVICE.
KEYW OIL THICKNESS, CONTAINMENT, CLEANUP, RECOVERY
CODE 6502F

AUTH KOWALSKI A.
TITL LIGHTWEIGHT OIL CONTAINMENT BARRIER FIELD TESTS
PUBL US NAVAL CIVIL ENG. LAB., SO EPA 670/2-75-063
CODE 2008H

AUTH KREBS C.T., BURNS K.A.
TITL LONG TERM EFFECTS OF AN OIL SPILL ON POPULATIONS OF THE SALT MARSH CRAB
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST DISCUSSION OF RESULTS OF LONG TERM EFFECTS OF OIL ON SALT MARSH CRABS.
KEYW CRAB POPULATIONS, SALT MARSHES, LONG TERM EFFECTS
CODE 2669F

AUTH KROGH F., HALDORSEN J., AUDUNSON T.
TITL OILSIM- A COMPUTER PROGRAM SIMULATING THE FATE OF OILSPILLS
PUBL NORWEGIAN MARITIME RESEARCH NO. 4/1976 REPRINT
ABST THIS PAPER PRESENTS A COMPUTER MODEL, OILSIM, FOR THE SIMULATION OF THE DRIFT, SPREADING, DISSIPATION AND WEATHERING OF OIL SPILLS. THE DISSIPATION COMPUTATIONS ARE BASED ON A SIMPLE ONE-DIMENSIONAL BUDGET MODEL.
KEYW OILSIM, OIL SPILLS, WEATHERING
CODE 7743F

AUTH KUTT E.C., MARTIN D.F.
TITL EFFECT OF SELECTED SURFACTANTS ON THE GROWTH CHARACTERISTICS OF GYMNODINIUM BREVE
PUBL MAR. BIO. 28:253-259
CODE 1013P

AUTH KUZNETSOV G.A., PANIN G.N.
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PUBL METEOROLOGY AND HYDROLOGY
CODE 0304R

AUTH LA ROCK P.A., AHFELD T.E.
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AUTH LACAZE J.
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PUBL EPA, PB-237805-T, JULY 23, 1973
ABST THE INFLUENCE OF THE ILLUMINATION IS USUALLY NEGLECTED IN THE ASSAYS OF BIODEGRADATION. IT IS THIS PARAMETER THAT WE STUDY IN THIS PAPER AND ITS ACTION ON THE BIODEGRADATION OF A NON-IONIC SURFACTANT.
KEYW BIODEGRADATION, TANKER SHIPS, SURFACTANTS, PETROLEUM INDUSTRY
CODE 5100F

AUTH LAFOND E.C., LAFOND K.G.
TITL SEA SURFACE SLICKS
PUBL PROC. NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER, MARCH 1971, REPORT NO. NUC TP 215
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TITL ENVIRONMENTAL EFFECTS OF PETROCHEMICAL WASTE DISCHARGES ON TALLABOA AND GUAYANILLA BAYS, PUERTO RICO
PUBL EPA, REGION IV, SURVEILLANCE AND ANALYSIS DIV., OCT. 1971
ABST OBJECTS OF REPORT: 1. CHARACTERIZE AND QUANTIFY WASTES. 2. DETERMINE THE EFFECTS OF THESE WASTES. 3. DOCUMENT VIOLATIONS OF PUERTO RICO'S FEDERAL STATE COASTAL WATER QUALITY STANDARDS.
KEYW CHARACTERIZE, QUANTIFY, EFFECTS, WASTES, VIOLATIONS, FEDERAL, STATE, STANDARDS
CODE 0031A

AUTH LALLIER R.
TITL CHANGES IN THE DIFFERENTIATION OF THE SEA URCHIN LARVA BY ACTION OF A DETERGENT UPON THE UNSEGMENTED EGG
PUBL EXPERIENTIA 29/6, SPECIALIA
ABST THIS PAPER DISCUSSES THE EFFECTS OF CHEMICAL DISPERSANTS ON THE SEA URCHIN LARVA.
KEYW SEA URCHIN LARVA, DISPERSANTS, DIFFERENTIATION
CODE 7126F.

AUTH LAMB W.
TITL AN ELECTRO-ACOUSTIC OIL LAYER THICKNESS GAUGE
PUBL URI THESIS 1975
ABST THIS PAPER DESCRIBES THE CONSTRUCTION AND TESTING OF A SUCCESSFUL ELECTRO-ACOUSTIC OIL LAYER THICKNESS GAUGE
KEYW OIL LAYER THICKNESS GAUGE, ACOUSTIC SIGNALS, THICKNESS MEASUREMENTS
CODE 0874F

AUTH LANGMUIR I.
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PUBL SCIENCE, VOL. 87, FEB. 11, 1936
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KEYW LONGITUDINAL SURFACE CURRENTS, HELICAL VORTICES, WIND DIRECTION
CODE 2654F

AUTH LAROCHE G., EISLER R., TARZWELL C.
TITL BIOASSAY PROCEDURES FOR OIL AND OIL DISPERSANT TOXICITY EVALUATION
PUBL JOURNAL OF WATER POLLUTION CONTROL, VOL. 42, NOV. 1970
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KEYW DISPERSANTS, TOXICITY, BIOASSAY PROCEDURES
CODE 2143F

AUTH LARRABEE R.M., BROWN G.A.
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PUBL URI DEPT. OF C.E., MAY 1974
ABST STUDY OF OIL BARRIER SHAPE AND TENSIONS AS INFLUENCED BY CURRENT AND WAVE ACTION TO ANALYZE DATA ON THE BARRIER SHAPE WITH EXISTING ANALYSES AND TO COMPARE RESULTS OF TENSION AND DRAG COEFFICIENT DATA WITH PREVIOUS INVESTIGATIONS.
KEYW BARRIERS, TENSION, CURRENT AND WAVES
CODE 4029G

AUTH LARSON J.J.
TITL AN EXAMINATION OF ALTERNATIVE METHODS FOR EMPLOYING BOOMS TO CONTAIN OIL SPILLS IN NAVY HARBORS
PUBL NAVAL POSTGRADUATE SCHOOL, AD 783-750, JUNE 1974
ABST IN THIS THESIS A PLAN IS FORMULATED WHICH ENABLES A DECISION MAKER TO DETERMINE THE RELATIVE EFFECTIVENESS OF 3 METHODS FOR EMPLOYING OIL SPILL CONTAINMENT BOOMS.
CODE 6104H

AUTH LASKIN A., LECHEVALIER H.
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PUBL CRITICAL REVIEW JOURNAL
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CODE 7206R

AUTH LATIFF S.A.
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CODE 1017A

AUTH LAU Y.L., KIRCHHEFER S.A.
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PUBL HYDRAULICS DIVISION INLAND WATERS DIRECTORATE, DEC. 1974, REPORT NO. EPS-3-EC-74-3
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KEYW ONE-DIMENSIONAL FLOWS, CONTINUITY AND MOMENTUM, THICKNESS
CODE 7142F

AUTH LAWLER G.C., WEN-AN L.
TITL ACCUMULATION OF SATURATED HYDROCARBONS IN TISSUES OF PETROLEUM-EXPOSED MALLARD DUCKS (ANASPLATYRHYNCHUS)
PUBL ENVIRONMENTAL SCIENCE & TECHNOLOGY, VOLUME 12, JANUARY 1978
ABST MALLARD DRAKES WERE DOSED WITH 5 ML A DAY OF SOUTH LOUISIANA CRUDE OIL FOR 14 DAYS. TISSUES FROM CONTROL AND EXPERIMENTAL DUCKS WERE THEN EXAMINED FOR PETROLEUM HYDROCARBONS BY COMBINED HIGH-RESOLUTION GAS CHROMATOGRAPHY AND MASS SPECTROMETRY.
KEYW MALLARD DUCKS, PETROLEUM HYDROCARBONS, GAS CHROMATOGRAPHY, MASS SPECTROMETRY
CODE 7707 F

AUTH LAWLER G.C., WEN-AN L., LASETER J.L.
TITL ACCUMULATION OF AROMATIC HYDROCARBONS IN TISSUES OF PETROLEUM EXPOSED MALLARD DUCKS (ANAS PLATYRHYNCHUS)

PUBL ENVIRONMENTAL SCIENCE & TECHNOLOGY VOLUME 12 JANUARY 1976
ABST MALLARD DRAKES WERE DOSED WITH 5 ML A DAY OF SOUTH LOUISIANA CRUDE OIL FOR FOURTEEN DAYS. TISSUES FROM CONTROL AND OIL DOSED DUCKS WERE EXAMINED FOR AROMATIC PETROLEUM HYDROCARBONS BY COMBINED HIGH-RESOLUTION GAS CHROMATOGRAPHY AND MASS SPECTROMETRY.
CODE 7708 F

AUTH LE BLANC L.
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PUBL DEPT. OF OCEAN EGR. URI
CODE 2004R

AUTH LEARY J.F.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2196, MAY 5-8, 1975
ABST THIS PAPER DISCUSSES THE DEVELOPMENT OF A RECOVERY SYSTEM FOR ROUGH WATER ENVIRONMENT. SPECIFIES FAST RESPONSE AND RECOVERY RATE.
KEYW RECOVERY, FREE VORTEX, WEIR-BASIN, DISC-DRUM
CODE 0822F

AUTH LEE C.Y., MASCH F.
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PUBL FEDERAL WATER POLLUTION CONTROL ADMINISTRATION, GRANT 5 R01 WP 00705-03, JULY 1965
ABST THIS REPORT INVOLVES A LAB. STUDY OF THE MACRO-SCALE TURBULENCE ASSOCIATED WITH WIND GENERATED WATER WAVES AND WHITE CAP CONDITIONS. THE PURPOSE OF THE INVESTIGATION IS TO EXPLORE THE NATURE OF WIND WAVE INDUCED TURBULENCE IN ORDER TO OBTAIN A BETTER UNDERSTANDING OF ITS ROLE IN THE MIXING AND DISPERSING PROCESS.
CODE 2925R

AUTH LEE R.F.
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PUBL SKIDAWAY INSTITUTE OF OCEANOGRAPHY, FOR EPA 1975 CONFERENCE
KEYW FATE, HYDROCARBONS, MARINE ZOOPLANKTON
CODE 0147R

AUTH LEE R.F., GARDNER W.S.
TITL FATE OF POLYCYCLIC AROMATIC HYDROCARBONS IN CONTROLLED ECOSYSTEM ENCLOSURES
PUBL ENVIRONMENTAL SCIENCE & TECHNOLOGY VOLUME 12, NUMBER 7, JULY 1976
ABST PRUDHOE CRUDE OIL ENRICHED WITH A NUMBER OF POLYCYCLIC AROMATIC HYDROCARBONS WAS ADDED AS A DISPERSION TO A CONTROLLED ECOSYSTEM ENCLOSURE SUSPENDED IN SAANICH INLET, CANADA. CONCENTRATIONS OF VARIOUS AROMATICS WERE DETERMINED IN WATER, ZOOPLANKTON, OYSTERS AND BOTTOM SEDIMENTS. THIS PAPER SUMMARIZES AN EXPERIMENTAL STUDY OF THE FATE OF A NUMBER OF POLYCYCLIC AROMATIC HYDROCARBONS OF INCREASING MOLECULAR WEIGHT IN A CONTROLLED ECOSYSTEM.
KEYW POLYCYCLIC HYDROCARBONS, CONCENTRATIONS, BIOLOGICAL DEGRADATION
CODE 7710 F

AUTH LEE R.F., SAUERHEBER R., DOBBS G.H.
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AUTH LEE W.Y.
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PUBL A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN CHEMISTRY, URI 1976
ABST THIS PAPER DISCUSSES THE IMPORTANCE OF THE QUANTITATIVE AND QUALITATIVE MEASUREMENTS OF HYDROCARBON CONTENTS IN THE MARINE ENVIRONMENT BECAUSE OF THEIR PERSISTENCE IN THE POSSIBLE TOXICITY TO ALL AQUATIC ORGANISMS.
KEYW INFRARED SPECTROSCOPY, GAS CHROMATOGRAPHY, THIN-LAYER CHROMATOGRAPHY
CODE 6076B

AUTH LEENDERTSE J.J.
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PUBL USAF PROJECT RAND, REPORT NO. RM-3368-PR, JAN. 1963
ABST THIS STUDY ANALYZES THE RESPONSE OF A MOORED VESSEL
KEYW HYDRODYNAMICS, WAVE MOTION, MOORING LINES
CODE 0522F

AUTH LEHR W.E.
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CODE 0426F

AUTH LEHR W.E., SCHERER J.
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PUBL UNKNOWN
ABST THE GENERAL REQUIREMENTS FOR HIGH SEAS OIL SPILL CLEANUP EQUIPMENT ARE DETAILED.
KEYW CLEANUP, HIGH SEAS BOOM DEVELOPMENT, RETENTION
CODE 0837F

AUTH LEIBOVICH S.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2158, MAY 5-8, 1975
ABST THE THEORETICAL PERFORMANCE OF OIL SPILL CONTROL EQUIPMENT IS CONSIDERED.
KEYW CONTROL, SKIMMERS, CONTAINMENT BOOMS
CODE 5128F

AUTH LEIBOVICH S.
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PUBL OCEAN ENGINEERING, VOL. 3, 1975
ABST A SIMPLE STATISTICAL MODEL IS DEVELOPED TO INVESTIGATE THE EFFECT OF TURBULENCE IN REMOVING OIL FROM THE SEA SURFACE.
KEYW VERTICAL TURBULENT TRANSPORT, OIL SPILL CONTAINMENT, CLEANUP
CODE 5111F

AUTH LEIBOVICH S.
TITL OIL SLICK INSTABILITY AND THE ENTRAINMENT FAILURE OF OIL CONTAINMENT BOOMS
PUBL ASME, MAY 1975, PRESENTED AT THE FLUIDS ENGINEERING CONFERENCE
ABST EXPERIMENTAL EVIDENCE SHOWING OIL SLICK INSTABILITY AND ENTRAINMENT FAILURE IS PRESENTED.
KEYW BARRIERS AND BOOMS, ENTRAINMENT FAILURE, STABILITY FOR OIL SLICK
CODE 0820

AUTH LEIGH J.T.
TITL OIL RECOVERY ON THE HIGH SEAS
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST TWO PROTOTYPE OIL RECOVERY SYSTEMS CURRENTLY UNDER CONSTRUCTION ARE DESCRIBED IN THIS PAPER.
KEYW RECOVERY, ROTATING DISC-DRUM, WAVE CONFORMING WEIRBASIN
CODE 0537F

AUTH LEMEHAUTE B.
TITL AN INTRODUCTION TO HYDRODYNAMICS AND WATER WAVES
PUBL SPRINGER-VERLAG, 1976
ABST A TEXT FOR A COURSE IN BASIC HYDRODYNAMICS, AS WELL AS A COURSE IN THE FUNDAMENTALS OF HYDRAULIC AND RELATED ENGINEERING DISCIPLINES.
KEYW HYDRODYNAMICS, WATER WAVES THEORETICAL HYDRAULICS
CODE 3510G

AUTH LEONARD R.L.
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PUBL PRESENTED AT THE WINTER ASME ANNUAL MEETING, HOUSTON, TX, NOV. 30 - DEC. 4, 1975
ABST THE PURPOSE OF THIS PAPER IS TO REPORT ON A TECHNOLOGY ASSESSMENT AND IMPLEMENTATION OF ITS RECOMMENDATIONS.
KEYW TECHNOLOGY ASSESSMENT, OIL AND GAS OPERATIONS, OUTER CONTINENTAL SHELF
CODE 2674F

AUTH LEOTTA J., WALLACE W.A.
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PUBL MARINE ENVIRONMENTAL PROTECTION DIVISION, USCG, FOR EPA 1975 CONFERENCE
KEYW INCIDENT REPORTING SYSTEM, PROGRAM MANAGEMENT, USCG
CODE 0094R

AUTH LEPPAKOSKI E.J., LINDSTROM L.S.
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PUBL JOURNAL OF THE FISHERIES, VOL. 33, NO. 5, MAY 1976
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KEYW MACROBENTHOS, POLLUTION ABATEMENT, RECOLONIZATION, SEDIMENT BIOTESTS
CODE 2669F

AUTH LESHT B.J., WHITE K.V., MILLER R.L.
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PUBL US DEPT. OF COMMERCE, PB 265 277
ABST THIS REPORT DESCRIBES THE DESIGNS TO MONITOR SEVERAL ASPECTS OF THE NEAR BOTTOM ENVIRONMENT.
CODE 7156R

AUTH LEVANTINE C.D.
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PUBL APRIL 1974, AD 784 106
CODE 0224R

AUTH LEWIS E.V.
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AUTH LEWIS J.B.
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PUBL MAR. POLLUTION BULL.
CODE 1045F

AUTH LIANG L.S.
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CODE 2030H

AUTH LICHATOWICH J.A., O KEEFE P., STRAND J., TEMPLETON W.
TITL DEVELOPMENT OF METHODOLOGY AND APPARATUS FOR THE BIOASSAY OF OIL
PUBL ECOLOGICAL EFFECTS
ABST THIS PAPER SUMMARIZES TECHNIQUES THAT MAY BE APPLIED IN THE BIOASSAY OF OIL AND OTHER NON-MISCIBLE MATERIALS.
KEYW BIOASSAY, TOXICITY, METERED INFLOW, NON-MISCIBLE MATERIALS
CODE 0563F

AUTH LIEBERMAN M.
TITL OIL POLLUTION SOURCE IDENTIFICATION
PUBL CONTRACT 61-00-01-0056, EDISON WATER QUALITY RESEARCH LAB., FEB. 1973
ABST A STUDY WAS CONDUCTED TO EVALUATE AND DEVELOP A METHOD FOR THE IDENTIFICATION OF SOURCES OF OIL POLLUTION. THE METHOD IS BASED ON THE COMPARISON OF CERTAIN STABLE CHEMICAL INDICES PRESENT IN UNWEATHERED SUSPECT OIL POLLUTION SOURCES AND THE WEATHERED POLLUTION SAMPLE.
CODE 0073R

AUTH LIN J.T., GAD-EL-HAK M., HSIEH T.L.
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PUBL PRESENTED AT SEMINAR AT NEWPORT, RI FEB. 1 + 2, 1978, FLOW RESEARCH CO.
ABST A STUDY TO CONDUCT EXPERIMENTS CONCERNING TURBULENT DISPERSION OF OIL SLICKS
KEYW TURBULENT DISPERSION, WIND-WAVES, PHOTODIODE WAVE GAUGE
CODE 2658F

AUTH LIN J.T., GAD-EL-HAK M., HSIEH-TA L.
TITL A STUDY TO CONDUCT EXPERIMENTS CONCERNING TURBULENT DISPERSION OF OIL SLICKS
PUBL FLOW RESEARCH CO.
ABST LABORATORY EXPERIMENTS WERE CONDUCTED IN A WIND-WAVE TANK TO STUDY THE TURBULENT CHARACTERISTICS IN THE WATER BOUNDARY-LAYERS UNDER THE ACTION OF WIND AND WAVES AND TO STUDY THE OIL DISPERSION CHARACTERISTICS UNDER THE ACTION OF BREAKING WAVES.
KEYW WIND-WAVE, TURBULENCE, DISPERSION, BREAKING WAVES
CODE 2656AF

AUTH LINDEN O.
TITL ACUTE EFFECTS OF OIL AND OIL/DISPERSANT MIXTURE ON LARVAE OF BALTIC HERRING
PUBL SWEDISH WATER AND AIR POLLUTION LAB (IVL), AMBIO, VOL.4 NO. 3, 1975
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KEYW DISPERSANTS, BIOLOGICAL IMPACT, HERRING
CODE 2128F

AUTH LINDENMUTH W.T.
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PUBL HYDRONAUTICS, INC., LAUREL, MD., JAN. 1970, REPORT NO. 948-1(1)
ABST A THEORETICAL ANALYSIS OF THE LOADS AND MOTIONS OF A CONTINUOUS, ELASTIC OIL RETENTION BOOM OF ARBITRARY CONFIGURATION IS PRESENTED.
KEYW PHYSICAL PROPERTIES, HYDRODYNAMIC PROPERTIES, MOORING CONDITIONS, ENVIRONMENTAL CONDITIONS
CODE 0544F

AUTH LINDENMUTH W.T.
TITL FINAL REPORT - DEVELOPMENT OF A NOVEL HIGH VELOCITY OIL SLICK SKIMMER
PUBL USCG, NO. TR-7411-1, CONTRACT NO. DOT-CG-41058A.
CODE 0377R

AUTH LINDENMUTH W.T., MILLER E.R., HSU C.C.
TITL FINAL REPORT STUDIES OF OIL RETENTION BOOM HYDRODYNAMICS
PUBL USCG, OFFICE OF RESEARCH AND DEVELOPMENT REPORT NO. 714102/A/008, DEC. 1970
ABST RESULTS OF AN EXPERIMENTAL INVESTIGATION OF OIL CONTAINMENT ARE PRESENTED WITH THEORETICAL ANALYSIS TO HELP THE EXPERIMENTAL FINDINGS.
KEYW CONTAINMENT, OIL BOOMS, HYDRODYNAMICS
CODE 0835F

AUTH LINDENMUTH W.T., SUNDARAM T., SINNARWALLA A.
TITL FINAL REPORT FAST CURRENT OIL RESPONSE SYSTEM STAGE I SYALS DEVELOPMENT
PUBL DEPT OF TRANSPORTATION, USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT NO. TR7501-1, MARCH 1975
ABST DISCUSSES STUDIES OF OIL SKIMMER DESIGNED TO RECOVER THIN OIL SLICKS IN HIGH RELATIVE CURRENTS.
KEYW BOOMS, SKIMMERS, CONTROL

CODE 0672F

AUTH LINDENMUTH, SCHERER, VAN DYKE
TITL NO. 4 - NO. 13
PUBL HYDRONAUTICS INC.
ABST GRAPHS INCLUDING OIL BOOM MODEL TEST DRAG, DRAG COEFFICIENT VERSUS BLOCKAGE RATION, DRAG COEFFICIENT VERSUS RELATIVE OIL DEPTH.
CODE 0024H

AUTH LISSAUER I.
TITL A TECHNIQUE FOR PREDICTING THE MOVEMENT OF OIL SPILLS IN NEW YORK HARBOR
PUBL DEPT. OF TRANSPORTATION, USCG.
ABST THROUGH EXPERIMENTS WHICH WERE CONDUCTED IT IS APPARENT THAT THE MAJOR FACTORS INVOLVED IN THE TRANSPORT OF AN OIL SLICK IN NEW YORK BAY ARE WINDS, TIDES AND FRESH WATER FLOW FROM THE HUDSON RIVER.
KEYW WINDS, TIDES, FLOWS, TRANSPORT OF AN OIL SLICK
CODE 25754 H

AUTH LISSAUER I., BACON J.
TITL FINAL REPORT, PREDICTED OIL SLICK MOVEMENT FROM VARIOUS LOCATIONS OFF THE NEW JERSEY - DELAWARE COASTLINE
PUBL USCG, DEPT. OF TRANSPORTATION, CGR-DC 13/75, JUNE 1975
ABST AVERAGE MONTHLY WIND SPEEDS AND DIRECTIONS AND MONTHLY CURRENT PATTERNS WERE USED FOR PREDICTING THE OIL SLICK MOVEMENT. PROBABLE AREAS OF IMPACT ALONG THE SHORELINE WERE INDICATED.
KEYW OIL SLICK MOVEMENT, PREDICTING MOVEMENT, CURRENT PATTERNS
CODE 2549F

AUTH LISSAUER I.M.
TITL FINAL REPORT, A TECHNIQUE FOR PREDICTING THE MOVEMENT OF OIL SPILLS IN NEW YORK HARBOR
PUBL USCG, DEPT. OF TRANSPORTATION, CG-D-6-75, FEB. 1974
ABST THIS PAPER DISCUSSES THE MAJOR FACTORS INVOLVED IN THE TRANSPORT OF AN OIL SLICK.
KEYW OIL TRANSPORT, SPILL FORECASTING, SPILL BOUNDARIES
CODE 2581F

AUTH LISSAUER I.M., WELSH J.P.
TITL FINAL REPORT, PRELIMINARY PROJECTIONS OF OIL SPILL MOVEMENT FOR THREE POTENTIAL DEEP WATER PORT SITES IN THE GULF OF MEXICO
PUBL USCG, DEPT. OF TRANSPORTATION, CGR AND DC 34/75, DEC. 1975
ABST PROJECTIONS OF THE MOVEMENT OF OIL SLICKS AND THEIR IMPACT LOCATION ALONG THE SHORELINES OF TEXAS, LOUISIANA, MISSISSIPPI, ALABAMA AND FLORIDA WERE DETERMINED FROM THREE POTENTIAL DEEP WATER PORT SITES. AVERAGE MONTHLY WIND SPEEDS, DIRECTIONS AND CURRENT PATTERNS WERE USED IN PREDICTING OIL SLICK MOVEMENT.
KEYW OIL SLICK MOVEMENT, PREDICTING, DEEPWATER PORTS, WIND DRIFT
CODE 2547F

AUTH LIU D.L., DUTKA B.J.
TITL BIOLOGICAL OXIDATION OF HYDROCARBONS AQUEOUS PHASE
PUBL JOURNAL WPCF, VOL. 45, NO. 2, FEB. 1973
CODE 1100R

AUTH LODER T.C.
TITL AUTOANALYZER METHODOLOGY AND ITS ROLE IN ESTUARINE AND OCEANIC ECOSYSTEM MODELING
PUBL UNIVERSITY OF NEW HAMPSHIRE, DURHAM 03824 DEPARTMENT OF EARTH SCIENCES 6TH TECHNICON INTERNATIONAL SYMPOSIUM ON ENVIRONMENTAL CHANGES AND BIOLOGICAL RESPONSE, TOKYO JAPAN 1976
ABST THE AUTOANALYZER PROVIDES THE MEANS FOR ANALYZING THE LARGE NUMBER OF SAMPLES REQUIRED IN MODELING RESEARCH. SPECIAL PRECAUTIONS MUST BE UTILIZED IN THE ANALYSIS OF THESE WATERS, DUE TO VARIABLE CHEMICAL NATURE AFFECTING THE ACCURACY OF THE ANALYSES. METHODS FOR DETERMINING THESE CORRECTIONS WITHOUT USING ARTIFICIAL SEA WATER ARE PRESENTED
KEYW ESTUARIES, NUTRIENTS, MODELS, OCEANOGRAPHIC DATA.
CODE 7704 F

AUTH LOFTAS T.
TITL THE UNSEEN DANGERS OF OIL
PUBL NEW SCIENTIST AND SCIENCE JOURNAL, 49(737):228, FEB. 40 1971
CODE 1110R

AUTH LOGAN J.W.K.
TITL OIL DISPERSANT TOXICITY
PUBL MARINE POLLUTION BULL. 4(6):90-93
CODE 1078F

AUTH LOGAN W., THORTON D., ROSS D.L.
TITL OIL SPILL COUNTERMEASURES FOR THE SOUTHERN BEAUFORT SEA: APPENDIX
PUBL BEAUFORT SEA PROJECT, TECH. REPORT NO. 31B, DEPT. OF THE ENVIRONMENT
ABST THIS REPORT DISCUSSES THE FEASIBILITIES OF CONTROLLING AND CLEANING UP AN OIL SPILL IN THE BEAUFORT SEA AS A RESULT OF AN EXPLORATORY WELL BLOWOUT.

KEYW BLOWOUT, CONTROL, CLEANUP
CODE 7144P

AUTH LOGAN W.J.
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PUBL CONTROL OF SPILL TECHNOLOGY, EPA, CONFERENCE 1975
ABST PAPER INCLUDES: THE BEAUFORT SEA PROJECT, OIL IN ICE STUDIES, COUNTERMEASURE STUDIES, AND PROGRESS MADE UP UNTIL DEC. 1974.
KEYW BEAUFORT SEA, OIL IN ICE, COUNTERMEASURES, PROGRESS
CODE 0104A

AUTH LOGAN W.J., THORNTON D.E., ROSS S.L.
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PUBL BEAUFORT SEA TECHNICAL REPORT NO. 31A
ABST THIS REPORT DISCUSSES THE FEASIBILITIES OF CONTROLLING AND CLEANING UP AN OIL SPILL IN THE BEAUFORT SEA AS A RESULT OF AN EXPLORATORY WELL BLOW-OUT.
KEYW BLOWOUT,CONTROL,CLEANUP
CODE 7147P

AUTH LONGUET-HIGGINS M.S.
TITL MASS TRANSPORT IN THE BOUNDARY LAYER AT A FREE OSCILLATING SURFACE
PUBL NATIONAL INSTITUTE OF OCEANOGRAPHY, NOV. 1955
ABST THIS PAPER DESCRIBES CAREFUL EXPERIMENTS WHICH CONFIRM THE HIGHER VALUE OF THE GRADIENT.
KEYW BOUNDARY LAYER, MASS-TRANSPORT GRADIENT, IRROTATIONAL THEORY, OSCILLATORY BOUNDARY LAYER
CODE 5112P

AUTH LOU T.
TITL A STUDY OF THE EFFECTS OF RAINDROPS ON OIL FILMS
PUBL SUBMITTED BY THOMAS LOU AS A PARTIAL FULFILLMENT OF OCE 592
ABST SPECIAL PROBLEM STUDY OF OIL/WATER MIXING PROCESS.
KEYW RAINDROP, OIL/WATER MIXING, INTERFACE PENETRATION
CODE 6315P

AUTH LOUCKS R.H.
TITL DISPERSION OF SPILLED OIL
PUBL FISHERIES RESOURCE BOARD OF CANADA, TECH. REPORT NO. 426, 1974
CODE 2034R

AUTH LOUCKS R.H., LAWRENCE D.J., INGRAHAM D.V.
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PUBL APPLIED STATISTICS, PROCEEDINGS OF THE CONFERENCE AT DALHOUSIE UNIV., HALIFAX, MAY 2-4, 1974
ABST THE PURPOSE OF THIS NOTE IS TO DESCRIBE A BORROWED TECHNIQUE FOR ESTIMATING PLUME DISPERSION FROM OCEAN CURRENT METER TIME SERIES DATA.
KEYW PLUME DISPERSION, OCEAN CURRENT METER, RANGE ANALYSIS
CODE 7415P

AUTH LU B.C., POLAK J.
TITL A STUDY OF THE SOLUBILITY OF OIL IN WATER
PUBL TECHNOLOGY DEVELOPMENT REPORT, NO. EPS-4-EC-76-1, ENVIRONMENTAL CONSERVATION DIRECTORATE, FEB. 1976
ABST EXPERIMENTS WERE CONDUCTED TO DETERMINE THE TOTAL SOLUBILITY OF OIL IN WATER. THREE OILS WERE EMPLOYED: NO. 2 FUEL OIL, MEDIUM BUNKER FUEL AND WESTERN CRUDE.
KEYW DISPERSION, HYDROCARBONS, SOLUBILITY
CODE 7140P

AUTH LUKENS H.R.
TITL OIL SLICK IDENTIFICATION
PUBL PREPARED BY GULF RADIATION TECH., CONTRACT NO. AT(04-3)-167
ABST INSTRUCTION MANUAL FOR OIL SLICK IDENTIFICATION BY TRACE ELEMENTS PATTERNS MEASURED WITH NEUTRON ACTIVATION ANALYSIS.
CODE 0004A

AUTH LUTHY R., AUBERT C., SELLECK E., GALLOWAY T.R.
TITL SURFACE PROPERTIES OF PETROLEUM REFINERY WASTE OIL EMULSIONS
PUBL UNKNOWN
ABST THE SURFACE PROPERTIES OF OIL DROPLETS IN REFINERY WASTEWATER WERE FOUND TO BE DETERMINED LARGELY BY WATER QUALITY RATHER THAN BY SOURCE OF OIL.
KEYW SURFACE PROPERTIES, OIL DROPLETS, REFINERY WASTEWATER,, WATER QUALITY
CODE 7662P

AUTH LYNCH P.F.
TITL THE WEATHERING AND SUBSEQUENT SOURCE IDENTIFICATIONS OF OIL SPILLS USING INFRARED SPECTROSCOPY
PUBL URI, 1973
ABST THIS MASTERS THESIS DISCUSSES HOW INFRARED SPECTROSCOPY ALONG WITH THE USE OF A COMPUTER PROGRAM PROVIDES A MEANS OF CATALOGING KNOWN PETROLEUM SAMPLES AND HAS MADE IT POSSIBLE TO MATCH AN OIL SPILL TO ITS SOURCE UP TO 30 DAYS AFTER THE ORIGINAL SPILL.
CODE 3083R

AUTH LYNCH P.F., BRADY H.R.
TITL COMPUTERIZED INFRARED SPECTROSCOPY AS A SEPARATION TECHNIQUE-ANALYSIS OF COMPLEX ORGANIC MIXTURES EXTRACTED FROM WATER
PUBL URI, DEPT. OF CHEMISTRY
ABST A METHOD FOR DETERMINATION OF CORRECT INSTRUMENTAL CONDITIONS FOR COLLECTION OF ACCURATE DISPERSIVE INFRARED DATA HAS BEEN OUTLINED AND SUCCESSFULLY USED ON SEVERAL COMPLEX ORGANIC MIXTURES.
KEYW INSTRUMENTAL CONDITIONS, DISPERSIVE INFRARED DATA, COMPLEX ORGANIC MIXTURES
CODE 7668P

AUTH LYSYJ I., RUSSELL E.C.
TITL DISSOLUTION OF PETROLEUM DERIVED PRODUCTS IN WATER
PUBL WATER RESEARCH, VOL. , 1974
CODE 2080P

AUTH LYTLE J.S.
TITL FATE AND EFFECTS OF CRUDE OIL ON AN ESTUARINE POND
PUBL GULF COAST RESEARCH LAB. FOR EPA 1975 CONFERENCE
KEYW FATE AND EFFECTS, CRUDE OIL, ESTUARINE POND
CODE 0153P

AUTH MACINTYRE W.G., SMITH C.L., MUNDAY J.C., GIBSON V.M., LAKE J.L.
TITL INVESTIGATION OF SURFACE FILMS - CHESAPEAKE BAY AREA
PUBL EPA - TECHNOLOGY SERIES REPORT, EPA 670/2-73-099
CODE 0303P

AUTH MACKAY D., LEINONEN P.J.
TITL MATHEMATICAL MODEL OF THE BEHAVIOR OF OIL SPILLS ON WATER WITH NATURAL AND CHEMICAL DISPERSION
PUBL FISHERIES AND ENVIRONMENT - CANADA, EPS 3-EC-77-19, OCT. 1977
ABST A MATHEMATICAL MODEL OF THE BEHAVIOR OF AN OIL SPILL ON WATER HAS BEEN ASSEMBLED AND SOLVED ON A DIGITAL COMPUTER TO YIELD DATA ON THE OIL SLICK SIZE, THICKNESS, PROPERTIES, AND COMPOSITION, ON THE AMOUNTS OF OIL EVAPORATED, DISSOLVED AND DISPERSED; AND ON THE CONCENTRATION HISTORY OF THE HYDROCARBONS DISSOLVED IN THE WATER COLUMN.
KEYW MATHEMATICAL MODEL, DIGITAL COMPUTER, SIZE, THICKNESS, PROPERTIES, COMPOSITION
CODE 7630P

AUTH MACKAY D., WOLKOFF A.W.
TITL RATE OF EVAPORATION OF LOW SOLUBILITY CONTAMINANTS FROM WATER BODIES TO ATMOSPHERE
PUBL ENVIRONMENTAL SCIENCE AND TECH. VOL 7, 1973
CODE 2082P

AUTH MACKAY G.D.
TITL STABILITY OF BUNKER C SEAWATER EMULSION
PUBL DEPT. OF CHEM. ENG., NOVA SCOTIA TECH. COLLEGE, 1970
CODE 2083P

AUTH MACKIE A.M.
TITL AVOIDANCE REACTIONS OF MARINE INVERTEBRATES TO EITHER STEROID GLYCOSIDES OF STARFISH OR SYNTHETIC SURFACE-ACTIVE AGENT.
PUBL J.EXP. MAR. BIOL. ECOL., 5:63-69, 1970
CODE 2014P

AUTH MACKIE P.R., HARDY R., WHITTLE K.J.
TITL PRELIMINARY ASSESSMENT OF THE PRESENCE OF OIL IN THE ECOSYSTEM AT EKOFISK AFTER THE BLOW OUT APRIL 22-30, 1977
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST THE MARINE ENVIRONMENT IN THE EKOFISK AREA WAS ASSAYED FOR THE PRESENCE OF OIL COMPONENTS AFTER THE BLOWOUT ON PLATFORM BRAVO WAS BROUGHT UNDER CONTROL. SEVERAL METHODS OF ASSAY WERE USED BUT THE RESULTS WERE NOT ALWAYS STRICTLY COMPARABLE.
KEYW EKOFISK, SURFACE FILM, SEDIMENT
CODE 2069P

AUTH MADSEN O.S.
TITL A REALISTIC MODEL OF THE WIND-INDUCED EKMAN BOUNDARY LAYER
PUBL REPRINTED FROM JOURNAL OF PHYSICAL OCEANOGRAPHY, MARCH 1977
ABST A PHYSICALLY REALISTIC AND GENERAL MODEL FOR THE VERTICAL EDDY VISCOSITY IN A HOMOGENEOUS FLUID IS PROPOSED. THE APPLICATION OF THE MODEL TO FINITE DEPTH CONDITIONS, INCLUDING THE EFFECTS OF SLOPE CURRENTS, IS OUTLINED.
KEYW VISCOSITY, EKMAN BOUNDARY
CODE 7760P

AUTH MAGY E.
TITL EVAPORATION OF OIL FROM SLICKS
PUBL PROC. OF A CONF. ON OIL AND THE CANADIAN ENVIRONMENT, UNIV. OF TORONTO, MAY 1973
CODE 2085R

AUTH MAINVILLE C.R.
TITL STATE-OF THE ART REVIEW OF OIL CONTAINMENT BARRIERS FOR USE AT OFFSHORE TERMINALS
PUBL REPORT MARC-272-23100-R1, US NAT. MARITIME RES. CENTER
CODE 0735R

AUTH MAJEWSKI J.J., OBRIEN E.B., REYNOLDS H.
TITL KINETIC STUDY OF A FUEL OIL UNDERGOING PHOTOCHEMICAL WEATHERING

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PUBL  ENVIRONMENTAL LETTERS
KEYW  KINETIC STUDY, PHOTOCHEMICAL WEATHERING
CODE  0301R

AUTH  MALINS D.C.
TITL  EFFECTS OF PETROLEUM ON ARCTIC AND SUBARCTIC
      MARINE ENVIRONMENT AND ORGANISMS VOLUME 1 NATURE
      AND FATE OF PETROLEUM
PUBL  ACADEMIC PRESS INC.
ABST  VOLUME 1 DEALS WITH THE NATURE AND FATE OF
      PETROLEUM IN THE MARINE ENVIRONMENT.  THE
      DISCUSSIONS ARE DIRECTED TOWARD RESEARCH WORKERS,
      ENVIRONMENTALISTS, ETC. CONCERNED WITH THE MANY
      ASPECTS OF PETROLEUM POLLUTION OF MARINE WATERS.
KEYW  ARCTIC , SUBARCTIC, HYDROCARBONS
CODE  7162 B

AUTH  MALINS D.C.(EDITED BY)
TITL  EFFECTS OF PETROLEUM ON ARCTIC AND SUBARCTIC
      MARINE ENVIRONMENT AND ORGANISMS  PART II:
      BIOLOGICAL EFFECTS
PUBL  ACADEMIC PRESS
ABST  IN THIS VOLUME AN ATTEMPT IS MADE TO COMPILE DATA,
      EVALUATE THE IMPLICATIONS TO POSSIBLE ALTERATIONS
      IN ORGANISMS AND ECOSYSTEMS AND OFFER SUGGESTIONS
      FOR FUTURE WORK WHERE SIGNIFICANT GAPS IN
      KNOWLEDGE EXIST.
KEYW  ARCTIC, SUBARCTIC, HYDROCARBONS
CODE  7163 B

AUTH  MANN K.K., CLARK R.B.
TITL  LONG TERM EFFECTS OF OIL SPILLS ON MARINE
      INTERTIDAL COMMUNITIES
PUBL  JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST  THIS PAPER DISCUSSES THE RESULTS OF STUDIES OF
      LONG TERM EFFECTS OF OIL SPILLS ON THE MARINE
      INTERTIDAL COMMUNITIES.
KEYW  HYDROCARBONS, FOOD WEBS, LONG-LIVED CONTAMINANTS,
      RECOVERY
CODE  2669F

AUTH  MANSER J.B.
TITL  HEAVY DUTY OIL CONTAINMENT SYSTEM PNEUMATIC
      BARRIER SYSTEM
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. 714102/A/004
CODE  0751R

AUTH  MARASCHINO M.J., TREYBAL R.E.
TITL  THE COALESCENCE OF DROPS IN LIQUID-LIQUID
      FLUIDIZED BEDS
PUBL  AICHE JOURNAL VOL. 17, NO. 5, SEPT 1971
ABST  THE COALESCENCE RATES OF EQUISIZED DROPS OF
      ORGANIC LIQUIDS FLUIDIZED BY WATER UNDER
      CONDITIONS OF MUTUAL SATURATION WERE STUDIED.
KEYW  COALESCENCE, FLUIDIZED, SATURATION
CODE  5076F

AUTH  MARCH F.
TITL  "DYNAMIC REEL" OIL CONTAINMENT
PUBL  PHYSICAL REMOVAL
ABST  RESULTS OF ANALYTICAL STUDIES AND MODELING TESTING
      ARE PRESENTED IN THIS PAPER.
KEYW  DYNAMIC REEL, BARRIERS, CONTAINMENT
CODE  0805F

AUTH  MARCH F.A.
TITL  A PHYSICAL BARRIER TO CONTAIN SPILLED HAZARDOUS
      MATERIALS IN WATER COURSES
PUBL  OCEAN SYSTEMS INC., FOR USEPA, NO. 68-01-0103,
      SSIE NO. 6B4-951-1
CODE  0438P

AUTH  MARCH F.A., BEACH R.
TITL  TESTING OF A HIGH SEAS OIL RECOVERY SYSTEM
PUBL  OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1750,
      APR. 29 - MAY 2, 1973
ABST  A SYSTEM FOR RECOVERY OF PETROLEUM PRODUCTS FROM
      ACCIDENTAL OFFSHORE SPILLS HAS BEEN DEVELOPED AND
      TESTED.
KEYW  RECOVERY, HIGH EFFICIENCIES, RECOVERY RATE
CODE  9122F

AUTH  MARCH F.A., BEACH R.L.
TITL  HIGH SEAS OIL RECOVERY SYSTEM
PUBL  CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST  A REPORT ON THE SYSTEM OF RECOVERY OF PETROLEUM
      PRODUCTS FROM ACCIDENTAL OFFSHORE SPILLS HAS BEEN
      DEVELOPED AND TESTED.
KEYW  CLEANUP, RECOVERY, CONTAINMENT
CODE  0545F

AUTH  MARINSKY D.
TITL  DIFFERENTIAL VISCOSITY OIL FILTER
PUBL  URI DEPT. OF MECHANICAL ENGINEERING
ABST  A STUDY TO OBTAIN DATA ON THE SEPARATION OF AN OIL
      AND WATER EMULSION BY MEANS OF FILTRATION ALSO
      INCLUDED IS REPORT AND ARTICLE TITLED
      "DETERMINATION OF VOLATILE AND NONVOLATILE OILY
      MATERIAL, INFRARED SPECTROMETRIC METHOD."
KEYW  DIFFERENTIAL VISCOSITY OIL FILTER, SEPARATION,
      FILTRATION
CODE  0063R

AUTH  MARK H., MATTSON J., KOLPACK R., YU T.C.
TITL  INFRARED ESTIMATION OF OIL CONTENT IN SEDIMENTS IN
      PRESENCE OF BIOLOGICAL MATTER
PUBL  ENVIRONMENTAL SCIENCE AND TECHNOLOGY, VOL. 6,
      SEPT. 1972
ABST  THE CRUDE OIL CONTENT OF MARINE SEDIMENTS WAS
      DETERMINED BY IR SPECTROMETRY FROM THE MAGNITUDE
      OF 2925 CM -1 ABSORBANCE, CALCULATIONS MADE OF OIL
      CONTENT IN THE PRESENCE OF BIOLOGICAL MATERIALS.
KEYW  OIL CONTENT, DETERMINATION, INTERNAL REFLECTANCE
      SPECTROMETRY
CODE  2638F

AUTH  MARKEL A., BIANCHI R.A.
TITL  PERFORMANCE TESTING OF PROTOTYPE SYSTEMS AND
      DEVICES DEVELOPED TO REMOVE AND SEPARATE SPILLED
      OIL
PUBL  REYNOLDS INTERNATIONAL FRO API, SSIE NO. PAP-73
CODE  0446A

AUTH  MARKS W., GEISS G., HIRSHMAN J.
TITL  THEORETICAL AND EXPERIMENTAL EVALUATION OF OIL
      SPILL CONTROL DEVICES
PUBL  PHYSICAL REMOVAL
ABST  THIS PAPER DESCRIBES THE FIRST PHASE OF A PROGRAM
      AIMED AT PROVIDING A MEANS FOR EVALUATION OF
      EXISTING OIL CONTAINMENT DEVICES AND FOR IMPROVING
      BASIC DESIGN.
KEYW  CONTAINMENT, BOOMS, BARRIERS
CODE  0812F

AUTH  MARTIN E.J., GUNTZ G.D.
TITL  STATE OF MD. WASTE OIL RECOVERY AND REUSE PROG.
PUBL  EPA 670/2-74-013, & PB 229801
CODE  2034N

AUTH  MARX W.
TITL  OIL SPILL
PUBL  SIERRA CLUB, SAN FRANCISCO, 1971
ABST  AN ECOLOGICAL VIEWPOINT OF THE HAZARDS OF COASTAL
      REFINERIES, SPILL, OIL, AND THE VULNERABILITY OF
      SUPERTANKERS.
CODE  6022N

AUTH  MATTSON J.S.
TITL  EXCHANGE OF COMMENTS: SYSTEMS CHEMICAL ANALYSIS OF
      PETROLEUM POLLUTANTS
PUBL  ANALYTICAL CHEMISTRY, VOL. 48, NO. 12, NOV. 1976
ABST  THIS PAPER DISCUSSES OIL IDENTIFICATION.
KEYW  IDENTIFICATION, SYSTEMS CHEMICAL ANALYSIS,
      PRECISION
CODE  1290F

AUTH  MATTSON J.S., KOLPACK R., MARK H., SCHUTT C.
TITL  A RAPID NON-DESTRUCTIVE TECHNIQUE FOR INFRARED
      IDENTIFICATION OF CRUDE OILS BY INTERNAL
      REFLECTION SPECTROMETRY
PUBL  AMERICAN CHEMICAL SOCIETY
ABST  A REPORT OF AN INVESTIGATION INTO THE EFFECTS OF
      AN OIL BLOW OUT ON THE COAST OF THE SANTA BARBARA
      CHANNEL.
KEYW  INTERNAL REFLECTION SPECTROSCOPIC TECHNIQUE,
      IDENTIFICATION, DIFFERENTIATION
CODE  2636F

AUTH  MAURER A., EDGERTON A.T.
TITL  FLIGHT EVALUATION OF US COAST GUARD AIRBORNE OIL
      SURVEILLANCE SYSTEM
PUBL  MTS JOURNAL VOL. 10, NO. 4, MAY 1976
ABST  A PROTOTYPE AIRBORNE OIL SURVEILLANCE SYSTEM WAS
      DEVELOPED FOR THE US COAST GUARD BY AEROJET
      ELECTROSYSTEMS CO. THE MULTISENSOR SYSTEM PERMITS
      REAL-TIME, DAY-NIGHT, ALL-WEATHER DETECTION,
      MAPPING, AND DOCUMENTATION OF OIL SPILLS AT SEA.
KEYW  SURVEILLANCE, MULTISENSOR SYSTEM, DETECTION
CODE  9124F

AUTH  MAURER D.
TITL  ENVIRONMENTAL VULNERABILITY OF THE DELAWARE BAY
      AREA TO DEEPWATER PORTS
PUBL  UNKNOWN
ABST  THE PURPOSE OF THIS PAPER IS TO BRIEFLY OUTLINE
      PROBABLE ENVIRONMENTAL EFFECTS AND PROBLEMS
      INVOLVED IN RATING AND COMPARING ENVIRONMENTAL
      VULNERABILITY.
KEYW  DEEPWATER PORTS, ENVIRONMENTAL VULNERABILITY,
      HYPOTHETICAL SCENARIO
CODE  7201F

AUTH  MAURER D.
TITL  OFFSHORE TERMINAL OPERATION IMPACT
PUBL  UNIV. OF DELAWARE, SCHOOL OF MARINE SCIENCE, SSIE
      NO. GBP-1113
CODE  0470R

AUTH  MAYER E.
TITL  THEORY OF LIQUID ATOMIZATION IN HIGH VELOCITY GAS
      STREAMS
PUBL  ARS JOURNAL, DEC. 1961
ABST  LIQUID ATOMIZATION BY HIGH VELOCITY GAS STREAMS IS
      INVESTIGATED ANALYTICALLY BY CONSIDERATION OF GAS
      LIQUIDS INTERFACE BEHAVIOR IN THE REGIME OF
      CAPILLARY WAVE (RIPPLE) PROPAGATION.
KEYW  LIQUID ATOMIZATION, HIGH VELOCITY GAS STREAMS,
      CAPILLARY WAVE
CODE  2574F

AUTH  MAYER J.F.
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TITL PLANNING FOR MINIMUM OIL SPILL RISK: ESTERO BAY OFFSHORE TERMINAL AND PIPELINE
PUBL STANDARD OIL CO OF CAL. FOR EPA 1975 CONFERENCE
KEYW RISK, ESTERO BAY, TERMINALS, PIPELINE
CODE 0109P

AUTH MAYO D.W., PAGE D.S., COOLEY J., SORENSON E., BRADLEY F., GILFILLAN E.S., HANSON S.A.
TITL WEATHERING CHARACTERISTICS OF PETROLEUM HYDROCARBONS DEPOSITED IN FINE CLAY MARINE SEDIMENTS, SEARSPORT, MAINE
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST THIS PAPER REPORTS THE ANALYSIS OF COLLECTED SEDIMENT SAMPLES IN WHICH IT WAS POSSIBLE TO MAKE A COMPARISON WITH HYDROCARBON DATA COLLECTED IN THE EARLIER INVESTIGATION. IN ADDITION, AN ASSESSMENT OF THE CURRENT STATE OF RECOVERY OF LONG COVE FROM 1971 OIL SPILL IS CONSIDERED.
KEYW GAS CHROMATOGRAPHY, WEATHERING, CLAY SEDIMENTS
CODE 2669F

AUTH MAZEWSKI C.E., KROOP R.H.
TITL AVIATION FUEL SPILL CONTAINMENT USING ABSORBENT MATERIALS
PUBL AFWL-TR-9, AD 776767
CODE 2011P

AUTH MCANIFF J.J., BROWN G.A.
TITL OCEAN BOTTOM ENVIRONMENTAL PARAMETERS FOR DEEP OCEAN SYSTEMS DESIGN, VOL. III - LITERATURE SURVEY INDEX
PUBL URI, DEPT. OF OCEAN ENGINEERING, TECH. REPORT NO. 4004-3, APRIL 1970
ABST THE LITERATURE SURVEY SUMMARIZED IN THIS VOLUME WAS CONDUCTED AS PART OF AN INVESTIGATION TO DEFINE RECOMMENDATIONS FOR DEEP-OCEAN OCEANOGRAPHIC RESEARCH.
KEYW DEEP OCEAN SYSTEMS, STATE OF THE ART KNOWLEDGE, RESEARCH
CODE 6187F

AUTH MCAULIFFE C.
TITL DETERMINATION OF C 1 - C 10 HYDROCARBONS IN WATER
PUBL MARINE POLLUTION MONITORING, PROCEEDINGS OF A SYMPOSIUM AND WORKSHOP, MAY 13-17, 1974
ABST THE METHOD REPORTED HERE IS BASED ON THE SUCCESSIVE GAS CHROMATOGRAPHIC ANALYSIS AFTER REPEATED EQUILIBRATION OF A HYDROCARBON-FREE GAS WITH AN AQUEOUS SAMPLE CONTAINING DISSOLVED HYDROCARBONS. ALL CLASSES OF HYDROCARBONS HAVING UP TO 11 CARBON ATOMS IN THE MOLECULE CAN BE DETERMINED.
KEYW GAS CHROMATOGRAPH, AQUEOUS SAMPLE, BIODEGRADATION
CODE 2627F

AUTH MCAULIFFE C.
TITL DETERMINATION OF DISSOLVED HYDROCARBONS IN SUBSURFACE BRINES
PUBL CHEMICAL GEOLOGY, VOL. 4, 1969
ABST THE CONCENTRATION AND DISTRIBUTIONS OF HYDROCARBONS DISSOLVED IN SURFACE BRINE HAS BEEN STUDIED WITH THE OBJECTIVE OF DETERMINING IF THE HYDROCARBONS CONTENT OF THE SAMPLED BRINE CAN BE USED TO DETERMINE IF AN EXPLORATORY WELL IS CLOSE TO PETRO ACCUMULATION AND TO PROVIDE INFO TO HELP ANSWER QUESTIONS CONCERNING ORIGIN, MIGRATION AND ACCUMULATION OF PETROLEUM.
KEYW PETROLEUM ACCUMULATION, ORIGIN OF PETROLEUM, MIGRATION OF PETROLEUM
CODE 2630F

AUTH MCAULIFFE C.
TITL EVAPORATION AND SOLUTION OF C 2 TO C 10 HYDROCARBONS FROM CRUDE OIL ON THE SEA SURFACE
PUBL CHEVRON OIL FIELD RESEARCH CO.
ABST EXPERIMENTAL DATA ARE PRESENTED ON THE EVAPORATION AND SOLUTION OF LOW MOLECULAR-WEIGHT HYDROCARBONS FROM FOUR OCEAN SPILLS OF TWO DIFFERENT CRUDE OILS.
KEYW TOXICITY, CONCENTRATION AND EXPOSURE, EVAPORATION
CODE 2634F

AUTH MCAULIFFE C.
TITL GC DETERMINATION OF SOLUTES BY MULTIPLE PHASE EQUILIBRIUM
PUBL CHEMICAL TECHNOLOGY, VOL. 1, JAN. 1971
ABST MULTIPLE PHASE EQUILIBRATION IS EXEMPLIFIED BY THE ANALYSIS OF HYDROCARBONS DISSOLVED IN WATER.
KEYW MULTIPLE PHASE EQUILIBRIUM, DISTRIBUTION COEFFICIENTS, VAPOR PRESSURE
CODE 2629F

AUTH MCAULIFFE C.
TITL OIL-IN-WATER EMULSIONS AND THEIR FLOW PROPERTIES IN POROUS MEDIA
PUBL JOURNAL OF PETROLEUM TECHNOLOGY, JUNE 1973
ABST THE LABORATORY STUDIES DESCRIBED HERE IN DETAIL WERE CONDUCTED TO ASCERTAIN THE PROPERTIES OF OIL-WATER EMULSIONS AND TO DETERMINE IF SUCH EMULSIONS COULD ACT AS A SELECTIVE PLUGGING AGENT TO IMPROVE OIL RECOVERY IN WATERFLOODS.
KEYW OIL IN WATER EMULSIONS, SELECTIVE PLUGGING AGENT, RECOVERY
CODE 2628F

AUTH MCAULIFFE C.
TITL SOLUBILITY IN WATER OF NORMAL C 9 AND C 10 ALKANE HYDROCARBONS
PUBL SCIENCE 158:478
CODE 5059P

AUTH MCAULIFFE C.
TITL SOLUBILITY IN WATER OF NORMAL C 9 AND C 10 ALKANE HYDROCARBONS
PUBL SCIENCE, VOL. 158, JAN. 31, 1969
ABST A NEW METHOD FOR EQUILIBRATING WATER CONTAINING ALKANE HYDROCARBONS WITH GAS PHASE AND ANALYZING THE GAS FOR CHROMATOGRAPHY EXTENDS ANALYTICAL SENSITIVITY TO BETTER THAN 0.1 PART PER BILLION.
KEYW EQUILIBRATING WATER, GAS PHASE, GAS CHROMATOGRAPHY
CODE 2631P

AUTH MCAULIFFE C.
TITL SOLUBILITY IN WATER OF PARAFFIN CYCLOPARAFFIN AND AROMATIC HYDROCARBONS
PUBL JOURNAL OF PHYSICAL CHEMISTRY VOL. 70: 1966
CODE 2081P

AUTH MCAULIFFE C.
TITL SOLUBILITY IN WATER OF PARAFFIN, CYCLOPARAFFIN, OLEFIN, ACETYLENE, CYCLOOLEFIN AND AROMATIC HYDROCARBONS
PUBL JOURNAL OF PHYSICAL CHEMISTRY, VOL. 70, NO. 4, APRIL 1966
CODE 2632F

AUTH MCAULIFFE C.
TITL SOLUBILITY IN WATER OF PARAFFIN, CYCLOPARAFFIN, OLEFIN, ACETYLENE, CYCLOOLEFIN, AND AROMATIC HYDROCARBONS
PUBL JOURNAL OF PHYSICAL CHEMISTRY 70, 1267 REPRINT 1966
ABST THE SOLUBILITIES IN WATER AT ROOM TEMPERATURE OF 65 HYDROCARBONS HAVE BEEN MEASURED USING A GAS-LIQUID PARTITION CHROMATOGRAPHIC TECHNIQUE. FOR EACH HOMOLOGOUS SERIES OF HYDROCARBONS, THE LOGARITHM OF THE SOLUBILITY IN WATER IS A LINEAR FUNCTION OF THE HYDROCARBON MOLAR VOLUME. BRANCHING INCREASES WATER SOLUBILITY FOR PARAFFIN, OLEFIN AND ACETYLENE HYDROCARBONS.
KEYW HYDROCARBONS, VAPOR PRESSURE, SOLUBILITY
CODE 2637F

AUTH MCAULIFFE C., PALMER L.L.
TITL ENVIRONMENTAL ASPECTS OF OFFSHORE DISPOSAL OF DRILLING FLUIDS AND CUTTINGS
PUBL SOCIETY OF PETROLEUM ENGINEERS OF AIME, SPE 5864, APR. 5-6, 1976
ABST LAB. STUDIES USING VARIOUS ORGANISMS SHOW THESE MATERIALS TO GENERALLY BE RELATIVELY NONTOXIC. THIS INDICATES THAT OFFSHORE DISCHARGE IS AN ENVIRONMENTALLY ACCEPTABLE METHOD FOR DISPOSAL OF DRILLING WASTES.
KEYW DRILLING FLUID DISCHARGE, ENVIRONMENTAL EFFECTS, DISPOSAL OF DRILLING WASTE
CODE 2621F

AUTH MCAULIFFE C.D.
TITL DISPERSAL AND ALTERATION OF OIL DISCHARGED ON A WATER SURFACE
PUBL CHEVRON OIL FIELD RESEARCH CO.
ABST THE MOVEMENT AND ALTERATION OF OIL DISCHARGED ONTO A WATER SURFACE ARE DISCUSSED IN RELATION TO ENVIRONMENTAL EFFECTS, INCLUDING ARCTIC AND SUBARCTIC CONDITIONS. TECHNIQUES TO MINIMIZE POSSIBLE ADVERSE EFFECTS FROM OIL SPILLS ARE PROPOSED ALONG WITH SUGGESTED RESEARCH NEEDS.
KEYW SPREADING AND MOVEMENT, EVAPORATION, EMULSIFICATION
CODE 2622F

AUTH MCAULIFFE C.D.
TITL ENVIRONMENTAL ASPECTS OF OCS PETROLEUM DEVELOPMENT
PUBL GREATER LOS ANGELES AREA ENERGY SYMPOSIUM, "ENERGY L.A.: TACKLING THE CRISIS", MAY 15, 1976
ABST ENVIRONMENTAL ASPECTS OF THE DISCHARGE OF DRILLING FLUIDS AND CUTTINGS, AND OF THE PRODUCED WATER FROM COASTAL AND OFFSHORE OIL AND GAS EXPLORATION AND PRODUCTION WELLS ARE DISCUSSED. THESE DISCHARGES ARE REVIEWED AND PLACED IN PERSPECTIVE WITH OTHER DISCHARGE SOURCES. COSTS FOR ALTERNATE DISPOSAL OF DRILLING AND PRODUCTION DISCHARGES ARE CONSIDERED AND FOUND TO BE VERY EXPENSIVE AND ENVIRONMENTALLY UNNECESSARY.
KEYW ENVIRONMENTAL ASPECTS, DISCHARGES, EXPLORATION
CODE 2624F

AUTH MCAULIFFE C.D.
TITL SURVEILLANCE OF THE MARINE ENVIRONMENT FOR HYDROCARBONS
PUBL MARINE SCIENCE COMMUNICATIONS VOL. 2, NO. 1, 1976
ABST THIS PAPER REVIEWS AND EVALUATES THE MEASURED CONCENTRATIONS AND AMOUNTS OF HYDROCARBONS NOW IN MARINE WATERS AND SEDIMENTS, AND COMPARES THESE CONCENTRATIONS AND AMOUNTS WITH HYDROCARBON INPUTS. THE MECHANISMS THAT DESTROY HYDROCARBONS ARE DISCUSSED. AN ESTIMATE OF HYDROCARBON DISTRIBUTION IS GIVEN FOR THE NORTH ATLANTIC OCEAN.
KEYW SURVEILLANCE, CONCENTRATIONS, WATER AND SEDIMENTS
CODE 2625F

AUTH MCAULIFFE C.D., SMALLEY A.E., GROOVER R.D. JONES G.F.
TITL CHEVRON MAIN PASS BLOCK 41 OIL SPILL: CHEMICAL AND BIOLOGICAL INVESTIGATION
PUBL PROCEEDINGS OF THE JOINT CONFERENCE ON PREVENTION AND CONTROL OF OIL SPILLS SAN FRANCISCO, 1975
ABST DURING A THREE WEEK PERIOD IN 1970 AN ESTIMATED 65,000 BARRELS OF 353 API GRAVITY CRUDE OIL WERE DISCHARGED FROM THE CHEVRON MAIN PASS BLOCK 41 C PLATFORM, 11 MILES EAST OF THE MISSISSIPPI RIVER DELTA. TWO THOUSAND BARRELS OF CHEMICAL DISPERSANTS WERE SPRAYED ON THE PLATFORM AND SURROUNDING WATER SURFACE.
KEYW CHEMICAL AND BIOLOGICAL STUDIES, DISPERSANTS, DISCHARGE
CODE 2626F

AUTH MCCAIN B.B., HODGINS H.O., GRONLUND W.D., HAWKES J.W., BROWN D.W., MYERS M.S., VANDERMEULEN J.H.
TITL BIOAVAILABILITY OF CRUDE OIL FROM EXPERIMENTALLY OILED SEDIMENTS TO ENGLISH SOLE (PAROPHRYS VETULUS) AND PATHOLOGICAL CONSEQUENCES
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST ENGLISH SOLE WERE EXPOSED TO EXPERIMENTALLY OILED SEDIMENTS OVER A 4 MONTH PERIOD TO ASSESS THE BIOAVAILABILITY AND TISSUE HYDROCARBON DISTRIBUTION KINETICS IN FLATFISH.
KEYW FLATFISH, BIOAVAILABILITY, PATHOLOGY, AROMATIC HYDROCARBONS, BOTTOM SEDIMENTS, DEPURATION
CODE 2669F

AUTH MCCARTHY J.A., WILDER I., DORRLER J.S.
TITL STANDARD DISPERSANT EFFECTIVENESS AND TOXICITY TESTS
PUBL ENVIRONMENTAL PROTECTION TECHNOLOGY SERIES, EPA-R2-73-201, MAY 1973
ABST A BRIEF HISTORY OF THE DEVELOPMENT OF THE STANDARD EPA DISPERSANT EFFECTIVENESS AND TOXICITY TEST IS OUTLINED. THE STANDARD TESTS ARE PRESENTED AND DISCUSSED. AN ANALYSIS OF VARIANCE IS PERFORMED ON THE DATA DEVELOPED BY THREE INDEPENDENT LABORATORIES IN ORDER TO DETERMINE THE REPRODUCIBILITY OF TEST PROCEDURES.
KEYW DISPERSANTS, TOXICITY, TESTING
CODE 2599F

AUTH MCCARTHY L.T.JR., LINDBLOM G.P., WALTER H.F.
TITL CHEMICAL DISPERSANT FOR THE CONTROL OF OIL SPILLS
PUBL ASTM STP 659
ABST SYMPOSIUM WAS HELD AT WILLIAMSBURG, VA., OCT.4-5, 1977. PAPERS PRESENTED ADDRESS TECHNOLOGICAL NATURE, LABORATORY EFFECTIVENESS TOXICITY TESTING CONSIDERATIONS AND GENERAL NATURE OF DISPERSANT ISSUE.
KEYW DISPERSANTS, CRUDE OIL, TOXICITY TESTING, SAUTER MEAN DROP DIAMETER, MIXING ENERGY
CODE 7723F

AUTH MCCORMACK A., FOURNIER W., KNIGHT W.
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PUBL TEXAS INSTRUMENTS FEB. 1974
ABST THE OIL ON WATER SENSOR SYSTEM DETECTS THE PRESENCE OF OIL ON WATER BY EMITTING A WIDEBAND IR PULSE AND RECEIVING REFLECTIONS AT 2 NARROW SPECTRAL BANDS.
CODE 6136F

AUTH MCCOWN D.L., HARRISON W., ORVOSH W.
TITL WATER RESOURCES RESEARCH PROGRAM, TRANSPORT AND DISPERSION OF OIL REFINERY WASTES IN THE COASTAL WATERS OF SOUTHWESTERN LAKE MICHIGAN
PUBL ENERGY AND ENVIRONMENTAL SYSTEMS DIVISION, ANL/ES 76-4, W-31-109-ENG-38, JULY 1976
ABST THIS REPORT IS THE FIRST OF A SERIES THAT WILL BE DEVOTED TO THE TRANSPORT AND DISPERSION OF OILY WATERS DISCHARGED INTO THE COASTAL WATERS OF S.W. LAKE MICHIGAN.
KEYW DISCHARGE, SURFACE PLUME, DISPERSION, TRANSPORT
CODE 6353F

AUTH MCCOWN D.L., SAUNDERS K.D., ALLENDER J.H., DITMARS J.D., HARRISON W.
TITL TRANSPORT OF OILY POLLUTANTS IN THE COASTAL WATERS OF LAKE MICHIGAN: AN APPLICATION OF RARE EARTH TRACERS
PUBL ARGONNE NATIONAL LABORATORY, ENERGY AND ENVIRONMENTAL SYSTEMS DIVISION
ABST A METHOD WAS DEVELOPED FOR TAGGING OILY WASTE WITH DYSPROSIUM AND THE ASSOCIATED FRESH WATER WITH SAMARIUM. THE METHOD WAS APPLIED IN TWO FIELD EXPERIMENTS THAT INVOLVED TRACING OILY WASTES AND POLLUTED WATER FROM THE INDIANA HARBOR CANAL (INC) INTO LAKE MICHIGAN
KEYW RARE EARTH ELEMENTS NEUTRON ACTIVATION ANALYSIS DYSPROSIUM, SAMARIUM, OILY WASTE, OIL TRACING, WATER TRACING
CODE 7717 F

AUTH MCCRACKEN W.E.
TITL HYDRODYNAMICS OF DIVERSIONARY BOOMS
PUBL MASON AND HANGER-SILAS MASON CO., INC.
ABST THE FAILURE OF BOOMS TO CONTAIN FLOATING OIL ON CURRENTS ABOVE 0.5 M/S APPEARS TO BE WELL ESTABLISHED. A METHOD SUGGESTED TO SURMOUNT THIS LIMITATION OF CURRENTS WHERE CONTAINMENT AND REMOVAL CAN BE ACCOMPLISHED. THIS REPORT DESCRIBES FULL SCALE TESTING OF THE FLOW FIELD AROUND A COMMERCIAL OIL BOOM. THE METHODS, RESULTS, AND TECHNIQUES DESCRIBED ARE OF INTEREST TO THOSE INTERESTED IN SPECIFYING, USING OR TESTING SUCH EQUIPMENT.
KEYW FLOW FIELD, OIL SPILL BOOM, ENTRAINMENT
CODE 7720F

AUTH MCDERMOTT J.
TITL LIQUIFIED NATURAL GAS TECHNOLOGY
PUBL CHEMICAL TECHNOLOGY REVIEW NO. 10, NOYES DATA CORP, PARK RIDGE, NJ, 1973
ABST THIS BOOK SUPPLIES DETAILED CHEMICAL INFORMATION AND CAN BE USED AS A GUIDE TO THE US PATENT LITERATURE IN THIS FIELD.
KEYW LNG TECHNOLOGY, CHEMICAL INFORMATION, PATENT INFORMATION
CODE 4015E

AUTH MCGOLDRICK L.F.
TITL WAVE MEASUREMENT SYSTEMS
PUBL THE JOHN HOPKINS GRAVITOHYDRODYNAMICS LAB. REPORT NO. 1 SEPT. 1965
ABST THIS REPORT DESCRIBES TWO DIFFERENT LINEAR TYPES OF SYSTEMS FOR MEASURING SURFACE WAVES. ONE IS BEST SUITED FOR LAB WORK, THE OTHER, FIELD WORK.
CODE 6042F

AUTH MCKAY W.C.
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PUBL GOVERNMENT REPORTS ANNOUNCEMENTS 73(10):121
CODE 1076F

AUTH MCKAY W.C.
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CODE 0624P

AUTH MCKINNEY A.W., DIXON A.L., JORDON R.L.
TITL METHODS FOR ELIMINATION OF OIL SLICKS
PUBL OFFICIAL GAZETTE OF US PATENT OFFICE, VOL. 927, NO. 4, OCT. 22, 1974
ABST REMOVAL OF OILS BY FREEZE-DRYING (1) MICROORGANISMS ALONG WITH NUTRIENTS, (2) MICROORGANISMS WITHIN A CARRIER MATERIAL (3) MICROORGANISMS WITHIN A CARRIER ALONG WITH NUTRIENTS.
CODE 3127P

AUTH MCLEAN A.Y.
TITL THE BEHAVIOR OF OIL SPILLED IN A COLD WATER ENVIRONMENT
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1522, MAY 1-3, 1972
ABST THIS PAPER DEALS WITH THE WAY IN WHICH OIL BEHAVES WHEN IT INTERACTS WITH THE COLD ENVIRONMENT AND THE EFFECT OF THESE INTERACTIONS ON THE EFFECTIVENESS OF CLEANUP TECHNIQUES.
KEYW CLEANUP, ENVIRONMENTAL IMPACT, RECOVERY
CODE 3579F

AUTH MCLEAN A.Y., BETANCOURT O.J.
TITL PHYSICAL AND CHEMICAL CHANGES IN SPILLED OIL WEATHERING UNDER NATURAL CONDITIONS
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1748, APR. 29-MAY 2, 1973
ABST THIS PAPER DISCUSSES THE STUDY OF LONG TERM BEHAVIOR OF SPILLED OIL WEATHERING UNDER NATURAL CONDITIONS.
KEYW ENVIRONMENTAL IMPACT, DIFFUSION, EVAPORATION, BIODEGRADATION
CODE 0853F

AUTH MCLEAN A.Y., ODEDRA D.A.
TITL THE PROPERTIES OF SABLE ISLAND CRUDE OIL IN RELATION TO ITS BEHAVIOR IN THE EVENT OF A SPILL AT SEA
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1981, MAY 6-8, 1974
ABST DISCUSSION OF RELATIONSHIP OF PROPERTIES OF OIL TO THE FOLLOWING PROCESSES:OXIDATION, EVAPORATION, EMULSIFICATION, DISPERSION, SOLUTION
KEYW OXIDATION, EVAPORATION, EMULSIFICATION, DISPERSION, SOLUTION
CODE 0858F

AUTH MCLEOD W.R., MCLEOD D.L.
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KEYW RECOVERY, CLEANUP, CONTINGENCY
CODE 0583F

AUTH MCMINNS D.A., CONNELL D.W.
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AUTH MCMINN T.J.
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ABST THIS PAPER DISCUSSES THE RESEARCH PROGRAM INITIATED TO DETERMINE THE FATE AND BEHAVIOR OF CRUDE OIL DISCHARGES IN AN ARCTIC ENVIRONMENT.
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CODE 0578F

AUTH MCMINN T.J., GOLDEN P.
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PUBL USCG, 1973 JOINT CONFERENCE
KEYW BEHAVIORAL CHARACTERISTICS, CLEANUP, NORTH SLOPE CRUDE OIL, ARCTIC ENVIRONMENT
CODE 0295F

AUTH MCNEELEY B.H.
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AUTH MCNEIL C.S.L., ENG P.
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PUBL THE MICROBIAL DEGRADATION OF OIL POLLUTANTS CENTER FOR WETLAND RESOURCES, LSU-SG-73-01, 1973
ABST A REPORT OF WEATHERED OILS COLLECTED FROM SOUTHERN CALIFORNIA BEACHES.
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CODE 2637F

AUTH MEI C.
TITL RESONANT SCATTERING BY A HARBOR WITH TWO COUPLED BASINS
PUBL JOURNAL OF ENGINEERING MATH., VOL. 10, 1976
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KEYW RECTANGULAR BASINS, SCATTERING THEORY, WAVES
CODE 7600M

AUTH MEIJS F.M., JONGBLOOD L.J., TYDEMA, H.J.
TITL NEW METHODS FOR COMBATTING OIL SLICKS
PUBL EXPLORATION AND PRODUCTION LAB ROYAL DUTCH SHELL, THE NETHERLANDS, 1969 JOINT CONFERENCE.
KEYW COMBATTING, METHODS
CODE 0263R

AUTH MELLOR G.L., YAMADA T.
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PUBL JOURNAL OF THE ATMOSPHERIC SCIENCES, VOL. 31, OCT. 1974
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CODE 1214F

AUTH MELVIN P., EHRENSPECK H.
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ABST EIGHTH QUARTERLY COMPILATION OF SUMMARIES OF OIL SPILL EVENTS, CURRENT RESEARCH PROJECTS, LITERATURE CITATIONS, PATENTS.
KEYW REPORTS, PUBLICATIONS, PATENTS, RESEARCH PROJECT CONFERENCES
CODE 7005B

AUTH MENSING A.
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CODE 6050R

AUTH MENSING A.E., STOEFFLER R.C., DAVIDSON W.R., HOOVER T.E.
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PUBL UNITED AIRCRAFT RESEARCH LAB., CONTRACT NO. DOT-CG-00566-A, NOV. 1970
ABST STUDIES WERE MADE TO DETERMINE THE SIZE AND WEIGHTS OF COMPONENTS FOR FULL SIZE VORTEX SEPARATORS.
KEYW CLEANUP, VORTEX FLOWS, VORTEX SEPARATORS, SKIMMERS
CODE 8030F

AUTH MERTENS E.W.
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PUBL PRESENTED BEFORE THE U.S. DEPT. OF INTERIOR, BUREAU OF LAND MANAGEMENT HEARING, FEB. 6-8, 1975
ABST STATEMENT BY THE AUTHOR IN REGARD TO THE PROPOSED INCREASE IN ACREAGE TO BE OFFERED FOR OIL AND GAS LEASING ON THE OUTER CONTINENTAL SHELF.
KEYW ENVIRONMENTAL PROBLEMS, CONTAMINATION, LEASING
CODE 2910F

AUTH MERTENS E.W., GOULD J.R.
TITL THE EFFECTS OF OIL ON MARINE LIFE: AN OVERVIEW OF RESEARCH SPONSORED BY THE AMERICAN PETROLEUM INSTITUTE
PUBL CHEVRON RESEARCH CO.
ABST THIS PAPER IS CONCERNED ONLY WITH THOSE STUDIES RELATING TO THE HEART OF THE OVERALL PROBLEM OF OIL SPILLS - THE EFFECTS OF OIL ON MARINE LIFE.
KEYW MARINE LIFE, EFFECTS, STUDIES
CODE 7677F

AUTH MEYNELL P.J.
TITL A HYDROBIOLOGICAL SURVEY OF A SMALL SPANISH RIVER/ GROSSLY POLLUTED BY OIL REFINERY AND PETROCHEMICAL WORKS
PUBL FRESHWATER BIOLOGY, 3(4)503-52-, 1973
CODE 1357P

AUTH MEYS F.M.
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PUBL 1969 JOINT CONFERENCE
CODE 2114R

AUTH MICHAEL A.D.
TITL THE EFFECTS OF PETROLEUM ON MARINE POPULATION AND COMMUNITIES
PUBL UNKNOWN
ABST THIS PAPER DISCUSSES THE EFFECTS OF OIL AS THEY CONCERN ORGANISMS IN THEIR NATURAL SURROUNDINGS. FIELD STUDIES OF COMMUNITIES AND POPULATIONS.
KEYW LIVING ORGANISMS, RECOVERY, MARINE COMMUNITIES
CODE 7132F

AUTH MICHAEL A.D., VAN RAALT C.R., BROWN L.S.
TITL LONG-TERM EFFECTS OF AN OIL SPILL AT WEST FALMOUTH, MASS.
PUBL MARINE BIOLOGICAL LAB., WOODS HOLE, MASS. FOR EPA 1975 CONFERENCE
ABST PAPER INCLUDES: METHODS, HYDROCARBON ANALYSIS, AND BIOLOGICAL EFFECTS AND RESULTS.
KEYW METHODS, LONG-TERM EFFECTS, BIOLOGICAL EFFECTS AND RESULTS
CODE 0150AR

AUTH MIGET R.J., OPPENHEIMER C.H., KATOR H.I., LAROCK P.A.
TITL MICROBIAL DEGRADATION OF NORMAL PARAFFIN HYDROCARBONS IN CRUDE OIL
PUBL IN API/FWPCA CONFERENCE ON PREVENTION AND CONTROL OF OIL SPILLS.API
CODE 5029M

AUTH MIKOLAJ P., ALLEN A.A., SCHLUETER R.S.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO.. 1549, MAY 1-3, 1972
ABST THIS PAPER DISCUSSES THE OIL AND GAS SEEPS BEING INVESTIGATED BY USE OF AERIAL, SURFACE AND UNDERWATER SURVEY TECHNIQUES.
KEYW OCEAN FLOOR CONDITIONS, MODES OF OIL RELEASE, SEEPAGE FLOW RATES
CODE 0648F

AUTH MIKOLAJ P.G.
TITL ENVIRONMENTAL APPLICATIONS OF THE WEIBULL DISTRIBUTION FUNCTION: OIL POLLUTION
PUBL SCIENCE, VOL. 176, JUNE 1972
ABST THE WEIBULL DISTRIBUTION FUNCTION APPEARS TO BE A POWERFUL TOOL FOR THE STATISTICAL ANALYSIS AND INTERPRETATION OF ENVIRONMENTAL POLLUTION DATA. TO ILLUSTRATE ITS POTENTIAL, THE METHOD IS APPLIED TO A VARIETY OF OIL POLLUTION TOPICS. OTHER APPLICATIONS ARE SUGGESTED.
KEYW SAMPLING, CONCENTRATION, ENVIRONMENTAL POLLUTION ANALYSIS, WEIBULL DISTRIBUTION FUNCTION
CODE 2109F

AUTH MILES D.H., COIGN M.J., BROWN L.R.
TITL THE ESTIMATION OF THE AMOUNT OF EMPIRE MIX CRUDE OIL IN MULLET, SHRIMP, AND OYSTERS BY LIQUID CHROMATOGRAPHY
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KEYW EMPIRE MIX CRUDE OIL, MULLET, SHRIMP, OYSTERS, LIQUID CHROMATOGRAPHY
CODE 0087B

AUTH MILGRAM H.J.
TITL COMBINED EFFECTS OF WAVES AND CURRENT ON PERFORMANCE OF OIL BARRIERS, OIL POLLUTION
PUBL MIT FOR USCG, SSIE NO. GZ-12116
CODE 0639B

AUTH MILGRAM J.
TITL BEING PREPARED FOR FUTURE ARGO MERCHANTS
PUBL NATIONAL OCEAN AND ATMOSPHERIC ADMINISTRATION, APR. 1977, MIT SEA GRANT PROGRAM, MITSG 77-10, SG 04-6-158-4408-1
ABST THIS REPORT GIVES POSSIBLE MEANS FOR DEALING WITH SUCH EVENTS AND WITH SIMILAR EVENTS BY CONSIDERING

OPTIMUM EQUIPMENT, PERSONNEL TRAINING AND PLANNING FOR DIMINISHING THE MAGNITUDE OF SUCH DISASTERS AS THE ARGO MERCHANT.
KEYW WATER POLLUTION TREATMENT, TANKERS, ACCIDENTS, ARGO MERCHANT
CODE 7207F

AUTH MILGRAM J., O DEA J.
TITL FINAL REPORT, EVALUATION OF THE STRENGTH AND SAFEKEEPING ABILITY OF POLLUTION CONTROL BARRIERS
PUBL USCG, DEPT. OF TRANSPORTATION REPORT NO. CG-D-55-75, TASK NO. 4102.5.4, SEPT. 1974
ABST THE PURPOSE OF THE WORK DESCRIBED BY THE REPORT IS TO PROVIDE A BASIS FOR THE EVALUATION OF ARBITRARY OIL POLLUTION CONTROL BARRIERS WITHOUT THE NEED FOR FULL SCALE TESTING.
KEYW OIL POLLUTION CONTROL, OIL BARRIERS, BOOMS, CLEANUP
CODE 0813F

AUTH MILGRAM J.H.
TITL FORCES AND MOTIONS OF A FLEXIBLE FLOATING BARRIER
PUBL JOURNAL OF HYDRONAUTICS VOL. 5, NO. 2, APRIL 1971
ABST THE PROBLEMS OF DETERMINING THE MOTIONS, THE STRUCTURAL AND THE HYDRODYNAMIC FORCES ON A FLEXIBLE FLOATING BARRIER ARE CONSIDERED.
CODE 6005P

AUTH MILGRAM J.H.
TITL PHYSICAL REQUIREMENTS FOR OIL POLLUTION CONTROL BARRIERS
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST THIS PAPER REVIEWS THE FULL SCALE TRIALS OF BARRIERS, THEORETICAL STUDIES AND MODEL TESTS.
KEYW CONTROL BARRIERS, CONTAINMENT, STRENGTH AND SAFEKEEPING
CODE 0539F

AUTH MILGRAM J.H.
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PUBL MIT NO. GSI 4434-1
CODE 0347R

AUTH MILGRAM J.H.,
TITL OIL SLICK CONTROL IN OFFSHORE ENVIRONMENTS
PUBL FUNDING PROPOSAL JULY 1, 1975 - JUNE 30, 1977
ABST PROJECT IS DESIGNED TO PROVIDE RELIABLE DATA TO ESTABLISH THE BASIS NECESSARY TO DESIGN EFFECTIVE, EFFICIENT OIL-BOOM BARRIERS FOR CONTAINMENT OF OIL SPILLS AT SEA.
CODE 3073A

AUTH MILGRAM J.H., BRADLEY R.G.
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PUBL J. OF FLUID MECH. VOL. 50, 1971
CODE 2394P

AUTH MILGRAM J.H., HALKYARD J.E.
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PUBL JOURNAL OF SHIP RESEARCH, VOL. 15, NO. 2, JUNE 1971
CODE 0711R

AUTH MILGRAM J.H., VAN HOUTEN R.J.
TITL MECHANICS OF A RESTRAINED LAYER OF FLOATING OIL ABOVE A WATER CURRENT
PUBL J. HYDRONAUTICS, VOL. 12, JULY 3, 1978
ABST THIS PAPER DETERMINES THE RELATIVE IMPORTANCE OF THE INTERFACIAL SHEAR STRESS AND DYNAMIC PRESSURE IN DETERMINING THE THICKNESS DISTRIBUTION OF A LAYER OF FLOATING OIL CONTAINED BY A BARRIER ABOVE A WATER CURRENT. THIS IS DONE BY USE OF AN EQUATION RELATING VERTICAL LOCATION OF THE OIL-WATER INTERFACE, DYNAMIC PRESSURE AND SHEAR STRESS.
KEYW INTERFACIAL SHEAR STRESS, DYNAMIC PRESSURE, THICKNESS DISTRIBUTION
CODE 7683F

AUTH MILLER E., LINDENMUTH W., ALTMANN A.
TITL ANALYSIS OF LIGHTWEIGHT OIL CONTAINMENT SYSTEM SEA TRIALS
PUBL USCG, DEPT. OF TRANSPORTATION, OCT. 1973, REPORT NO. CG-D-72-74, TASK NO. 4132/2
ABST THE RESULTS OF THESE TESTS WITH RESPECT TO OIL CONTAINMENT ARE PRESENTED AND ANALYZED.
KEYW HIGH SEAS CONTAINMENT BARRIER, FIELD TESTING, BOOM, OIL LOSS RATES AND MECHANISMS, TEST INSTRUMENTATION
CODE 0540F

AUTH MILLER E., STEPHENS L. RICKLIS J.
TITL DEVELOPMENT AND PRELIMINARY DESIGN OF SORBENT OIL RECOVERY SYSTEM
PUBL HYDRONAUTICS INC., JAN. 1973
CODE 6080P

AUTH MILLER E.R., LINDENMUTH W.T., LEHR E.W., ABRAHAMS R.N.
TITL EXPERIMENTAL PROCEDURES USED IN THE DEVELOPMENT OF OIL RETENTION BOOM DESIGNS
PUBL MARINE TECHNOLOGY
ABST THE EXPERIMENTAL PROCEDURES USED IN THE DEVELOPMENT OF OIL RETENTION BOOM DESIGN CRITERIA ARE PRESENTED.
KEYW CONTAINMENT, CLEANUP, RECOVERY
CODE 0541F

AUTH MILLER M.C., BACON J.C., LISSAUER I.M.
TITL FINAL REPORT - A COMPUTER SIMULATION TECHNIQUE FOR OIL SPILLS OFF THE NEW JERSEY - DELAWARE COASTLINE
PUBL USCG, DEPT. OF TRANSPORTATION, CGR-DC24/75, SEPT. 1975
ABST PREDICTIONS OF THE MOVEMENT OF OIL SLICKS AND THEIR IMPACT LOCATIONS ALONG THE SHORELINE OF N.J. AND DEL. WERE DETERMINED FOR 2 POTENTIAL DEEP WATER PORTS AND 2 POTENTIAL DRILLING SITES.
KEYW OIL SLICK MOVEMENT, COMPUTER SIMULATION, DEEPWATER PORTS
CODE 2540F

AUTH MILZ E.A., FRASER J.P.
TITL A SURFACE-ACTIVE CHEMICAL SYSTEM FOR CONTROLLING AND RECOVERING SPILLED OIL
PUBL JOURNAL OF PETROLEUM TECHNOLOGY, MAR. 1972
ABST A SYSTEM INVOLVING THE USE OF A SURFACE-TENSION MODIFIER IS FEASIBLE FOR CONTROLLING AND RECOVERING OIL SPILLED ON THE OCEAN IN A WIDE RANGE OF WEATHER CONDITIONS.
KEYW SURFACE-TENSION MODIFIER, DISPERSANTS, CLEAN-UP, RECOVERY
CODE 2135P

AUTH MILZ E.A., FRASER J.P.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE PAPER NO. 1376, APRIL 19-21, 1971
ABST RESEARCH ON THE CONTROL AND RECOVERY OF OIL BY USE OF SURFACE ACTIVE CHEMICALS AND IN-SITU GENERATION OF POLYURETHANE FOAM IS DISCUSSED.
KEYW RECOVERY, SURFACE ACTIVE CHEMICALS, POLYURETHANE FOAM
CODE 0532F

AUTH MILZ, E.A.
TITL EVALUATING OIL SPILL CONTROL EQUIPMENT AND TECHNIQUES
PUBL OCEAN INDUSTRY VOL. 5, NO. 7, JULY 1970
ABST THIS ARTICLE EVALUATES SEVERAL CATEGORIES OF OIL SPILL EQUIPMENT - SKIMMER, BOOMS, AIR BARRIERS, SORBENTS AND GIVES STATISTICS ON PROPERTIES AND EFFECTIVENESS OF THE EQUIPMENT TESTED.
KEYW SORBENTS, SKIMMERS, BOOMS
CODE 3078P

AUTH MINISTRY OF DEFENCE: WORKING PARTY 1973
TITL THE FATE OF OIL SPILT AT SEA
PUBL DEFENCE RESEARCH INFORMATION CENTRE
ABST A REPORT ON THE EFFECTS OF NATURAL FACTORS ON THE MOVEMENT, DISPERSAL AND DESTRUCTION OF OIL AT SEA.
KEYW MOVEMENT DISPERSAL, DESTRUCTION, TORREY CANYON
CODE 2592F

AUTH MITCHELL R.
TITL FOAM PLASTIC BARRIERS FOR STOPPING SPILLS OF HAZARDOUS MATERIAL FROM LEAKING CONTAINERS
PUBL ROCKWELL INTERNATIONAL CORP. FOR USEPA, NO. 68-01-0106, SSIE NO. GHA-96-D-2
CODE 0468P

AUTH MOHN F.
TITL PUMPING APPARATUS FOR SKIMMING AND RECOVERING OIL LAYERS FROM A BODY OF WATER.
PUBL OFFICIAL GAZETTE OF US PATENT OFFICE, VOL. 929, NO. 2, DEC. 17, 1974
ABST DISCUSSES A DISC WHOSE PERIPHERY IS POSITIONED EXACTLY AT THE PLANE OF SEPARATION AND ALLOWS OIL TO FLOW INTO IT.
CODE 3129A

AUTH MONA D.
TITL OIL SPILL SURVEILLANCE SYSTEM STUDY
PUBL EPA CONTRACT 68-01-0150 MAY 1973
CODE 6088A

AUTH MOK Y.I., TREYBAL R.E.
TITL CONTINUOUS - PHASE MASS TRANSFER COEFFICIENTS FOR LIQUID EXTRACTION IN AGITATED VESSELS: II.
PUBL AICHE JOURNAL VOL 17, NO. 4, JULY 1971
ABST FURTHER TESTS TO CONFIRM THE NECESSITY OF THE COALESCENCE TERM, BY MAKING MEASUREMENTS WITH ANOTHER LIQUID-LIQUID SYSTEM.
KEYW CONTINUOUS-PHASE MASS TRANSFER, CONTINUOUS FLOW CONTACT, COALESCENCE
CODE 9073F

AUTH MOMMESSIN P.R., RAJA J.C.
TITL CHEMICAL AND PHYSICAL CHARACTERIZATION OF TAR SAMPLES FROM THE MARINE ENVIRONMENT
PUBL SHELL DEV. CO., FOR EPA 1975 CONFERENCE
ABST A SUMMARY OF A STUDY CONDUCTED TO CHARACTERIZE TAR SAMPLES RECOVERED FROM THE MARINE ENVIRONMENT.
KEYW CHEMICAL AND PHYSICAL CHARACTERIZATION, TAR SAMPLES, MARINE ENVIRONMENT
CODE 8018P

AUTH MOONEY K.A.
TITL A METHOD FOR MANUALLY CALCULATING THE LOCAL WIND CURRENT (UNPUBLISHED MANUSCRIPT)

PUBL U.S. COAST GUARD TECHNICAL REPORT
ABST A METHOD TO MANUALLY CALCULATE THE LOCAL WIND CURRENT IN DEEP WATER IS DEVELOPED. THE METHOD IS BASED ON TIME-DEPENDENT EKMAN DYNAMICS. THE METHOD IS TUNED AND TESTED AGAINST A 2 1/2 MONTH LONG CURRENT AND WIND RECORD IN THE NORTH ATLANTIC.
KEYW WIND CURRENTS, EKMAN, WIND DRIFT
CODE 7727F

AUTH MOORE S., DWYER R.
TITL EFFECTS OF OIL ON MARINE ORGANISMS: A CRITICAL ASSESSMENT OF PUBLISHED DATA
PUBL WATER RESEARCH, VOL. 8, 1974
ABST THIS PAPER DISCUSSES EFFECTS OF OIL ON MARINE ORGANISMS.
KEYW MARINE ENVIRONMENT IMPACT, TOXICITIES, BIOLOGICAL HABITATS
CODE 1295F

AUTH MOORE S., DWYER R., KATZ A.
TITL A PRELIMINARY ASSESSMENT OF THE ENVIRONMENTAL VULNERABILITY OF MACHIAS BAY, MAINE, TO OIL SUPERTANKERS
PUBL M.I.T., DEPT. OF CIVIL ENGINEERING, REPORT NO. 162, JAN. 1973
ABST THIS REPORT DISCUSSES THE PRELIMINARY ASSESSMENT OF THE ENVIRONMENTAL VULNERABILITY OF MACHIAS BAY, MAINE, TO OIL SUPERTANKERS.
KEYW SUPERTANKERS, INDIVIDUAL, POPULATION, COMMUNITY, ECOSYSTEMS
CODE 0834F

AUTH MOORE S.F.
TITL SOME ASPECTS OF DEEPWATER TERMINAL SITE SELECTION IN NORTHERN NEW ENGLAND COASTAL AREAS
PUBL UNKNOWN
ABST THE RESEARCH REPORTED HERE IS PART OF A STUDY IN WHICH THE PRIMARY OBJECTIVE IS TO ASSESS THE ENVIRONMENTAL VULNERABILITY OF THE MACHIAS BAY REGION TO A HYPOTHETICAL SUPERTANKER TERMINAL.
KEYW IMPORTS, TANKERS, DEEPWATER PORTS
CODE 7200F

AUTH MOORE T.
TITL DISPERSANTS OF OIL SLICKS IN PORTS AND AT SEA
PUBL INTERNATIONAL CONFERENCE ON OIL POLLUTION OF THE SEA, OCT. 1968
CODE 5013P

AUTH MORGAN N.L.
TITL A RAPID METHOD OF DETERMINING BUNKER C FUEL OIL IN MARINE ORGANISMS
PUBL BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY VOL. 14, NO. 3.
CODE 5047F

AUTH MUFSON P.J.
TITL THE ARGO MERCHANT OIL SPILL A SCIENTIFIC ASSESSMENT - APRIL 1977
PUBL SCIENCE APPLICATIONS, INC.
ABST THIS REPORT PROVIDES A FINAL ANALYSIS AND EVALUATION OF THE SCIENTIFIC INVESTIGATIONS CONDUCTED BY VARIOUS FEDERAL, STATE AND PRIVATE AGENCIES FOLLOWING THE ARGO MERCHANT OIL SPILL IN DECEMBER 1976. IT DOCUMENTS PHYSICAL, CHEMICAL AND BIOLOGICAL INVESTIGATIONS, AS WELL AS RESEARCH INTO THE SOCIOECONOMIC EFFECTS OF THE SPILL.
KEYW ARGO MERCHANT, OIL SPILL
CODE 7752F

AUTH MOSSTELLER T.L.
TITL PREPARATION OF AN OIL SPILL PREVENTION TRAINING PROGRAM
PUBL CONFERENCE ON THE PREVENTION AND CONTROL OF OIL POLLUTION
ABST THIS PAPER HIGHLIGHTS ITEMS NECESSARY TO DEVELOP A PACKAGE LEARNING PROGRAM ON SPILL PREVENTION.
KEYW PREVENTION, INVOLVEMENT, KNOWLEDGE, TERMINAL OPERATORS
CODE 0815F

AUTH MOSTERT N.
TITL THE AGE OF THE OILBERG
PUBL MAY ISSUE OF ARTICLES.
ABST DISCUSSION OF OIL SPILLS IN HAZARDOUS CONDITIONS.
KEYW TANKER TRANSPORT, SUPERSHIPS, OIL DUMPING
CODE 2708F

AUTH MOULDER D.S., VARLEY A.
TITL A BIBLIOGRAPHY ON MARINE AND ESTUARINE OIL POLLUTION
PUBL MARINE POLLUTION INFORMATION CENTRE, MARINE BIOLOGICAL ASSOCIATION OF THE U.K., JUNE 1975
ABST THIS REPORT IS A SUPPLEMENT TO "A BIBLIOGRAPHY ON MARINE AND ESTUARINE OIL POLLUTION" OF SEPT. 1971.
KEYW BIBLIOGRAPHY, MARINE, ESTUARINE
CODE 4071B

AUTH MUENCH R.
TITL A STUDY OF THE HYDROGRAPHY AND WIND-INDUCED CURRENTS IN EASTERN PRINCE WILLIAM SOUND
PUBL UNIV. OF ALASKA, SSIF NO. 68P-1015
CODE 0440A

AUTH MUNK W.H.
TITL WIND STRESS ON WATER: AN HYPOTHESIS
PUBL SCRIPPS INSTITUTE OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, FEB. 1955.
ABST THIS PAPER DISCUSSES WIND STRESS ON WATER.
KEYW FORM DRAG, WIND SPEED, TWO DIMENSION SPECTRUM
CODE 6599F

AUTH MURPHY J.M.
TITL EFFECTS OF OFFSHORE OIL AND NATURAL GAS DEVELOPMENT ON THE COASTAL ZONE
PUBL LIBRARY OF CONGRESS STUDY, AD HOC SELECT COMMITTEE ON OUTER CONTINENTAL SHELF, HOUSE OF REPRESENTATIVES, MARCH 1976
ABST STUDY ON ONSHORE EFFECTS OF OFFSHORE OIL AND GAS DEVELOPMENT.
KEYW GAS AND OIL RESERVES, ENVIRONMENTAL AND SOCIOECONOMIC EFFECTS, REGULATIONS
CODE 2513F

AUTH MURPHY T.A.
TITL ENVIRONMENTAL EFFECTS OF OIL POLLUTION
PUBL JOURNAL OF THE SANITARY ENGINEERING DIV., ASCE PROCEEDINGS VOL. 97, NO. SA3, PAPER 8221, JUNE 1971
CODE 5011P

AUTH MURPHY T.A., MCCARTHY L.T.
TITL EVALUATION OF THE EFFECTIVENESS OF OIL DISPERSING CHEMICALS
PUBL UNKNOWN
ABST THIS PAPER DISCUSSES THE PROBLEM OF THE EFFECTIVENESS OF OIL DISPERSING CHEMICALS WHICH HAS BEEN DEVELOPED.
KEYW DISPERSANTS, TOXICITY, ENVIRONMENTAL EFFECTS
CODE 2115F

AUTH MURRAY S.P.
TITL OCEANOGRAPHIC OBSERVATION AND THEORETICAL ANALYSIS OF OIL SLICKS DURING THE CHEVRON SPILL
PUBL NTIS
ABST OCEANOGRAPHIC OBSERVATIONS NEAR THE CHEVRON SPILLINGS WELL OFF THE MISSISSIPPI DELTA IN MARCH 1970
KEYW OBSERVATIONS, CHEVRON SPILL, SLICKS
CODE 2579B

AUTH MURRAY S.P.
TITL TURBULENT DIFFUSION OF OIL IN THE OCEAN
PUBL LIMNOL. OCEANOGRAPHY, VOL. 17, 1972
CODE 2043A

AUTH MURRAY S.P.
TITL WIND AND CURRENT EFFECTS ON LARGE-SCALE OIL SLICKS
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2305, MAY 5-8, 1975
ABST THIS PAPER DISCUSSES THE EFFECTS OF LOCAL WINDS AND SURFACE CURRENTS IN DETERMINING MOVEMENT OF OIL SLICKS.
KEYW WINDS AND CURRENTS, WIND SHIFTS, DENSITY FRONTS
CODE 0857F

AUTH MURTY T., KHANDEKAR M.L.
TITL SIMULATION OF MOVEMENT OF OIL SLICKS IN THE STRAIT OF GEORGIA USING SIMPLE ATMOSPHERE AND OCEAN DYNAMICS
PUBL FATE OF OIL
ABST THIS PAPER DISCUSSES THE HYDRODYNAMICAL TECHNIQUES USED TO INVESTIGATE THE MOVEMENT OF OIL SLICKS.
KEYW HYDRODYNAMICS, WIND AND WAVE CURRENT, OIL SLICK MOVEMENT
CODE 0861F

AUTH MURTY T.S.
TITL THE MOVEMENTS OF OIL SLICKS
PUBL RAPP. P. - V. REUN. CONS. INT. EXPLOR. MER, VOL. 167, 1974
CODE 2042P

AUTH MURTY T.S., BARBER F.G.
TITL RIP CURRENT PATTERNS IN OIL SLICKS
PUBL PROCEEDINGS OF THE FIRST CANADIAN SYMP. ON REMOTE SENSING, VOL. 1 FEB. 1972
CODE 2041P

AUTH MURTY T.S., KHANDEKAR M.L.
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PUBL CANADA MARINE SCIENCES DIRECTORATE, MANUSCRIPT REPORT SERIES 32
CODE 0335A

AUTH NAGELL B., NOTINI M.
TITL TOXICITY OF FOUR OIL DISPERSANTS TO SOME ANIMALS FROM THE BALTIC SEA
PUBL MAR. BIOL., 28:237-243, 1974
CODE 1022B

AUTH NASH A.E.K., MANN D.E., OLSEN P.G.
TITL OIL POLLUTION AND PUBLIC INTEREST: A STUDY OF THE SANTA BARBARA OIL SPILL
PUBL INSTITUTE OF GOVERNMENTAL STUDIES, UNIV. OF CAL. 1972
ABST THIS DISCUSSION OF THE SANTA BARBARA OIL SPILL HAS SOME PERTINENT INFORMATION ON PREVENTION AND REMEDIAL ACTION AND FEDERAL AND STATE LEGISLATION.
CODE 3008P

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AUTH  NAVFAC
TITL  INTEGRATED LOGISTICS SUPPORT PLAN FOR HARBOR OIL
      SPILL REMOVAL RECOVERY SYSTEMS
PUBL  NAVFAC ILSP-001
ABST  REFLECTS NAVFAC'S PHILOSOPHY OF A COMPLETE SYSTEMS
      APPROACH FOR THE PLANNING, ANALYZING,DESIGNING,
      AND MANAGEMENT OF LOGISTICS RELATED DISCIPLINES IN
      SUPPORT OF THE AQUISITION OF EQUIPMENT.
CODE  3140R

AUTH  NEAL R.W., JOHNSON E.E., BIANCHI R.A.
TITL  THE DESIGN AND DEMONSTRATION OF A
      REMOTELY-CONTROLLED HIGH SEAS OIL RECOVERY SYSTEM
PUBL  CONFERENCE ON THE PREVENTION AND CONTROL OF OIL
      POLLUTION
ABST  THE OBJECT OF THE PROGRAM WAS TO DEMONSTRATE AND
      TEST A SPILLED OIL RECOVERY SYSTEM UNDER OFFSHORE
      CONDITIONS.
KEYW  REMOTE-CONTROL SKIMMER, RECOVERY, OFFSHORE
      CONDITIONS
CODE  0557F

AUTH  NENECEK E., RODRIGUES S., MIKOLAJ P.
TITL  FREE VORTEX RECOVERY OF FLOATING OIL
PUBL  UNKNOWN
ABST  A CONCEPT EMPLOYING A FREE VORTEX FOR USE IN
      RECOVERING OIL FROM HIGH SEAS OIL SPILLS IS
      PRESENTED.
KEYW  FREE VORTEX, RECOVERY, IMPELLERS
CODE  9115F

AUTH  NEFF J.M., ANDERSON J.
TITL  AN ULTRAVIOLET SPECTROPHOTOMETRIC METHOD FOR THE
      DETERMINATION OF NAPHTHALENE AND ALKYLNAPHTHALENES
      IN THE TISSUES OF OIL CONTAMINATED MARINE ANIMALS
PUBL  BULLETIN OF ENVIRONMENTAL CONTAMINATION AND
      TOXICOLOGY, VOL. 14 NO. 1, 1975
ABST  THIS PAPER DESCRIBES A DIRECT SPECTROPHOTOMETRIC
      METHOD FOR THE SEMIQUANTITATIVE DETERMINATION IN
      SEA WATER AND THE TISSUES OF MARINE ANIMALS.
KEYW  TOXICITY CHROMATOGRAPHIC - MASS.
      SPECTROPHOTOMETRIC ANALYSIS
CODE  2571F

AUTH  NEFF J.M., ANDERSON J.W.
TITL  ACCUMULATION, RELEASE AND DISTRIBUTION OF BENZO
      (A) PYRENE - C 14 IN THE CLAM RANGIA CUNEATA
PUBL  DEPT. OF BIOLOGY, TEXAS A & M UNIVERSITY FOR EPA
      10975 CONFERENCE
KEYW  ACCUMULATION, RELEASE, DISTRIBUTION BENZO PYRENE,
      CLAM
CODE  0136F
AUTH  NELSON-SMITH A.
TITL  EFFECTS OF OIL POLLUTION AND EMULSIFIED CLEANSING
      ON SHORELIFE IN SOUTHWEST BRITAIN
PUBL  J. APPL. ECOL. 5:97-107
CODE  1043R

AUTH  NELSON-SMITH A.
TITL  THE PROBLEM OF POLLUTION OF THE SEA
PUBL  AD. MAR. BIOL. 8:2-15-306
CODE  1090H

AUTH  NEWMAN D.E., MACBETH N.I.
TITL  OIL BOOMS AT A TIDAL INLET
PUBL  HYDRAULIC RESEARCH STATION, REPORT NO INT 118,
      1973
CODE  0736R

AUTH  NICOL C.W.
TITL  THE MIZUSHIMA OIL SPILL - A TRAGEDY FOR JAPAN AND
      A LESSON FOR CANADA
PUBL  DEPT. OF THE ENVIRONMENT, EPS NO. EPS-8-EC-76-2,
      MAY 1976
ABST  THIS REPORT SUMMARIZES NICOL'S OBSERVATIONS ON THE
      ENVIRONMENTAL DAMAGE AND THE CLEANUP EFFORTS
      RESULTING FROM THIS CATASTROPHIC SPILL.
KEYW  CLEAN UP, ENVIRONMENTAL EFFECTS, TECHNIQUES AND
      SYSTEMS
CODE  7153J

AUTH  NIEMAN L.D., CLINE W.G., WOODFORD C.R.
TITL  DESIGN OF A REFINERY DOCK TO PREVENT OIL SPILLS
PUBL  SHELL OIL CO. 1973 CONFERENCE
ABST  THIS MODERN DOCK OPERATED BY SHELL OIL CO. AS
      PART OF THE WOOD RIVER REFINERY IN ILL. WAS
      DESIGNED TO INCLUDE FEATURES WHICH MINIMIZE THE
      POSSIBILITY  OF OIL SPILLS.
CODE  6111R

AUTH  NIGHTINGALE J. NICHOLS J.A.
TITL  BEACH PROTECTION: SHELL OIL HERDER CHEMICAL
PUBL  WARREN SPRING LABORATORY, LR 184(OP), 1973
ABST  THIS REPORT COVERS BRIEFLY THE ASSESSMENT OF A
      CHEMICAL PRODUCT, SHELL OIL HERDER, WHICH CAN BE
      USED TO PROTECT BEACHES FROM OIL WASHED ASHORE.
KEYW  SHELL OIL HERDER, PROTECTION, PREVENTION, CLEANUP
CODE  2920F

AUTH  NIHOUL C.J.
TITL  A SIMPLE MODEL OF ENTRAINMENT AND TURBULENT
      DIFFUSION ACROSS A DENSITY INTERFACE IN THE OCEAN
PUBL  JOURNAL OF THE SCIENTIFIC SOCIETY OF BRUSSELS,
      VOL. 86, NO. III, 1972
ABST  THE AIM OF THE PRESENT STUDY IS THE INTERPRETING
      OF AN INSITU EXPERIMENT MADE BY WOODS IN THE
      MEDITERRANEAN OFF MALTA (WOODS 1968).
KEYW  DENSITY, SHEAR, ENTRAINMENT
CODE  6534F

AUTH  NIILER P., GOLDSTEIN R.
TITL  NUMERICAL MODEL FOR PREDICTION OF SURFACE CURRENTS
      IN THE OCEAN
PUBL  USCG, OFFICE OF RESEARCH AND DEVELOPMENT, REPORT
      NO. CG-D-40-75, MAY 1974
CODE  0813R

AUTH  NIXON R.M.
TITL  DELEGATION FUNCTIONS UNDER THE FEDERAL WATER
      POLLUTION CONTROL ACT
PUBL  OFFICE OF THE PRESIDENT FEDERAL REGISTER,
      35:11677, 1972
CODE  1111F

AUTH  NOAA REPORT
TITL  PRELIMINARY SCIENTIFIC REPORT, THE ARGO MERCHANT
      OIL SPILL
PUBL  NOAA REPORT, MARCH 1977
ABST  THIS REPORT DISCUSSES THE SCIENTIFIC ACTIVITY
      AIMED AT DESCRIBING THE MOVEMENT AND FATE OF OIL
      RELEASED BY THE TANKER AS A STEP IN ASSESSING THE
      ECOLOGICAL EFFECTS OF THE SPILL.
KEYW  PHYSICAL-CHEMICAL MOVEMENT OF OIL, LOGISTICS,
      PHYSICAL,CHEMICAL, BIOLOGICAL PROCESSES
CODE  0574F

AUTH  NOLL C.
TITL  EVAPORATION AND DISSOLUTION OF OIL SPILLS
PUBL  OCEAN ENGINEERING DEPT., URI, AUG. 1977
ABST  THIS PAPER DISCUSSES THE FIRST CHANGES OF
      PETROLEUM SPILLED ON WATER - EVAPORATION.
KEYW  EVAPORATION, DISSOLUTION, WIND AND WATER ACTION
CODE  6505F

AUTH  NOLL C.J.
TITL  A PREDICTIVE MODEL OF THE SPREAD AND TRANSPORT OF
      OIL SPILLS. M.S. THESIS  (ROUGH DRAFT)
PUBL  NORDCO LIMITED - CANADA
ABST  SPREADING OF OIL CAN VARY GREATLY DEPENDING UPON
      THE PHYSICAL AND CHEMICAL CHARACTERISTICS (I.E.
      VISCOSITY, SURFACE TENSION, SURFACE ACTIVE AGENTS,
      ETC.) OF THE OIL AND THOSE OF THE SURROUNDING
      ENVIRONMENT.
KEYW  VISCOSITY, SURFACE TENSION, OIL SPILL
CODE  7748F

AUTH  NOLL C.J., SPAULDING M.L.
TITL  APPLICATION OF AN OIL SPILL COMPUTER MODEL TO
      NARRAGANSETT BAY AND RHODE ISLAND SOUND
PUBL  DEPT. OF OCEAN ENGINEERING, URI
ABST  TWO MODELS HAVE BEEN DEVELOPED. A LONG TERM MODEL
      WHICH PREDICTS SURFACE DRIFT ONLY OVER A TIME
      PERIOD ON THE ORDER OF DAYS. THE SECOND MODEL, A
      SHORT TERM MODEL, WITH REAL TIME CAPABILITIES IS
      MORE COMPLEX AND INCLUDES ESTIMATIONS OF
      SPREADING, DRIFT, OIL DENSITY CHANGES, AND
      EVAPORATION AND DISSOLUTION OF OIL OVER A TIME
      PERIOD ON THE ORDER OF HOURS. THE MODELS ARE USED
      TO SIMULATE ACTUAL AND HYPOTHETICAL SPILLS IN
      RHODE ISLAND SOUND AND NARRAGANSETT BAY.
KEYW  CONTINGENCY, CLEANUP, COMPUTER MODEL, SPREADING,
      DRIFTING
CODE  7661F

AUTH  NORTON R.L., LEACH D.
TITL  AN OIL RECOVERY SYSTEM FOR SAN FRANCISCO BAY AREA
PUBL  CONFERENCE ON PREVENTION AND CONTROL OF OIL
      POLLUTION
ABST  THIS PAPER DESCRIBES IN DETAIL THE PERFORMANCE
      SPECIFICATION FOR THE RECOVERY SYSTEMS.
KEYW  RECOVERY, WAVE TANK PREDICTIONS, REQUIREMENTS FOR
      TANK VESSEL CERTIFICATION
CODE  8507F

AUTH  NOTINI M.
TITL  LONG TERM EFFECTS OF AN OIL SPILL ON FUCUS
      MACROFAUNA IN A SMALL BALTIC BAY
PUBL  JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST  LONG TERM EFFECTS OF AN OIL SPILL OCT. 6, 1970.
      THE SMALL TANKER IRINI RAN AGROUND IN THE SOUTHERN
      PART OF THE STOCKHOLM ARCHIPELAGO, RELEASING ABOUT
      1000 TONS OF MEDIUM AND HEAVY FUEL OIL.
KEYW  ALGEA, LITTORAL COMMUNITY, TANKER IRINI
CODE  2069F

AUTH  OBRIEN J.A.
TITL  OIL SPREADING ON WATER FROM A STATIONARY LEAKING
      SOURCE
PUBL  CHEM. EGR. NO. 224 1970
CODE  2043R

AUTH  OBRIEN J.A.
TITL  WIND TUNNEL EXP. ON OIL SLICK TRANSPORT
PUBL  J. OF HYDRONAUTIC RESEARCH, VOL. 5, 1971
CODE  2044R

AUTH  OBRIEN V.
TITL  UNSTEADY CAVITY FLOWS: OSCILLATORY FLAT BOX FLOWS
PUBL  ASME PUB.
ABST  THE OSCILLATORY CAVITY FLOWS REPORTED HERE ARE
      EXTENSIONS OF PREVIOUSLY STUDIED STEADY CLOSED
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	RECTANGULAR CAVITY FLOWS GLPOX FLOWS.
CODE	2902R

AUTH	ODA A.
TITL	EVALUATION OF POLYCOMPLEX A-11 AS AN OIL DISPERSANT
PUBL	THE ONTARIO WATER RESOURCES COMMISSION, DIVISION OF RESEARCH, PAPER NO. 2020, JUNE 1968
ABST	THIS PAPER DISCUSSES THE EFFECTIVENESS OF POLYCOMPLEX A-11 AS A DISPERSANT.
KEYW	DISPERSANTS, EMULSIFIER, BIOLOGICAL TREATABILITY
CODE	2137F

AUTH	ODA A.
TITL	LABORATORY EVALUATION OF CHEMICAL OIL DISPERSANTS
PUBL	ONTARIO WATER RESOURCES COMMISSION
ABST	THIS PAPER DISCUSSES SOME OF THE METHODS WHICH CAN BE USED TO EVALUATE CHEMICAL OIL DISPERSANTS IN ORDER TO OBTAIN SOME PRELIMINARY DATA RELATED TO THEIR EFFECTIVENESS AS DISPERSANTS AND PROBLEMS THAT MAY RESULT FROM THEIR USE.
KEYW	CHEMICAL OIL DISPERSANTS, EFFECTIVENESS, PROBLEMS
CODE	2150R

AUTH	OFFSHORE OIL TASK GROUP
TITL	SUMMARY THE GEORGES BANK PETROLEUM STUDY, VOL. I AND II
PUBL	M.I.T., SEA GRANT PROJECT OFFICE, FEB. 1, 1973
ABST	VOLUME I AND VOLUME II OF A THREE VOLUME REPORT STUDYING THE IMPLICATIONS OF A PETROLEUM DEVELOPMENT ON THE NEW ENGLAND CONTINENTAL SHELF.
KEYW	REGIONAL INCOME, PETROLEUM DISCOVERY, ENVIRONMENTAL QUALITY, DISCHARGES, SPILLS
CODE	0573P

AUTH	OFFWAY S.
TITL	THE COMPARATIVE TOXICITIES OF CRUDE OIL. THE ECOLOGICAL EFFECTS OF OIL POLLUTION ON LITTORAL COMMUNITIES
PUBL	INST. PETROL. LONDON, 172-180
CODE	1091P

AUTH	OIL AND HAZARDOUS MATERIALS RESEARCH SECTION
TITL	OIL SKIMMING EQUIPMENT
PUBL	U.S. DEPARTMENT OF THE INTERIOR, FEDERAL WATER QUALITY ADMINISTRATION, MAY 1970
ABST	OIL SKIMMING DEVICES ARE USED TO PHYSICALLY RECOVER OIL FROM THE WATERS SURFACE.
KEYW	OIL SKIMMING DEVICES, SKIMMERS, OIL RECOVERY DEVICES, REMOVAL
CODE	0564F

AUTH	OPPENHEIMER C.
TITL	MICROBIOLOGICAL SEEDING TO ACCELERATE DEGRADATION OF HYDROCARBONS
PUBL	UNIV. OF TEXAS, FOR EPA, NO. 15080EHF, 72P21565, SSIE NO. GMA 3643-1
CODE	0471B

AUTH	ORR C.
TITL	THE ELECTRICAL PROCESS IN THE BREAKING OF DILUTE OIL-IN-WATER EMULSIONS
PUBL	OFFICE OF WATER RESOURCES RESEARCH JUNE 1974
ABST	OILS, GREASES, AND WAXES FREQUENTLY OCCUR IN INDUSTRIAL WASTE WATERS AS HIGHLY DISPERSED DROPLETS. PROBLEMS TO DETERMINE WHICH CHEMICAL AND WHAT QUANTITY OF THAT CHEMICAL NEEDED TO INDUCE A GIVEN EMULSION TO BREAK.
KEYW	OIL GREASE AND WAX, WASTE WATERS, DISPERSED DROPLETS, EMULSIONS
CODE	7531R

AUTH	OTTO L.
TITL	ENVIRONMENTAL FACTORS IN OPERATIONS TO COMBAT OIL SPILLS
PUBL	WORLD METEOROLOGICAL ORGANIZATION, WMC-350-MAS-9
CODE	0410N

AUTH	OTTO L.
TITL	OCEANOGRAPHIC ASPECTS OF OIL POLLUTION
PUBL	NAUTISCH, TECHN. T., VOL. 1, 1972
CODE	2367N

AUTH	OVERFIELD J.L.
TITL	DEVELOPMENT OF A NON-TOXIC SIMULATED OIL FOR MARINE TESTING PROGRAMS
PUBL	OTC PAPER NO. OTC 1524, OFFSHORE TECHNOLOGY CONFERENCE, MAY 1972
CODE	0642P

AUTH	OVERTON E.B., BRACKEN J., LASETER J.L.
TITL	APPLICATION OF GLASS CAPILLARY COLUMNS TO MONITOR PETROLEUM-TYPE HYDROCARBONS IN MARINE SEDIMENTS
PUBL	JOURNAL OF CHROMATOGRAPHIC SCIENCE VOLUME 15, MAY 1977
ABST	HIGH RESOLUTION GLASS CAPILLARY COLUMNS COATED WITH SE 52 LIQUID PHASE WERE USED TO RESOLVE THE INDIGENOUS HYDROCARBONS EXTRACTED FROM SEDIMENT SAMPLES COLLECTED FROM THREE OUTER CONTINENTAL SHELF AREAS.
CODE	7706 F

AUTH	OWEN R.W.
TITL	SMALL-SCALE HORIZONTAL VORTICES IN THE SURFACE LAYER OF THE SEA
PUBL	JOURNAL OF MARINE RESEARCH, VOL. 24, 1966
ABST	A VORTEX SYSTEM IN THE WATER NEAR THE SEA SURFACE HAS BEEN INFERRED FROM COLLECTION INTO PARALLEL ROWS OF A POSITIVELY PHOTOTAXIC ZOOPLANKTON POPULATION.
KEYW	VORTEX SYSTEM, WATER VELOCITY, CONVERGENCE PLANES
CODE	6566F

AUTH	OWENS E. LESLIE J.
TITL	COASTAL ENVIRONMENTS OF CANADA: THE IMPACT AND CLEAN-UP OF OIL SPILLS
PUBL	RESEARCH AND DEVELOPMENT DIVISION, ENVIRONMENTAL EMERGENCY BRANCH, EPS-3-EC-77-13, APRIL 1977
ABST	A REVIEW OF THE SHORELINE AND PROCESS CHARACTERISTICS OF CANADA'S COASTS INVOLVED DEFINITION AND DESCRIPTION OF 34 COASTAL ENVIRONMENTS AND SHOWS THAT LITTORAL PROCESSES OPERATE AT RELATIVELY LOW-ENERGY LEVELS IN MANY REGIONS DUE TO THE SMALL FETCH AREAS ON MOST COASTS AND THE SIGNIFICANT ROLE OF ICE IN ALL LITTORAL ENVIRONMENTS, EXCEPT FOR THE BRITISH COLUMBIA AND SOUTHERN NOVA SCOTIA COASTS.
KEYW	COASTAL ENVIRONMENTS, FETCH, ICE ROLES
CODE	7156F

AUTH	OWENS E.H.
TITL	MECHANICAL DISPERSAL OF OIL STRANDED IN THE LITTORAL ZONE
PUBL	JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST	THIS REVIEW OF THE CONCEPTS ASSOCIATED WITH LITTORAL PROCESSES, IN TERMS OF THE MECHANICAL DISPERSAL OF STRANDED OIL, PROVIDES THE BASIS FOR ESTIMATION OF THE PERSISTENCE OF OIL ON SHORELINES.
KEYW	WEATHERING, DISPERSAL OF PETROLEUM, COASTAL PROCESSES, WAVE ENERGY, SEA ICE
CODE	2669F

AUTH	OWENS E.H. LESLIE J.
TITL	COASTAL ENVIRONMENTS, OIL SPILLS AND CLEAN-UP PROGRAMS IN THE BAY OF FUNDY
PUBL	EPA, ATLANTIC REGION, EPS-3-EC-77-9, FEB. 1977
ABST	GUIDELINES AND RECOMMENDATIONS FOR PROTECTION AND CLEANUP OF THE SHORES OF THE BAY OF FUNDY ARE PRESENTED AND ARE RELATED TO THE NATURE OF THE SHORELINE, THE SEDIMENTS , THE SHORELINE PROCESSES AND THE EFFECTIVENESS OF AVAILABLE TECHNIQUES.
KEYW	COASTAL FEATURES, SHORELINE PROCESSES, IMPACT AND PERSISTENCE
CODE	7166F

AUTH	OXENHAM J.P.
TITL	A STUDY OF THE PERFORMANCE CHARACTERISTICS OF THE OLEOPHILIC BELT "OIL SCRUBBER"
PUBL	PHYSICAL REMOVAL
ABST	THIS PAPER DISCUSSES THE PERFORMANCE OF THE "OIL SCRUBBER". THE STABILITY OF THE BELT IS A PRIMARY CONCERN FOR OPERATIONS IN THE PRESENCE OF TRANSVERSE CURRENTS.
KEYW	REMOVAL, RECOVERY RATE, EFFICIENCY
CODE	0029I

AUTH	OXMAN B.H.
TITL	OCEAN POLLUTION: WHAT CAN THE LAW OF THE SEA CONFERENCE DO?
PUBL	LAW OF THE SEA: THE ENERGY REGIME OF THE OCEANS, BALLINGER PUBLISHING CO. 1976
ABST	REGARDS THE STANDARDS SET UP FOR REHL AND MAKES A PLEA FOR STRONGER RULES AND REGULATIONS GUARDING THE SEA.
CODE	3104R

AUTH	PACIFIC NORTHWEST LABORATORIES
TITL	RECOVERY OF OIL SPILLS USING VORTEX ASSISTED AIRLIFT SYSTEM
PUBL	EPA, WATER QUALITY OFFICE, WATER POLLUTION CONTROL RESEARCH SERIES, JULY 1970
ABST	STUDIES WERE CONDUCTED TO DETERMINE THE FEASIBILITY OF A CONCEPT FOR RECOVERY OF FLOATING OIL SLICKS WHICH UTILIZES A PUMP INDUCED VORTEX AND A VACUUM SUCTION OF COANDA NOZZLE.
KEYW	VORTEX, COANDA NOZZLE, WAVE SUPPRESSOR
CODE	0567F

AUTH	PAL D.
TITL	THE COANDA-EFFECT OIL-WATER SEPARATOR: A FEASIBILITY STUDY
PUBL	NAVAL UNDER WATER SYSTEMS CENTER, NEWPORT, RI. REPORT NO. N-1331, FEB. 1976
ABST	AN EXPERIMENTAL INVESTIGATION WHICH ESTABLISHES THE FEASIBILITY OF USING THE COANDA EFFECT IN DEVELOPING AN OIL WATER SEPARATOR IS DESCRIBED.
KEYW	FLUID DYNAMIC PHENOMENON, "WALL ATTACHMENT"
CODE	9513F

AUTH	PANCIROV R.J.
TITL	COMPOSITIONAL DATA ON API REFERENCE OILS USED IN BIOLOGICAL STUDIES: A NO. 2 FUEL OIL, A BUNKER C, KUWAIT CRUDE OIL AND SOUTH LOUISIANA CRUDE OIL
PUBL	API, REPORT NO. AID 1BA 74, FEB. 5, 1974
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KEYW SEDIMENT TRANSPORT, LAGRANGIAN MARKER, EULERIAN CELL
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KEYW ENVIRONMENTAL MONITOR, INFREQUENT SAMPLING
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KEYW CONTINGENCY, ESTUARY, SOURCE, RESPONSE
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KEYW MICROBIAL DEGRADATION, TURBULENCE, HYDROCARBON LAYERS
CODE 7664F

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KEYW WATER WAVES, OIL POLLUTION, DETECTION
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KEYW SEASTATE, BREAKING WAVES, TURBULENCE
CODE 2656F

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KEYW ACTIVATED SLUDGE, ENERGY CONVERSION, ENVIRONMENTAL ENGINEERING
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PUBL JOURNAL OF APPLIED METEOROLOGY, VOL. 13, FEB. 1974
ABST THIS PAPER DISCUSSES THE TESTING TO STUDY VARIOUS ASPECTS OF POLLEN TRANSPORT.
KEYW POLLEN TRANSPORT AND DISPERSANTS, CONCENTRATIONS, VERTICAL DISTRIBUTION
CODE 1215F

AUTH REED M.
TITL A FISHERY-OILSPILL INTERACTION MODEL: SIMULATED CONSEQUENCE OF A BLOWOUT
PUBL DEPARTMENT OF OCEAN ENGINEERING UNIVERSITY OF RHODE ISLAND
ABST THE PROCEEDINGS OF THE NATO CONFERENCE ON APPLIED OPERATIONS RESEARCH IN FISHERIES, TRONDHEIM, NORWAY, 1979, THIS PAPER SHOWS THE EFFECTS OF A MAJOR OIL WELL BLOWOUT ON THE YIELD OF A COMMERCIAL COD STOCK THROUGH A SET OF INTERACTING COMPUTER MODELS.
KEYW OIL WELL BLOWOUT, HYDROCARBON TOXICITY
CODE 7777F

AUTH REGIER H.A., COWELL E.B.
TITL APPLICATIONS OF ECOSYSTEM THEORY, SUCCESSION, DIVERSITY, STABILITY, STRESS AND CONSERVATION
PUBL BIOLOGICAL CONSERVATION JANUARY 1972
ABST PROCESSES AT THE ECOSYSTEM LEVEL OF ORGANIZATION ARE EXAMINED AS THEY ARE AFFECTED BY CONVENTIONAL REGIMES OF FISHERY EXPLOITATION AND POLLUTION, THE LATTER INCLUDING BOTH NUTRIENT AND TOXIC MATERIALS. EXPLOITATION AND POLLUTION ARE TREATED

AS STRESSES THAT DEFORM AND TRANSFORM COMMUNITY STRUCTURE AND REVERSE THE USUAL SEQUENCE OF ECOLOGICAL SUCCESSION WITH RESPECT TO DOMINANCE OF VARIOUS TAXA, DIVERSITY, STABILITY AND PRODUCTION. IMPLICATIONS OF SUCH PROCESSES ARE OUTLINED.
KEYW ECOSYSTEM, POLLUTION
CODE 7757F

AUTH REINHOLDT R., LASKO L., SHAW C., WIRNOWSKI E.
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PUBL BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY, VOL. 11, NO. 2., 1974
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KEYW DISPERSANTS, COLLECTING AGENTS, TOXICITY
CODE 2144F

AUTH REID G.W., STREEBIN L.E.
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ABST AN EVALUATION ON POLLUTION PROBLEMS, ABATEMENT PROCEDURES AND CONTROL TECHNIQUES RELEVANT TO THE PETROLEUM AND COAL INDUSTRIES.
KEYW ABATEMENT, CONTROL TECHNIQUES, PETROLEUM AND COAL INDUSTRIES
CODE 0068P

AUTH REISBIG R.
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PUBL DEPT. OF TRANSPORTATION USCG, OCT. 1973
ABST THE RESULTS IN THIS INVESTIGATION SHOW THAT WAVE EFFECTS ARE COUPLED TO WIND EFFECTS IN A COMPLICATED MANNER AND NEGLECTING THE WAVES CAN LEAD TO SERIOUS ERRORS.
KEYW WAVE EFFECTS, WIND EFFECTS, OIL SPILL DRIFT
CODE 2546P

AUTH REISBIG R.L.
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ABST ONE YEAR STUDY OF THE POTENTIAL EFFECT OF WIND AND WAVES ON OIL WAS INITIATED TO EVALUATE THE IMPORTANCE OF COUPLED WIND AND WAVE DRIFT MECHANISM COMPUTER SIMULATION OF THE TOTAL DRIFT
KEYW POTENTIAL EFFECT, WIND AND WAVES, OIL SPILL DRIFT
CODE 2577R

AUTH REISH D.J.
TITL A CRITICAL REVIEW OF THE USE OF MARINE INVERTEBRATES AS INDICATORS OF VARYING DEGREE OF MARINE POLLUTION
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2262, MAY 5-8, 1975
ABST A DESCRIPTION OF THESE OPERATIONS AND SUMMARY OF THE RESULTS ARE PRESENTED.
KEYW SKIMMER, CLEANUP, CONTAINMENT, COLLECTION, PUMPING, STORAGE TRANSFER
CODE 0559F

AUTH RICE S.D., MOLES D.A., SHORT J.W.
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KEYW PRUDHOE BAY CRUDE OIL, SURVIVAL, PINK SALMON
CODE 0141P

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PUBL NAVAL RESEARCH REVIEWS, SEPT. 1976.
ABST THIS PAPER DISCUSSES A STUDY ON EFFECTS OF CYCLONIC RINGS GENERATED BY THE GULF STREAM.
KEYW CYCLONIC RINGS, GULF STREAM, MESOSCALE OCEANIC FEATURES
CODE 6579F

AUTH RICHARDSON W.S.
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PUBL NOVA UNIV. AD 787787, USCG D 18-75
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AUTH RICKARD W.E., DENEKE F.
TITL PETROLEUM SPILLAGE, HAINES - FAIRBANKS MILITARY PIPELINE
PUBL ARMY RESEARCH OFFICE, LIFE SCIENCES DIV., D A PROJECT 2NO61102A871D, APRIL 1972
ABST PRELIMINARY INVESTIGATION OF PETROLEUM SPILLAGE
CODE 6059R

AUTH RIDWAY N.M.
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ABST A REVIEW OF THE PUBLISHED LITERATURE AND OF SELECTED UNPUBLISHED DATA ON THE DISTRIBUTIONS AND CONCENTRATIONS OF POLLUTANTS IN MARINE MAMMALS HAS SHOWN THAT ALL MARINE MAMMAL POPULATIONS ARE NOW EXPOSED TO A CERTAIN LEVEL OF ANTHROPOGENIC CHEMICALS.
KEYW MARINE MAMMALS, MARINE POLLUTION
CODE 7766F

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PUBL EPA, NO. R2-72-033, NTS-05717, AUG. 1973
ABST AN AIR MODULATED VACUUM OIL RECOVERY TECHNIQUE WAS DEVELOPED IN AN EXPERIMENTAL AND ENGINEERING DESIGN PROJECT AS A METHOD OF COLLECTING OIL SPILLED ON WATER.
KEYW AIR MODULATED VACUUM, RECOVERY TECHNIQUE, COLLECTING OIL
CODE 0067R

AUTH RITCHIE J.E., ALLEN F.J.
TITL PETROLEUM SYSTEMS RELIABILITY ANALYSIS, A PROGRAM FOR PREVENTION OF OIL SPILLS USING AN AGR. APPROACH TO A STUDY OF OFFSHORE AND ONSHORE CRUDE OIL PETROLEUM SYSTEMS
PUBL EPA, OFFICE OF RESEARCH AND MONITORING, OFFICE OF WATER PROGRAM OPERATIONS
ABST THE ANALYSIS EXAMINED IN DETAIL THE CAUSES OF POLLUTING SPILLS FROM SELECTED PET. SYSTEMS ONSHORE AND OFFSHORE CRUDE OIL DRILLING PRODUCTION AND GATHERING/DISTRIBUTION SYSTEMS. THE STUDY INCLUDES THE COMPILATION OF DATA FROM FEDERAL, STATE AND INDUSTRIAL SPILL REPORTS, A FIELD SURVEY OF THE VARIOUS TYPES OF FACILITIES AND AN ANALYSIS OF SPILL-CAUSING FAILURES.
CODE 6033R

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PUBL FEDERAL WATER POLLUTION CONTROL ADMINISTRATION CONTRACT OF 15080ESL
ABST FOR THE RATIONAL DESIGN OF AN OIL SLICK CONTAINMENT AND COLLECTION SYSTEM, THE BEHAVIOR OF AN OIL SLICK HELD AGAINST A SURFACE BARRIER BY A STEADY CURRENT MUST BE KNOWN. DERIVATIONS FOR CALCULATING THIS QUANTITY ARE SHOWN.
CODE 3052P

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AUTH ROBERTS A.C.
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PUBL PROJECT 15080FVP, MAY 1973
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1377, APR. 19-21, 1971, JOURNAL OF PETROLEUM TECHNOLOGY, JAN. 1972
ABST IN THIS PAPER THE RESULTS OF A STUDY OF THE EFFECTS OF CHEMICAL DISPERSING AGENTS ON THE RATE OF MICROBIAL DESTRUCTION OF CRUDE OIL IN AQUEOUS ENVIRONMENTS ARE DESCRIBED.
KEYW DISPERSANTS, BIODEGRADATION, MICROBIAL DESTRUCTION
CODE 0052F

AUTH ROBINSON A.J.
TITL ASSESSMENT OF DEVICES FOR THE REMOVAL OF OIL FROM INSHORE AND INLAND WATERS
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     OIL AT SEA
PUBL DEPT. OF TRADE AND INDUSTRY, SSIE NO. : WDO-742
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     OF OIL AT SEA
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CODE 0356R

AUTH ROBINSON J.
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PUBL CONFERENCE ON THE PREVENTION AND CONTROL OF OIL
     POLLUTION
ABST THIS PAPER DESCRIBES A PRACTICAL OIL SPILL
     TRAINING COURSE OFFERED BY  TEXAS ENGINEERING
     EXTENSION SERVICE, TEXAS A AND M UNIVERSITY
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KEYW PREVENTION, CONTROL, TRAINING COURSES
CODE 0810F

AUTH RODENBARGER C.A.
TITL A SYSTEMS EGR. SOLUTION FOR OPEN SEA OIL SPILLS
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     OIL
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1988,
     MAY 6-8, 1974
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     FREE VORTEX APPROACH TO FLOATING OIL RECOVERY ARE
     PRESENTED.
KEYW HIGH SEAS OIL SPILL RECOVERY, FREE VORTEX,
     SKIMMING
CODE 0824F

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     CONTAMINATED WITH PRUDHOE BAY CRUDE OIL: INFLUENCE
     OF FEEDING TYPE OF TEST SPECIES AND AVAILABILITY
     OF POLYCYCLIC AROMATIC HYDROCARBONS
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST SELECTED BENTHIC ANIMALS WERE EXPOSED TO MARINE
     SEDIMENTS CONTAMINATED WITH PRUDHOE BAY CRUDE OIL,
     AND UPTAKE OF HYDROCARBONS WAS MONITORED UNDER
     VARIOUS EXPERIMENTAL SCHEMES.
KEYW HYDROCARBONS, SEDIMENTS, BIVALVE, SIPUNCULID,
     FEEDING TYPE
CODE 2649F

AUTH ROGERS B., STEVENSON T.
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     CULTURE METHODS AND THE DETERMINATION OF CRUDE OIL
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     MICROGADUS
PUBL PRE-PROPOSAL, EPA, URI GRADUATE SCHOOL OF
     OCEANOGRAPHY
ABST BECAUSE OF THE VULNERABILITY TO POLLUTANTS,
     TELEOSTS ARE DESIRABLE TO USE FOR TESTING THE
     EFFECTS OF POLLUTANTS.
KEYW TELEOSTS, MICROBIAL DEGRADATION, TOXICITY
CODE 7655F

AUTH RORHOLM N., LAMPE H.C., MARSHALL N., FARRELL J.F.
TITL ECONOMIC IMPACT OF MARINE ORIENTED ACTIVITIES A
     STUDY OF THE SOUTHERN NEW ENGLAND MARINE REGION
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KEYW ECONOMIC IMPACT, SOUTHERN NEW ENGLAND, MARINE
     ORIENTED ACTIVITIES
CODE 0365P

AUTH ROSEN A.
TITL THE FOUNDATIONS OF ORGANIC POLLUTANT ANALYSIS
PUBL MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY,
     USEPA, PB761 309, DEC. 1976
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     METHODS, CARBON ADSORPTION
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AUTH ROSS S.L.
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     DEVELOPMENT PROJECTS TAKING PLACE IN CANADA.  THE
     TECHNOLOGY DEVELOPMENT AND RESEARCH EFFORT IN
     CANADA HAS BEEN DIRECTED TOWARD COLD ENVIRONMENT
     PROBLEMS.
KEYW CONTAINMENT, CLEANUP, CONTROL
CODE 0515F

AUTH ROSS S.L., FINGAS
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PUBL RESEARCH AND DEVELOPMENT DIVISION, ENVIRONMENTAL
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CODE [illegible]

AUTH ROSS W.M.
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     OF PUGET SOUND AND THE  STRAITS OF GEORGIA
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     CONTROL OIL POLLUTION. IT ALSO DESCRIBES AND
     EVALUATES LEGISLATION IN THE US SINCE 1972
KEYW OIL POLLUTION, PUGET SOUND LEGISLATION
CODE 3079P

AUTH ROTHBAUM H.
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ABST THE SCOPE OF THE STUDY IS LIMITED TO THE
     INTERNATIONAL UNION AND ITS ANALYSIS IS FOCUSED ON
     THE PRIMARY FUNCTIONS OF THE UNIONS. THE OCAW IS
     CONSIDERED A WEAK UNION.
CODE 3084P

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TITL BUZZARDS BAY OIL SPILL AN ARCTIC ANALOGUE
PUBL COASTAL RESEARCH DIVISION, DEPT.OF  GEOLOGY, UNIV.
     OF SO. CAROLINA
ABST THIS PAPER ANALYZES THE INTERACTION OF THE ICE
     COVER WITH THE RATE AND EXTENT OF DISPERSAL OF THE
     SPILLED OIL. SPECIAL EMPHASIS HAS BEEN PLACED ON
     AREAS OF OIL ACCUMULATION WITHIN THE ICE AND WAYS
     IN WHICH THE ICE COVERS TEND TO PROTECT THE
     SHORELINE FROM CONTAMINATION.
KEYW CLEAN UP, CONTINGENCY, OIL ON ICE
CODE 7651F

AUTH RUCKENSTEIN E., CHI C.
TITL STABILITY OF MICROEMULSIONS
PUBL UNKNOWN
ABST A THERMODYNAMIC TREATMENT TO OBTAIN INFORMATION ON
     THE STABILITY OF MICROEMULSIONS AND THE SIZE OF
     THE DROPLETS IN STABLE MICROEMULSIONS IS PROPOSED.
KEYW THERMODYNAMICS, MICROEMULSIONS, STABILITY
CODE 6139F

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PUBL EPA REPORT NO. R2-72-007
CODE 2087P

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PUBL CONTRACT NO. 68-01-0140, PROJECT NO. 15080HOR,
     AUG. 1972
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CODE 6072R

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TITL AERIAL DETECTION OF SPILL SOURCES
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ABST THE PURPOSE OF THE PROJECT WAS TO DEVELOP AN
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     PHOTOGRAPHS.
CODE 6048R

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     AN FLAPSEC CHANNEL
PUBL HYDRAULICS RESEARCH STATION, WALLINGFORD, ENGLAND
CODE 2967A R

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     SPILL DISPERSANTS
PUBL EPA
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     PETROLEUM DERIVED ORGANIC COMPOUNDS IN THE OCEAN
     AND THEIR SUBLETHAL EFFECTS ON MARINE ORGANISMS
PUBL TEXAS A&M UNIV
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     ORGANIZATIONS SPONSORING THE DEVELOPMENT AND
     MAINTENANCE OF AN INTERNATIONAL CENTER FOR OIL
     SPILL TREATMENT
KEYW COMPUTER FACILITY, COMMUNICATIONS NETWORK,
     DEVELOPMENT AND MAINTENANCE
CODE 2936F

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TITL FLORIDA OIL SPILL IMPACT ON THE BUZZARDS BAY
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PUBL JOURNAL OF THE FISHERIES, VOL 35, NO. 5, MAY 1978
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KEYW BENTHOS, HYDROCARBONS, INTERTIDAL ZONE, LONG TERM
     EFFECTS, STATISTICS
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CODE 2069F

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PUBL AVAILABLE FROM NTIS AS PB-209 628, REPORT NO. WHOI-72-27, APRIL 1972
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PUBL EPA CONFERENCE 1975
ABST PAPER INCLUDES: PIPELINE DRAINAGE CALCULATIONS, CONTINGENCY ORGANIZATION, ENVIRONMENTAL CONSIDERATIONS, IMMEDIATE RESPONSE ACTIONS, AND CONTINGENCY PLAN DEVELOPMENT
KEYW CONTINGENCY PLAN, PIPELINE SYSTEMS, ENVIRONMENTAL CONSIDERATION
CODE 01079

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TITL OIL/SORBENT HARVESTING SYSTEM FOR USE ON VESSELS OF OPPORTUNITY
PUBL EDISON WATER QUALITY RESEARCH LAB., PREPARED FOR EPA, NO. R2-73-166, APR. 1973
ABST A THREE-PHASE TEST PROGRAM WAS CONDUCTED TO EVALUATE CANDIDATE SYSTEM COMPONENTS AND OPERATING SPECIFICATIONS FOR THE OIL/SORBENT HARVESTING SYSTEM.
KEYW RECOVERY, OIL/SORBENT HARVESTING SYSTEM, OIL ON WATER
CODE 61999

AUTH SARTOR J.D., PAPP R.H.
TITL DRAG COEFFICIENTS OF SMALL, IRREGULAR PARTICLES
PUBL THE RAND CORPORATION SANTA MONICA, CALIF.
ABST THIS REPORT PRESENTS THE RESULTS OF SEVERAL LABORATORY TESTS CONDUCTED WITH SPHERICAL AND IRREGULARLY SHAPED PARTICLES. THESE MEASUREMENTS WERE MADE TO CLARIFY THE LAW OF FALL OF IRREGULAR PARTICLES IN THE RANGE OF REYNOLDS NUMBERS FROM 0.035 TO 3.5. THE RESULTS OF THE EXPERIMENTS ARE PRESENTED IN TABULAR FORM, AND ARE COMPARED GRAPHICALLY WITH THE THEORETICAL APPROXIMATION TO THE RATE OF FALL OF SPHERES AND WITH THE ACCEPTED CURVE FOR SPHERES.
KEYW TERMINAL VELOCITY, REYNOLDS NUMBERS, FALL VELOCITY, DRAG COEFFICIENTS
CODE 7730F

AUTH SATO T., SUZUKI, Y., KASHIWAGI H., NANJO M., KAKUI Y.
TITL A METHOD FOR REMOTE DETECTION OF OIL SPILLS USING LASER-EXCITED RAMAN BACKSCATTERING AND BACKSCATTERED FLUORESCENCE
PUBL IEEE JOURNAL OF OCEANIC ENGINEERING, VOL. OE 3, NO. 1, JAN. 1978
ABST A LASER METHOD FOR THE REMOTE DETECTION OF OIL PRESENT AS A POLLUTANT IN THE SEA WATER USING RAMAN BACKSCATTERING AND BACKSCATTERED FLUORESCENCE IS DISCUSSED.
KEYW LASER METHOD, DETECTION, BACKSCATTERING, BACKSCATTERED FLOURESCENCE
CODE 7657F

AUTH SAUNDERS K.D., VAN LOON L.S.
TITL WATER RESOURCES RESEARCH PROGRAM, NEARSHORE CURRENTS AND WATER TEMPERATURES IN SOUTHWESTERN LAKE MICHIGAN
PUBL ENERGY AND ENVIRONMENTAL SYSTEMS DIV., ARGONNE NATIONAL LABORATORY, ANL/WR 76-2, MAY 1976. JUNE - DEC. 1975
ABST THE PRESENT STUDY WAS DESIGNED TO INVESTIGATE THE TEMPORAL AND SPATIAL COHERENCE OF CURRENTS OFF SO. CHICAGO, ILL. AND E. CHICAGO, IND.
KEYW COASTAL CURRENTS, SPATIAL AND TEMPORAL VARIABILITY
CODE 6520F

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PUBL ARGONNE NATIONAL LAB., ILL. MAY 1976
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PUBL PAPER NO. 71-840, 26TH ANNUAL ISA CONF. 1971
CODE 2070R

AUTH SAWLEY
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PUBL ASME PUBL.
ABST A MEANS IS DESCRIBED FOR PREDICTING THE DECAY OF ACOUSTICAL ENERGY IN A PIPING SYSTEM WITH DISTANCE ON THE PIPE FROM THE SOURCE OF NOISE. THE APPLICATION OF THE METHOD TO PRACTICAL SITUATIONS IS DISCUSSED.
CODE 2903A

AUTH SAWYER R.C.
TITL OIL SPILL SPECIALISTS EMERGE AS "SLICK" ENGINEERS
PUBL NEW ENGLANDER BUSINESS MAGAZINE, OCT. 1975
ABST REPORT ON COASTAL SERVICES. THIS PAPER DISCUSSES THE N.E. CLEANUP CONTRACTORS.
KEYW CLEANUP, DISPERSANTS, CONTRACTORS
CODE 2940F

AUTH SCHARFENSTEIN C.F., LEARY J.
TITL TESTING THE LOCKHEED DISC-DRUM ROUGH WATER OIL RECOVERY SYSTEM
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1997, MAY 6-8, 1974
ABST THIS PAPER DISCUSSES THE QUALIFICATION TESTING OF THE LOCKHEED PROTOTYPES HIGH SEAS OIL RECOVERY SYSTEM.
KEYW RECOVERY, INLAND POOL TEST, HIGH SEAS TESTS
CODE 0554F

AUTH SCHATZBURG P., HARRIS L.R., ADEMA C.M., JACKSON D.F., KELLY C.M.
TITL OIL-WATER SEPARATION WITH NONCELLULOSIC ULTRAFILTRATION SYSTEMS
PUBL NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, FOR EPA 1975 CONFERENCE
KEYW OIL-WATER SEPARATION, NONCELLULOSIC ULTRAFILTRATION SYSTEMS
CODE 01328

AUTH SCHEDVIN J.C., GIBSON C.H., DEATON T.K.
TITL MEASUREMENTS OF TURBULENCE, TEMPERATURE AND SALINITY MICROSTRUCTURE IN THE UPPER LAYERS OF THE OCEAN-AN INTERCOMPARISON TEST
PUBL SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, SAN DIEGO CA
ABST SMALL SCALE FLUCTUATIONS OF TEMPERATURE, CONDUCTIVITY AND VELOCITY WERE MEASURED FROM TOWED BODIES AT DEPTHS FROM 10-1000 METERS. RESULTS OF US TEMPERATURE MEASUREMENTS BELOW THE BASE OF A WIND MIXED LAYER ARE PRESENTED.
KEYW TEMPERATURE INVERSION, FOSSIL TEMPERATURE TURBULENCE, SPECTRAL ANALYSIS
CODE 7702 F

AUTH SCHIFF L.J
TITL AIR BUBBLE BREAKWATER
PUBL HYDRODYNAMICS LABORATORIES
ABST CONSIDERED ARE PROPERTIES OF BUBBLY WATER, THE TRANSMISSION OF WAVES THRU A SINGLE BUBBLE SCREEN, AND FINALLY THE TRANSMISSION THROUGH A SERIES OF EQUALLY SPACED SCREENS.
CODE 6600P

AUTH SCHINKE G.R., GOODIER J.L.
TITL INFORMATION FOR FIGHTING OIL POLLUTION, A CASE HISTORY
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1373, APR. 1971
ABST THIS PAPER OUTLINES A MODEL COASTAL POLLUTION CONTROL PROGRAM UNDERTAKEN AT A MULTI-USE TEST SITE IN MASS.
KEYW PREVENTION, CONTROL, GOVERNMENT/INDUSTRIAL COOPERATION
CODE 0631F

AUTH SCHINDLER H.D., TREYBAL R.E.
TITL CONTINUOUS - PHASE MASS TRANSFER COEFFICIENTS FOR LIQUID EXTRACTION IN AGITATED VESSELS
PUBL AICHE JOURNAL, VOL. 14, NO. 5, SEPT. 1968
ABST IN THIS WORK, INTERFACIAL AREA WAS DETERMINED IN SITU BY A LIGHT TRANSMISSION TECHNIQUE.
KEYW CONTINUOUS PHASE, MASS TRANSFER, LIQUID EXTRACTION, LIGHT TRANSMISSION
CODE 9070F

AUTH SCHITZBERG P., JACKSON D.
TITL REMOTE SAMPLER FOR DETERMINING RESIDUAL OIL CONTENT OF SURFACE WATERS
PUBL NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, 1973 CONFERENCE
KEYW REMOTE SAMPLER, DETERMINATION, CONTENT
CODE 0781A

AUTH SCHNEIDER L.
TITL A REVIEW OF OIL HANDLING PROBLEMS AT OFFSHORE TERMINALS - PART II PROGRAM FOR EXPERIMENTALLY EVALUATING ADVANCED OIL BARRIERS
PUBL US NATIONAL MARITIME RESEARCH CENTER, REPORT NO. NMRC-272-23100-814
CODE 07308

AUTH SCHULTZ D., TEBO L.B.
TITL BOON CREEK OIL SPILL
PUBL EPA, SURVEILLANCE AND ANALYSIS DIV., BIOLOGICAL SERVICES BRANCH, FOR 1975 CONFERENCE
ABST PAPER INCLUDES SAMPLING METHODS OF MACRO INVERTEBRATE, FISH, PERIPHYTON, SEDIMENT, WATER SAMPLES, AND HYDROCARBON ANALYSIS.
KEYW SAMPLING METHODS, SEDIMENT, FISH
CODE 01514R

AUTH SCHWARTZBERG H.
TITL THE MOVEMENT OF OIL SPILLS
PUBL PHYSICAL-BIOLOGICAL EFFECTS
ABST THE EFFECTS OF WINDS AND CURRENTS AND THE PHYSICAL PROPERTIES OF OIL AND WATER ON THE DRIFT RATES OF OIL SPILLS WERE STUDIED IN TESTS CARRIED OUT IN A COMBINED WATER BASIN WIND TUNNEL.
KEYW WINDS, WAVES, AND CURRENTS, DRIFT RATES
CODE 0044F

AUTH SCHWARTZBERG H.G.
TITL SPREADING AND MOVEMENT OF OIL SPILLS
PUBL WATER POLLUTION CONTROL RESEARCH SERIES, NTIS.

PB192 052, MAR. 1970
ABST THE SPREADING AND MOVEMENT OF OIL SPILLS ON WATER WERE INVESTIGATED. AREAS FOR SPILLS WHICH FORM LENSES WERE MEASURED AND CORRELATED.
KEYW OIL WATER INTERFACES, DRIFTING, WAVE/WIND
CODE 2561F

AUTH SCHWARTZBERG H.G. TREYBAL R.E.
TITL FLUID AND PARTICLE MOTION IN TURBULENT STIRRED TANKS
PUBL I AND EC FUNDAMENTALS, VOL. 7, FEB. 1968
ABST DIFFERENT EQUATIONS DESCRIBING PARTICLE MOTION IN A TURBULENT FLUID WERE APPLIED TO A FLOW MODEL FOR TURBULENT STIRRED TANKS. THE CALCULATED SLIP VELOCITIES INDICATE THAT PARTICLE TO FLUID MASS TRANSFER CANNOT BE EXPLAINED IN TERMS OF A SIMPLE SLIP VELOCITY MODEL.
CODE 9075F

AUTH SCOTT J.C., HUSTER D.
TITL THE INFLUENCE OF SURFACE ACTIVE CONTAMINATION ON THE INTERACTION BETWEEN WIND AND WAVES
PUBL HOUSTON UNIV. HOUSTON TEXAS, AD 734199
CODE 2097F

AUTH SEARLE W.F.
TITL TWO OIL SPILL CONTROL SYSTEMS TAILORED FOR SPECIFIC TASKS.
PUBL OCEAN INDUSTRY, VOL. 5, NO. 7, JULY 1970
ABST THIS ARTICLE REPORTS ON TWO SYSTEMS FOR CONTAINMENT AND REMOVAL: 1) THE OIL SCRUBBER FOR CALM WATER IN SHORE OIL SLICK REMOVAL AND 2) THE TSF BOOM FOR USE IN CONTAINING FLOATING OIL SLICKS IN ROUGH, OFFSHORE WATERS.
KEYW CONTAINMENT, REMOVAL, SCRUBBER, BOOM
CODE 3029F

AUTH SEMTNER A.J.
TITL AN OCEANIC GENERAL CIRCULATION MODEL WITH BOTTOM TOPOGRAPHY
PUBL DEPT. OF METEOROLOGY, UNIV. OF CAL. DEC. 21, 1974
ABST DOCUMENTS A NEW OCEANIC GENERAL CIRCULATION MODEL, RECENTLY CONSTRUCTED AT UCLA. THE MODEL ALLOWS PREDICTION OF THE THREE DIMENSIONAL FIELDS OF VELOCITY, TEMPERATURE AND SALINITY IN AN OCEAN OF ARBITRARY GEOMETRY. THE COMPUTER PROGRAM FOR THE MODEL MINIMIZES CORE STORAGE. A DISCUSSION OF THE PROGRAM AND A COMPLETE PROGRAM LISTING ARE INCLUDED IN THE REPORT.
KEYW VELOCITY, TEMPERATURE, SALINITY, CORE STORAGE
CODE 7698F

AUTH SHAPIRO A., ERICKSON A.
TITL ON THE CHANGING SIZE SPECTRUM OF PARTICLE CLOUDS UNDERGOING EVAPORATION, COMBUSTION OR ACCELERATION
PUBL 1956 HEAT TRANSFER AND FLUID MECHANICS INST., JUNE 21-23, 1956
ABST A THEORETICAL TREATMENT IS GIVEN SHOWING HOW THE SIZE DISTRIBUTION OF A CLOUD OF PARTICLES CHANGES AS THE RESULT OF EVAPORATION, COMBUSTION, OR ACCELERATION. SOLUTIONS TO THE DIFFERENTIAL EQUATION ARE THEN OBTAINED FOR A NUMBER OF SPECIAL PROBLEMS OF INTEREST TO EVAPORATION AND COMBUSTION.
KEYW DISTRIBUTION OF CLOUD PARTICLES, EVAPORATION, COMBUSTION, ACCELERATION
CODE 7138F

AUTH SHELL OIL CO.
TITL ECOLIBRIUM
PUBL ECOLIBRIUM VOL. 3, NO. 3, FALL 1974
ABST VARIOUS ARTICLES PERTAINING TO SPILLS.
KEYW SKIMMERS, INDUSTRIAL APPROACH, MARINE ENVIRONMENT
CODE 6578F

AUTH SHELTON R.
TITL DISPERSANT TOXICITY TEST PROCEDURE
PUBL UNITED KINGDOM MINISTRY OF AGRICULTURE FISHERIES AND FOOD, ENGLAND
ABST IN THIS REPORT THE INVESTIGATION OF THE TOXICITY OF CHEMICALS USED TO DISPERSE OIL AT SEA AND ON THE SHORE IS DISCUSSED IN RELATION TO THE GENERAL PROBLEMS OF THE EFFECTS ON FISHERIES AND MARINE LIFE AND THE METHODS USED TO DEAL WITH OIL SPILLS.
KEYW TOXICITY, DISPERSANTS, FISHERIES, MARINE LIFE
CODE 2149F

AUTH SHELTON R.G.J.
TITL EFFECTS OF OIL AND OIL DISPERSANTS ON THE MARINE ENVIRONMENT
PUBL PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON, B, VOL. 177, 1972
CODE 5056F

AUTH SHONTING D.H.
TITL RHODE ISLAND SOUND SQUARE KILOMETER STUDY: 1967 FLOW PATTERNS AND KINETIC ENERGY DISTRIBUTION
PUBL JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 74, NO. 13, JUNE 20, 1969
ABST THIS PAPER DISCUSSES THE PROBLEM OF THE PREDICTION OF THE TIME VARIABLE DISTRIBUTION OF OCEANOGRAPHIC PARAMETERS AT A GIVEN LOCATION OF THE OCEAN.
KEYW FLOW PATTERNS, ENERGY DISTRIBUTION, SPACE AND TIME GRADIENTS
CODE 2672F

AUTH SHONTING D.H., COOK G.S.
TITL ON THE SEASONAL DISTRIBUTION OF TEMPERATURE AND SALINITY IN RHODE ISLAND SOUND
PUBL REPRINT FROM LIMNOLOGY AND OCEANOGRAPHY, VOL. 15, NO. 1, JAN. 1970
ABST THE TEMPERATURE AND SALINITY OF RHODE ISLAND SOUND WERE MEASURED BETWEEN JULY 1961 AND JULY 1964.
KEYW TEMPERATURE AND SALINITY, THERMOCLINE, SALINITY PATTERNS, THERMAL ENERGY
CODE 2671F

AUTH SHUCHMAN R.A., JACKSON P.L., FELDKAMP G.A.
TITL PROBLEMS OF IMAGING OCEAN WAVES WITH SYNTHETIC APERTURE RADAR
PUBL ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN-AUGUST 1977
ABST PROGRESS IS REPORTED ON THREE TASKS DESIGNED TO PROVIDE INFO TO EVALUATE THE OPERATIONAL USE OF SAR. TASK 1: A LIMITED LITERATURE SEARCH. TASK 2: SOLUTIONS TO SAR SIGNAL PROCESSING PROBLEMS WERE EXPLORED. ALSO A DIGITAL CORRECTION ALGORITHM WAS DEVELOPED AND TESTED. TASK 3: AN ANALYSIS OF OPTICAL TRANSFORM OPERATIONS ON SAR WAVE IMAGERY WAS PERFORMED
KEYW OCEAN WAVES, REMOTE SENSING, SAR IMAGERY, DIGITAL PROCESSING
CODE 7700 F

AUTH SHULEIKIN V.V.
TITL MOLECULAR PHYSICS OF THE SEA PART B
PUBL TRANS. FROM FIZIKA MORYA, MOSCOW, AD 711957
CODE 0435F

AUTH SHUTTLEWORTH F. JEFFERY P.G.
TITL DISPERSANTS FOR OIL SPILL CLEAN-UP OPERATION: CARRIAGE AND CONTAINMENT AT SEA
PUBL WARREN SPRING LABORATORY, LR 195(OP), 1974
ABST THIS REPORT DESCRIBES THE CONSIDERABLE DIFFICULTIES EXPERIENCED WITH THE LOADING, UNLOADING AND USAGE OF STEEL DRUMS OF DISPERSANT.
KEYW CLEAN UP, DISPERSANTS, STEEL DRUMS, TANK STORAGE
CODE 2922F

AUTH SICKA R.W.
TITL OIL RECOVERY (FOAMS)
PUBL PROJECT 15080 EHP AUG. 1972
ABST AIR MODULATED VACUUM-OIL FOAMS RECOVERY COLLECTION OF SPILLED OIL
CODE 6366F

AUTH SIEMENS A.
TITL STATEMENT BY RADM. ABE SIEMENS
PUBL PRESENTED BEFORE THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY SUBCOMMITTEE OF ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION, JULY 8, [illegible]
ABST REMARKS ARE LIMITED TO COAST GUARD ACTIVITIES, WITH AN OVERVIEW OF GENERAL ACTIVITIES AND RESPONSIBILITIES.
KEYW VESSEL SAFETY, PORT SAFETY, POLLUTION INCIDENTS AND CLEANUP
CODE 5093F

AUTH SILVERMAN H., [illegible] E.C.
TITL MARYLAND'S EXPERIENCE IN OIL SPILL PREVENTION AND CONTROL
PUBL STATE OF MARYLAND, WATER RESOURCES ADMIN., FOR EPA 1975 CONFERENCE
ABST AN EXISTING SPILL PREVENTION AND RESPONSE PROGRAM IS DESCRIBED UTILIZES THE STATE WRA. EMPHASIS IS ON PREVENTION.
KEYW PREVENTION, CONTROL, MARYLAND
CODE 0077F

AUTH SIMPSON A.C.
TITL OIL EMULSIONS AND COMMERCIAL SHELLFISH
PUBL FIELD STUDY.
CODE 9051F

AUTH SITTIG M.
TITL OIL SPILL PREVENTION AND REMOVAL HANDBOOK
PUBL POLLUTION TECHNOLOGY REVIEW NO. 11, ENERGY TECHNOLOGY REVIEW NO. 7, OCEAN TECHNOLOGY REVIEW NO. 1, NOYES DATA CORP, PARK RIDGE, NJ, 1974
ABST THIS BOOK ATTEMPTS TO ORGANIZE AND CLARIFY THE MANY WAYS AND MEANS MADE AVAILABLE IN THIS LITERATURE FOR THE REMOVAL OF THE CONTAMINATING OIL FROM BOTH THE OCEANS SURFACES AND ITS BEACHES.
KEYW CLEANUP, ENERGY SOURCE, MISHAPS
CODE 40148

AUTH SIVADIER H.O., MIKOLAJ P.G.
TITL MEASUREMENT OF EVAPORATION RATES FROM OIL SLICKS ON THE OPEN SEA
PUBL FATE OF OIL
ABST DISCUSSES DEVELOPMENT OF GAS CHROMATOGRAPHIC METHOD OF ANALYSIS TO MEASURE THE TIME DEPENDENT EXTENT OF EVAPORATION FROM AN OIL SLICK AT OPEN SEA.
KEYW OIL SEEPS, EVAPORATION, SEA SURFACES
CODE 0854F

AUTH SMALL S.
TITL WHAT'S NEXT IN SUPER-TERMINALS?
PUBL MARINE ENGINEERING BECHTEL, INC.
ABST THIS PAPER ATTEMPTS TO GIVE SOME INSIGHT INTO THE PROBLEM OF ENGINEERING DEVELOPMENT FOR

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      SUPERTERMINALS IN THE NEAR FUTURE.
KEYW  SUPER TERMINALS, ENGINEERING DEVELOPMENTS,
      PROBLEMS
CODE  7103F

AUTH  SMALL S.W.
TITL  THE SUBMARINE PIPELINE AND SINGLE BUOY MOORING
PUBL  1969 CONFERENCE
CODE  0496F

AUTH  SMITH A.J.
TITL  SUCCESSES AND FAILURES WITH OIL SPILLS IN THE
      SOUTHEASTERN INLAND WATERS
PUBL  APPLIED CONTROL TECHNOLOGY
ABST  THIS PAPER PRESENTS A BRIEF REVIEW OF SEVERAL
      SPILL CASES THAT HAVE OCCURRED IN THE SOUTHEAST
KEYW  CONTAINMENT, RETENTION, REMOVAL METHODOLOGY
CODE  0505F

AUTH  SMITH C., MACINTYRE W.
TITL  INITIAL AGING OF FUEL OIL FILMS ON SEA WATER
PUBL  PHYSICAL-BIOLOGICAL EFFECTS
ABST  THE PROCESS OF AGING OR WEATHERING OF NOS. 2, 4,
      AND 6 FUEL OIL FILMS ON SEA WATER HAS BEEN STUDIED
      BOTH IN LAB APPARATUS AND AT SEA.
KEYW  WEATHERING, EVAPORATION, DISSOLUTION
CODE  0045F

AUTH  SMITH C.L.
TITL  FINAL REPORT DETERMINATION OF THE LEEWAY OF OIL
      SLICKS
PUBL  USCG, DEPT. OF TRANSPORTATION, REPORT NO.
      CG-D-60-75, AUG. 1974
ABST  THE LEEWAY OF OIL SLICKS WAS DETERMINED AS A
      FUNCTION OF WIND VELOCITY IN THE RANGE 9-25 KNOTS
      TO ENABLE MORE PRECISE FORECASTING OF THE
      TRAJECTORY OF OIL SPILLS AND THUS AID EFFECTIVE
      CONTAINMENT AND CLEANUP OPERATIONS.
KEYW  LEEWAY, WIND DRIFT FACTOR, TRAJECTORY,
      CONTAINMENT, CLEANUP
CODE  6180F

AUTH  SMITH D.C.
TITL  REHABILITATING OILED AQUATIC BIRDS
PUBL  INTERNATIONAL BIRD RESCUE RESEARCH CENTER FOR EPA
      1975 CONFERENCE
KEYW  REHABILITATION, OILED AQUATIC BIRDS
CODE  0100F

AUTH  SMITH G. F., MCCRACKEN W. E.
TITL  OHMSETT "HIGH SEAS" PERFORMANCE TESTING: MARCO
      CLASS V OIL SKIMMER
PUBL  MASON & HANGER-SILAS MASON CO.,INC. LEONARDO, NEW
      JERSEY
ABST  A MARCO CLASS V OIL SKIMMER WAS TESTED AT THE U.S.
      ENVIRONMENTAL PROTECTION AGENCY'S OHMSETT FACILITY
      TO DETERMINE THE DEVICE'S HIGH SEAS PERFORMANCE
      CHARACTERISTICS.  PERFORMANCE DATA WAS OBTAINED
      FOR SEVERAL SIMULATED OFFSHORE WAVE CONDITIONS AT
      VARIOUS COLLECTION SPEEDS.  SKIMMER EFFICIENCY WAS
      DETERMINED AT VARIOUS BELT SPEEDS & INDUCTION PUMP
      RATES IN ORDER TO DEFINE OPTIMUM SKIMMER SETTINGS.
KEYW  SKIMMER, OIL/WATER SEPARATOR, SIMULATED RECOVERY
CODE  7649 F

AUTH  SMITH G.F.
TITL  TECHNIQUES FOR MIXING DISPERSANTS WITH SPILLED OIL
PUBL  MASON AND HANGER-SILAS MASON CO., INC. FINAL
      REPORT APRIL 22 - MAY 6, 1976
ABST  THE EFFECTIVE USE OF SOME OIL SPILL DISPERSANTS
      REQUIRES THE ADDITION OF MIXING ENERGY TO THE
      DISPERSANT-TREATED SLICK.  VARIOUS METHODS OF
      ENERGY APPLICATION HAVE INCLUDED THE USE OF FIRE
      HOSE STREAMS DIRECTED TO THE WATER SURFACE,
      OUTBOARD MOTORS MOUNTED ON WORK BOATS AND THE FIVE
      BAR GATE.  ANALYSIS OF THE RESULTS SHOWED THAT THE
      MODIFIED FIVE BAR GATE PRODUCED THE GREATEST
      OVERALL PENETRATION (2.4 M) AT A TOW SPEED OF 2/0
      M/S.  IN GENERAL, PERFORMANCE WAS UNAFFECTED BY
      WAVE ACTION, AND VARIATIONS IN INTERFACIAL TENSION
      PRODUCED NO OBSERVABLE TREND AMONG ALL DEVICES.
KEYW  OILSPILL CLEANUP, DISPERSANTS, PERFORMANCE TESTS
CODE  7735F

AUTH  SMITH J.E.
TITL  TORREY CANYON POLLUTION AND MARINE LIFE
PUBL  TORREY CANYON POLLUTION AND MARINE LIFE
ABST  A REPORT BY THE PLYMOUTH LAB OF THE MARINE
      BIOLOGICAL ASSOC. OF THE UNITED KINGDOM
CODE  1117F

AUTH  SMITH J.W.
TITL  THE CONTROL OF OIL POLLUTION
PUBL  GRAHAM AND TROTMAN LTD., LONDON, 1976
ABST  THE EFFECTS OF OIL SPILLS ON THE MARINE
      ENVIRONMENT AND METHODS OF DEALING WITH THEM ARE
      DISCUSSED.
KEYW  SOURCE OF OIL, REMOVAL, BACTERIAL DEGRADATION,
      ENVIRONMENTAL EFFECTS
CODE  3511B

AUTH  SMITH R.
TITL  OIL SPILL REMOVAL A BIBLIOGRAPHY WITH ABSTRACTS
PUBL  GOVERNMENT REPORTS ANNOUNCEMENTS, 74(13):104, JUNE
      1974
CODE  1127B

AUTH  SMITH R.F.
TITL  OIL WATER SEPARATORS
PUBL  NTIS/PS-76/0663, 1964-SPT. 1976
ABST  THE CITATIONS COVER FEDERALLY SPONSORED RESEARCH
      ON THESE DEVICES PRIMARILY FOR OIL POLLUTION
      CONTROL. OIL RECOVERY FROM OIL SPILLS AND
      SEPARATORS FROM BALLAST AND BILGE WATER ARE
      INCLUDED.
KEYW  FEDERALLY SPONSORED RESEARCH, CONTROL, SKIMMERS,
      RECOVERY
CODE  6588F

AUTH  SNOOKLER AL, HARDEN J.W.
TITL  NAVY SHIPBOARD INVESTIGATION OF OILY WASTES
PUBL  NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, FOR
      EPA 1975 CONFERENCE
ABST  THE NAVY'S SHIPBOARD OILY WASTE PROBLEM IS
      DEFINED. THE NATURE SOURCES, AND GENERATION RATES
      OF OILY WASTE PRODUCED BY NAVAL SHIPS WHILE IN
      PORT AND AT SEA UNDER VARIOUS MODES OF OPERATION
      ARE PRESENTED.
KEYW  OILY WASTE PROBLEM, SOURCES, GENERATION RATES,
      NAVY SHIPS
CODE  0092F

AUTH  SNOW N.B., SCOTT B.F.
TITL  THE EFFECT AND FATE OF CRUDE OIL SPILT ON TWO
      ARCTIC LAKES
PUBL  CONFERENCE ON THE PREVENTION AND CONTROL OF OIL
      POLLUTION
ABST  THIS PAPER DISCUSSES EXPERIMENTS PERFORMED ON OIL
      SPILLED ON ARCTIC LAKES.
KEYW  DELETERIOUS EFFECTS, BIODEGRADATION PROCESSES,
      CLEANUP AND CONTINGENCY
CODE  0575F

AUTH  SOLOMAN L.
TITL  A PNEUMATIC BOOM FOR CONTAINING OIL SLICKS ON THE
      SEA
PUBL  M.I.T. FEB. 1969
ABST  PRELIMINARY EXPERIMENTS WERE PERFORMED AS TO THE
      FEASIBILITY OF THE USE OF A PNEUMATIC BOOM IN
      CONTAINING OIL SLICKS.
KEYW  PNEUMATIC BOOMS, BUBBLE EXPERIMENTS, CONTAINMENT
CODE  0946F

AUTH  SOLSBERG L.B., ROSS C.W., LOGAN W., FINGAS M.
TITL  FIELD EVALUATION OF SEVEN OIL SPILL RECOVERY
      DEVICES
PUBL  ENVIRONMENTAL EMERGENCY BRANCH EPS, REPORT NO. EPS
      4-EC-76-3, AUG. 1976
ABST  THE ENVIRONMENTAL AND TEST CONDITIONS UNDER WHICH
      THE SEVEN DEVICES WERE EVALUATED ARE DESCRIBED
      HEREIN.
KEYW  OIL RECOVERY RATE, OIL RECOVERY FACTOR, OIL
      CONTENT FACTOR, EMULSIFICATION FACTOR
CODE  7145F

AUTH  SONG C.J.
TITL  ENVIRONMENTAL FACTORS CONTROLLING THE SPREAD OF
      OIL
PUBL  NAVAL RESEARCH REVIEW, VOL. 24, 1971
CODE  2071R

AUTH  SORENSEN, R.M., SPENCER E.R.
TITL  TWO-DIMENSIONAL WIND SETUP OF OIL ON WATER
PUBL  JOURNAL OF THE WATERWAYS, HARBORS AND COASTAL
      ENGINEERING DIVISION, AUG. 1971
ABST  THIS ARTICLE PRESENTS AN ANALYTICAL AND
      EXPERIMENTAL STUDY TO PREDICT THE TWO DIMENSIONAL
      SETUP AND SETDOWN OF OIL OF SPECIFIC DENSITY AND
      VISCOSITY SUBJECTED TO A WIND STRESS ACTING OVER A
      GIVEN FETCH.
KEYW  TWO-DIMENSIONAL SETUP AND SETDOWN, WIND STRESS,
      WIND VELOCITY AND FETCH
CODE  9120F

AUTH  SOIMAN F.
TITL  CHOIX DE PRODUIT POUR LUTTER CONTRE LA POLLUTION
      DU MILIEU MARIN PAR LES HYDROCARBON.I. MOTIF DU
      CHOIX
PUBL  FRANCE, INSTITUT SCIENTIFIQUE ET TECHNIQUE DES
      PECHES MARITIMES, NANTES. REVUE DES TRAVAUX
      36(1):81-83
CODE  1103R

AUTH  SOUTHWARD A.J., SOUTHWARD E.C.
TITL  RECOLONIZATION OF ROCKY SHORES IN CORNWALL AFTER
      USE OF TOXIC DISPERSANTS TO CLEANUP THE TORREY
      CANYON SPILL
PUBL  JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST  AN ACCOUNT OF THE RECOLONIZATION OF THE INTERTIDAL
      ZONE.
KEYW  DISPERSANT, RECOLONIZATION, COASTAL ECOLOGY
CODE  2669F

AUTH  SPAULDING M.
TITL  NUMERICAL MODELING OF POLLUTANT TRANSPORT USING A
      LAGRANGIAN MARKER PARTICLE TECHNIQUE  AUGUST 1976
PUBL  NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ABST  A DERIVATION AND CODE HAVE BEEN DEVELOPED FOR THE
      THREE-DIMENSIONAL MASS TRANSPORT EQUATION, USING A
      PARTICLE-IN-CELL SOLUTION TECHNIQUE, TO SOLVE THE
      WASTE.  IMPROVEMENTS IN THE PARTICLE MOVEMENT
      TECHNIQUES HAVE BEEN SUGGESTED AND TYPICAL
      EXAMPLES ILLUSTRATED.  PRELIMINARY MODEL COMP.
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WITH ANALYTIC SOLUTIONS FOR AN INSTANTANEOUS POINT RELEASE HAVE SHOWN GOOD RESULTS IN RESOLVING THE WASTE MOTION. THIS MODEL WILL PROVIDE A USEFUL TECHNIQUE TO STUDY THE MOTION OF SEDIMENT, DREDGED SPOILS, AND OTHER PARTICULATE WASTE LOADS DEPOSITED IN COASTAL WATERS.
CODE - 7754F

AUTH SPAULDING M.L., BROWN G.A., WHITE F.M.
TITL APPLYING WATER QUALITY MODEL TO POLLUTION MANAGEMENT
PUBL NOAA SEA GRANT, URI, MARINE TECHNICAL REPORT 26, 1974
ABST TO HELP PROVIDE TECHNICAL ALTERNATIVES THE AUTHORS DEVELOPED A WATER QUALITY MODEL FOR THE DISSOLVED OXYGEN-BIOCHEMICAL OXYGEN DEMAND SCHEME FOR NARRAGANSETT BAY
KEYW WATER POLLUTION MANAGEMENT, DISPOSAL, SELF CLEANING CAPACITIES
CODE 2941F

AUTH SPILLANE L.T.
TITL MOVEMENT OF OIL ON THE SEA SURFACE
PUBL AUSTRALIAN METEOROLOGICAL MAG., VOL. 19, NO. 4,
CODE 2072P

AUTH SPRIGG R.C., MCEWIN S.
TITL POLLUTION AND CONSERVATION OF THE AUSTRALIAN COASTLINE
PUBL AUSTRALIAN PETROLEUM EXPLORATION ASSOCIATION JOURNAL, 1971
ABST DISCUSSION ON OIL POLLUTION WHILE DRILLING ON THE GREAT BARRIER REEF, ALSO INCLUDES MENTION OF ADVANTAGES OF OFFSHORE DRILLING.
CODE 3069R

AUTH STAINKEN D.M.
TITL EFFECTS OF UPTAKE AND DISCHARGE OF PETROLEUM HYDROCARBONS ON THE RESPIRATION OF THE SOFT-SHELL CLAM, MYA ARENARIA
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST A WINTER SPILL CONDITION WAS SIMULATED IN WHICH YOUNG SOFT SHELL CLAMS WERE EXPOSED TO SUBACUTE CONCENTRATIONS OF NO. 2 FUEL OIL-IN-WATER EMULSIONS FOR 28 DAYS.
KEYW RESPIRATION, PETROLEUM EMULSION, PETROLEUM ACCUMULATION, DEPURATION
CODE 2669F

AUTH STAINKEN D.M.
TITL PRELIMINARY OBSERVATIONS ON THE MODE OF ACCUMULATION OF NO. 2 FUEL OIL BY THE SOFT SHELL CLAM, MYA ARENARIA.
PUBL RUTGERS UNIV., DEPT. OF ZOOLOGY AND PHYSIOLOGY FOR EPA CONFERENCE 1975
KEYW OBSERVATIONS, MODE OF ACCUMULATION, NO. 2 FUEL OIL, SOFT SHELL CLAM
CODE 0135A

AUTH SJAMULIS A.
TITL FINAL REPORT - THE VORTEX PRINCIPLE, A METHOD FOR CONCENTRATING MATERIALS FROM A LIQUID PHASE
PUBL NAVAL RESEARCH LAB., AD 730802, NRL-MR-2401
CODE 0403R

AUTH STANFORD A.E., JARVIS B.N.
TITL WAYS AND MEANS OF DEALING WITH OIL POLLUTION
PUBL IN SYMPOSIUM ON MARINE POLLUTION LONDON ROYAL INSTITUTE OF NAVAL ARCHITECTS
CODE 3101R

AUTH STANLEY M.G., KAPLANER D.W.
TITL FINAL REPORT - A BIBLIOGRAPHY ON OCEAN WASTE DISPOSAL SECOND EDITION
PUBL EPA, OCEAN DISPOSAL PROGRAM, PB 265 031, SEPT. 1976, REPORT NO. 440000417
ABST THIS RESEARCH BIBLIOGRAPHY WAS PREPARED FOR THE OFFICE OF WATER PROGRAM OPERATIONS, USEPA. IT IS RESTRICTED TO DOCUMENTS RELEVANT TO THE FIELD OF OCEAN WASTE DISPOSAL. IT IS PRIMARILY LIMITED TO RECENT PUBLICATIONS IN THE CATEGORIES OF: GENERAL OCEAN WASTE DISPOSAL, NON-POINT SOURCE, OCEANIC DISPOSAL OF RADIOACTIVE WASTES, AT-SEA INCINERATION.
KEYW OCEAN WASTE DISPOSAL, COASTAL ZONE MANAGEMENT, DREDGE SPOIL
CODE 7211F

AUTH STEARS R.P., ROSS D.E., MORRISON R.
TITL OIL SPILL: DECISIONS FOR DEBRIS DISPOSAL VOL.II
PUBL EPA-600/2-77-153B, AUG. 1977
ABST THIS REPORT WAS PREPARED TO GUIDE PERSONS RESPONSIBLE FOR DISPOSING OF OIL SPILL CLEANUP DEBRIS IN SELECTING SUITABLE SITES FOR DEBRIS DEPOSITION AND IN EFFECTING PROPER DISPOSAL OPERATIONS.
KEYW DEBRIS DISPOSAL, CLEANUP, PRIOR PLANNING
CODE 2661F

AUTH STEGEMAN J.J.
TITL INFLUENCE OF ENVIRONMENTAL CONTAMINATION ON CYTOCHROME P-450 MIXED-FUNCTION OXYGENASES IN FISH: IMPLICATIONS FOR RECOVERY IN THE WILD HARBOR MARSH
PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST DISCUSSION ON LEVELS OF CONTAMINANTS IN MUMMICHOG, FUNDULUS HETEROCLITUS IN CONTAMINATED MARSHES.
KEYW MIXED FUNCTION OXYGENASES, ENVIRONMENTAL CONTAMINATION, RECOVERY
CODE 2669F

AUTH STEINHART C.E. AND J.S.
TITL BLOWOUT - A CASE STUDY OF THE SANTA BARBARA OIL SPILL
PUBL DUXBURY PRESS, BELMONT, CALIFORNIA 1972
ABST THIS BOOK EXAMINES IN MINUTE DETAIL ALL OF THE SANTA BARBARA'S POLITICAL, ECOLOGICAL, AND SCIENTIFIC RAMIFICATIONS. IT ASSESSES THE ENVIRONMENTAL CONCERNS INVOLVED AS WELL AS THOSE OF THE PETROLEUM INDUSTRY AND THE GOVERNMENTAL AGENCIES.
CODE 3060R

AUTH STEINMAN G.C., CHAPPEL W.P.
TITL THE MARITIME ADMINISTRATION PROGRAM FOR THE PREVENTION AND CONTROL OF OIL POLLUTION FROM VESSELS
PUBL ENVIRONMENTAL ACTIVITIES GROUP, MARITIME ADMIN., FOR EPA 1975 CONFERENCE
ABST THIS PAPER PROVIDES AN OVERVIEW OF THE MARITIME ADMIN. PROGRAM TO ABATE AND CONTROL OIL POLLUTION FROM SHIPS. RECOMMENDATION FOR FUTURE ACTION TO ABATE SHIP-GENERATED POLLUTION AT THE NATIONAL AND INTERNATIONAL LEVELS ARE PROVIDED.
KEYW MARITIME ADMINISTRATION PROGRAM, ABATEMENT, FEDERAL, NATIONAL, INTERNATIONAL
CODE 0090R

AUTH STEWART J.E., MARKS L.J.
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KEYW HYDROCARBON, HYDROCARBON-UTILIZING BACTERIA, PETROLEUM SEDIMENT
CODE 2669F

AUTH STEWART J.R.
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PUBL APPLIED CONTROL TECHNOLOGY
ABST THIS PAPER IS PURELY DESCRIPTIVE AND FINDINGS REFLECT ACTUAL PHYSICAL CONSTRUCTION AND TESTS ONLY.
KEYW RECOVERY, JET WATER SYSTEM, SURFACE TENSION
CODE 0014F

AUTH STEWART R.J.
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PUBL US COUNCIL ON ENVIRONMENTAL QUALITY, MIT 1974
CODE 2073R

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PUBL SCIENCE, VOL. 195, JAN. 1976
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KEYW DRILLING, TANKERS, BLOWOUTS
CODE 2661F

AUTH STEWART W.S.
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PUBL EXXON RESEARCH AND ENGINEERING CO., FOR EPA 1975 CONFERENCE
ABST INFORMATION IS PRESENTED CONCERNING THE EFFECTIVE DOSAGE OR CONCENTRATION LEVELS OF THE MATERIALS REQUIRED TO AFFORD PROTECTION OF ROCKS AGAINST OIL CONTAMINATION, THE METHODS OF APPLICATION, THE EFFECTS OF TEMPERATURE, THE DURATION OF PROTECTION OFFERED, AND THE OVERALL EFFICIENCY OF THE SYSTEMS.
KEYW PROTECTION, MICROBIOLOGICAL AND NATURAL PRODUCTS SYSTEMS, CONTAMINATION
CODE 0129R

AUTH STIRLING A.G.
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CODE 3135R

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AUTH STRAUGHAN D.
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PUBL INTERLIBRARY LOAN, OHIO UNIVERSITY LIBRARY, ATHENS, OHIO 45701
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KEYW ENVIRONMENTAL FACTORS, SYNERGISTIC EFFECTS, SANTA BARBARA CHANNEL
CODE 2541F

AUTH STRAUGHAN, D.
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ABST THIS PAPER PROVIDES SOME BIOLOGICAL BACKGROUND ON THE SANTA BARBARA OIL SPILL IN 1969 AND DISCUSSES BIOLOGICAL STUDIES SUBSEQUENT TO THIS OIL SPILL.
KEYW SAMPLING, ANALYTICAL TECHNIQUES, BIOLOGICAL IMPACT
CODE 2640F

AUTH STRUZESKI E.J., DEWLING R.T.
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ABST STEADY DISSOLVING OF A LOW SURFACE TENSION LIQUID AT THE FREE SURFACE OF A HIGHER SURFACE TENSION ONE. EFFECTS OF SURFACE TENSION AND CONCENTRATION DIFFERENCES AS WELL AS THAT OF VISCOSITY ARE EXAMINED.
KEYW SURFACE TENSION, CONCENTRATION DIFFERENCES, VISCOSITY
CODE 6307S

AUTH SUESS M.J.
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CODE 1109P

AUTH SULLIVAN C.E.
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PUBL REP. OIL POLLUT. RES. UNIT. FLD. STUD. COUN., 1971, 14-21
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AUTH SURVEYOR AMERICAN BUREAU OF SHIPPING
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PUBL CORNELL UNIV. FOR EPA 1975 CONFERENCE
KEYW EFFECTS, LIGHT OIL, PERSISTENCE
CODE 01524P

AUTH SWANSON J.C., SPAULDING M.L.
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PUBL DEPT. OF OCEAN ENGINEERING, URI
ABST USING AN EXPLICIT NUMERICAL TECHNIQUE, THE TWO DIMENSIONAL (R-Z) MOMENTUM EQUATIONS FOR OIL SPREADING ON AN OIL SURFACE ARE SOLVED.
KEYW OIL SPREAD ON ICE SURFACE, NUMERICAL TECHNIQUE, MODEL PREDICTIONS
CODE 2943S

AUTH SWEDMAN M., GRANMO A., KOLLBERG S.
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PUBL WATER RESEARCH, VOL. 7, 1973
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KEYW DISPERSANTS, CLEANUP, TOXICITY
CODE 7126F

AUTH SWEDMARK M.
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AUTH SWEET W.E.
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PUBL FIFTH ANNUAL CONFERENCE, APRIL 29 - MAY 2, 1973, PAPER NO. OTC 1803
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AUTH SWEET, W.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2002, MAY 6-8, 1974
ABST THE CONTENTION OF THIS PAPER IS THAT NATURAL SEEPAGE COULD ACTUALLY ACCOUNT FOR A MAJOR PORTION OF THE TAR BALLS FOUND IN THE SEA.
KEYW TARBALLS, SEEPAGE, NEW CONCEPT
CODE 0860F

AUTH SWIFT W., TOWHILL C.J., MANEY W.A., MARATANI R.F., PETERSON P.L. DES VOIGNE D.S.
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PUBL FEDERAL WATER POLLUTION CONTROL ADMINISTRATION, NO. 14-12-530 FWPCA NO. 15080EA, JULY 1969
ABST EFFECTS AND OPERATIONS CONCERNED WITH SANTA BARBARA OIL EMISSION INCIDENT.
KEYW SOURCES, EFFECTS, CONTROL, TREATMENT, TOXICITY
CODE 9042F

AUTH SWIFT W.H., TOUHILL C.J., PETERSON P.L.
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AUTH SWISHER R.D.
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PUBL UNKNOWN
ABST FACTORS PROMPTING THE REDESIGN OF COMMERCIAL SURFACTANTS IN THE 1960'S, RELATIONSHIP OF THEIR CHEMICAL STRUCTURE TO THEIR BIODEGRADATION AND THE METABOLIC PATHWAYS INVOLVED ARE REVIEWED.
KEYW COMMERCIAL SURFACTANTS, BIODEGRADATION, METABOLIC PATHWAYS
CODE 2942F

AUTH TALTS A., BRYER J., MARTIN C., REEVES D.
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PUBL UNKNOWN
ABST THIS PAPER DISCUSSES SPILL PLANS FOR TERMINALS IN AREAS WITH POROUS SOIL SHOULD INCLUDE PROVISIONS FOR CONTAINMENT AND RECOVERY OF POTENTIAL LEAKS AND SPILLS FROM WITHIN THE GROUND.
KEYW CONTAINMENT, RECOVERY, TERMINALS
CODE 6357F

AUTH TARZWELL C.M.
TITL COMMENTS ON STANDARD METHODS FOR THE DETERMINATION OF THE RELATIVE TOXICITY AND VARIOUS OILS TO AQUATIC ORGANISMS
PUBL AMERICAN PETROLEUM INSTITUTE, PROCEEDINGS OF THE INDUSTRY GOVERNMENT SEMINAR ON THE OIL SPILL TREATING AGENTS, WASHINGTON, D.C., PP. 80-85
KEYW TOXICITY, DISPERSANTS, AQUATIC ORGANISMS
CODE 1025P

AUTH TARZWELL C.M.
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CODE 1123H

AUTH TAYFUN M.A., WANG H.
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CODE 0418P

AUTH TAYLOR G.
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PUBL RECEIVED 24 MARCH 1955
ABST THE CONDITIONS UNDER WHICH AN OUTWARD-FLOWING SURFACE CURRENT CAN PREVENT PASSAGE OF WAVES COMING IN FROM THE SEA ARE INVESTIGATED MATHEMATICALLY.
KEYW OUTWARD-FLOWING SURFACE CURRENT, WAVES
CODE 3521P

AUTH TAYLOR W.E.L.
TITL TORREY CANYON EXERCISE MOP UP
PUBL ADMIRALTY OIL LABORATORY,REPORT NO 52, MARCH 1968
ABST THE WRECKING OF THE TORREY CANYON ON THE 18TH OF MARCH 1967 CAUSED SEVERE OIL POLLUTION OF THE COASTLINE OF CORNWALL AND THE BRITTANY COAST OF FRANCE. THIS PAPER DISCUSSES THE VARIOUS METHODS THE BRITISH AND FRENCH USED IN CLEAN-UP, THE EFFECT OF WIND AND WEATHER ON SUCH OPERATIONS AND VARIOUS TESTS ON COMMERCIAL MATERIALS.
KEYW TORREY CANYON, CLEANUP, WIND AND WEATHER
CODE 3010P

AUTH TAYLOR W.E.L., WYLLIE D.
TITL FRANCE AND THE TORREY CANYON
PUBL ADMIRALTY OIL LABORATORY, A.O.L. TECHNICAL NOTE NO. 31, AUG. 1967
ABST THIS REPORT CONCERNS THE FRENCH APPROACH TO THE SPILLAGE FROM THE TORREY CANYON ON MARCH 18, 1967. SINCE THE FRENCH WERE UNABLE TO USE DETERGENTS BECAUSE OF THEIR VALUABLE INSHORE FISHERIES THEY RELIED ON MECHANICAL MEANS AND SAWDUST AND STRAW. IT DISCUSSES THE EFFECT ON THE BEACHES AND INCLUDES SEVERAL MAPS OF THE AFFECTED AREAS.
CODE 3008P

AUTH TEAL J.M., BURNS K., FARRINGTON J.
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KEYW AROMATIC HYDROCARBONS, GAS CHROMATOGRAPHY, MASS SPECTROMETRY
CODE 2669F

AUTH TEISON D.H.
TITL THE MOVEMENT OF OIL SLICKS AT SEA: PRELIMINARY MODEL STUDIES OF WIND AND CURRENT EFFECTS IN STUDY OF OIL SLICK DRIFT
PUBL U.R.I. THESIS, 1969
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KEYW PREDICTING BEHAVIOR, DRIFT PROCESS, WIND AND -CURRENT
CODE 0853F

AUTH TEMPLETON W.L.
TITL ECOLOGICAL EFFECTS OF OIL POLLUTION
PUBL WATER POLLUTION CONTROL FEDERAL JOURNAL, VOL. 44, NO. 6, JUNE 1972
ABST THIS PAPER DISCUSSES MONITORING OCEANS FOR POLLUTION AND PROTECTION.
KEYW PROTECTION, DISPERSANTS, ECOLOGICAL EFFECTS
CODE 2119F

AUTH TEMPLETON W.L., SUTTON E.A., DEAN R.M., ARNETT R.C., WILDUNG R.E., BLAYLOCK J.W., MOORE N.J.
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ABST THE RESULTS OF A TWO-YEAR STUDY ON THE IMPACT OF OIL DISCHARGES ON THE FISHERY RESOURCES OF LAKE MARACAIBO, VENEZUELA ARE PRESENTED.
KEYW OIL DISCHARGES, FISHERY RESOURCES, EFFECTS, LAKE MARACAIBO, VENEZUELA
CODE 0119R

AUTH TEMPLETON W.L., WALKUP P.C., MACKLAN J.
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PUBL INDUSTRY GOVERNMENT SEMINAR, API, US DEPT. OF THE INTERIOR, 1970
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KEYW DISPERSANTS, TREATING AGENTS, EFFECTIVENESS, TOXICITIES
CODE 9070F

AUTH TEXAS A AND M UNIVERSITY
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PUBL TEXAS A AND M UNIVERSITY, SEA GRANT PROGRAM, DEC. 1972
ABST THE OBJECTIVE OF THIS STUDY WAS TO CONDUCT AN EVALUATION OF THE ENVIRONMENTAL IMPACT OF A DEEP SEA PORT OFF THE TEXAS COAST.
KEYW ENVIRONMENTAL IMPACT, CONSTRUCTION AND OPERATION, PHYSICAL, BIOLOGICAL, AND CULTURAL FEATURES IMPACTED
CODE 0802F

AUTH TEZUKA T., ARAMAKI K.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2000, MAY 6-8, 1974
ABST MODEL BUILT OF A PROTOTYPE OF AN OIL RECOVERY BOAT TO CONDUCT WATER TANK TESTS. ACTUAL PERFORMANCE TESTS WERE CONDUCTED ON SEA WATERS.
KEYW RECOVERY, CATAMARANS, TESTING
CODE 0551F

AUTH THOMAS J.F., PAULS C.F.
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CODE 0476R

AUTH THOMAS M.L.H.
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PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
ABST THIS STUDY SHOWS SEVERAL ADDITIONAL BIOTIC EFFECTS OF OIL IN CHEDABUCTO BAY AND CONFIRMS PREVIOUS ONES.
KEYW HYDROCARBON, INTERTIDAL COMMUNITY, SEDIMENT
CODE 2669F

AUTH THOMAS M.L.H.
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CODE 1094R

AUTH THYRUM P.
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PUBL NAVAL AIR PROPULSION TEST CENTER, AD-A036367, FEB. 1975
ABST RECENT DECISIONS TO ENFORCE FEDERAL WATER POLLUTION CONTROL LAWS HAVE LED TO AN URGENT NEED FOR SENSITIVE RAPID AND SIMPLE FIELD METHOD FOR DETERMINATION OF OIL IN WATER. A NEW DETECTOR MEETING THESE REQUIREMENTS AND DESIGNED FOR SHIPBOARD USE WAS DESIGNED. THIS PAPER EXPLAINS THIS PROCEDURE.
KEYW CONTAMINATION, CONTAMINATION DETECTORS, BILGE CONTAMINATION
CODE 6352F

AUTH TIBBETTS A.M.
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PUBL CONFERENCE ON THE PREVENTION AND CONTROL OF OIL POLLUTION
ABST THIS PAPER DISCUSSES THE TRAINING OF A CLEANUP RESPONSE TEAM.
KEYW CLEANUP TEAMS, RESPONSE TEAM, JOB DESCRIPTION, OBJECTIVES, SEMINARS, PRACTICE
CODE 0816F

AUTH TINGLE A., DIETERLE D.
TITL A NUMERICAL STUDY OF POLLUTANT DISTRIBUTIONS IN SEA BREEZE CIRCULATIONS
PUBL NATIONAL BUREAU OF STANDARDS, BNL-21600, 763918-2
ABST IN THIS PAPER PRELIMINARY RESULTS OF A NUMERICAL STUDY OF THE EFFECT OF SEA BREEZE CIRCULATIONS ON AIR POLLUTANT DISTRIBUTIONS ARE EXAMINED.
KEYW SEA/LAKE BREEZE FLOWS, CONTAMINATION, RECIRCULATION OF POLLUTANTS
CODE 1290R

AUTH TINGLE A.G., DIETERLE D.A.
TITL A NUMERICAL OIL TRAJECTORY FORECAST MODEL USED TO ASSESS THE HAZARD TO LONG ISLAND BEACHES FROM OIL ENTERING THE NEW YORK BIGHT AREA FROM FE. 11-24, 1977
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ABST THIS PAPER IS A REPORT ON OIL SPILLING INTO THE HUDSON RIVER FROM A GROUNDED BARGE ENTERING THE N.Y. BIGHT AREA ON FEB. 11, 1977.
CODE 2677F

AUTH TOLZENBACH K.D., MADSEN O.S., ADAMS E.E., POLLACK A.M., COOPER C.K.
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PUBL MIT REPORT NO. MITSG 77-8, MARCH 1977
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KEYW LOCATION, SIZE, PROPERTIES, TRANSPORT, PHYSICAL, BIOLOGICAL AND CHEMICAL TRANSFORMATIONS
CODE 6135S

AUTH TOMS
TITL OIL POLLUTION OF INLAND WATERS IN ENGLAND AND WALES
PUBL WESSEX WATER AUTHORITY
ABST DESCRIBES THE SET UP OF TEN WATER AUTHORITIES IN ENGLAND TO MANAGE THE CLEANLINESS OF WATER AND TREATMENT OF SEWAGE. ALSO THE NEW CONTROL OF POLLUTION ACT 1974 IS EXAMINED.
KEYW WATER AUTHORITIES, CLEANLINESS AND SEWAGE

TREATMENT, CONTROL OF POLLUTION ACT 1974
CODE 0072P

AUTH TRACY H., WORLES C.E., LEE R.A., SANBORN G.
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PUBL WATER-POLLUTION CONTROL FEDERAL JOURNAL, VOL. 41, JULY-DEC. 1969
ABST THIS PAPER DISCUSSES RESULTS FROM TESTS ON OIL DISPERSING PRODUCTS.
KEYW DISPERSANTS, TOXICITY, EMULSIFYING-EFFICIENCY TESTS
CODE 2118F

AUTH TRAVERS W.B., LUNEY P.R.
TITL DRILLING, TANKERS, AND OIL SPILLS ON THE ATLANTIC OUTER CONTINENTAL SHELF
PUBL SCIENCE, VOL. 194, NO. 4267, NOV. 19, 1976
ABST THIS ARTICLE DISCUSSES FIRST THE GEOLOGIC CONDITIONS WHICH HAVE CONTRIBUTED TO SPILLS ON THE WEST COAST AND GULF COAST AREAS AND THEN DISCUSSES THOSE WHICH WILL AFFECT DRILLING ON THE ATLANTIC OUTER CONTINENTAL SHELF.
KEYW PREDICTING, TANKERS, DRILLING
CODE 2635F

AUTH TRAXLER R.W.
TITL MICROBIAL DEGRADATION OF PETROLEUM AT LOW TEMPERATURE
PUBL MARINE POLLUTION BULLETIN, AUG. 1973, VOL. 4, (NO. 8)
ABST BACTERIA WERE ISOLATED FROM LITTORAL SEDIMENTS COLLECTED IN CHEDABUCTO BAY, NOVA SCOTIA, AND FROM OIL-CONTAMINATED SOIL ADJACENT TO A NATURAL OIL SEEP AT CAPE SIMPSON, ALASKA. DATA ARE PRESENTED ON THE RANGE OF HYDROCARBON UTILIZATION AND GROWTH TEMPERATURE OF 2 BACTERIA, WHICH SUGGESTS THAT BACTERIA EXISTING IN THESE ENVIRONMENTS PLAY A SIGNIFICANT ROLE IN THE BIODEGRADATION OF POLLUTANT HYDROCARBONS.
CODE 6123R

AUTH TRAXLER R.W.
TITL PETROLEUM DEGRADATION IN LOW TEMPERATURE MARINE AND ESTUARINE ENVIRONMENTS
PUBL URI DEPT. OF PLANT PATHOLOGY-ENTOMOLOGY, ANNUAL REPORT NO. 1, OFFICE OF NAVAL RESEARCH CONTRACT NO. N00014-68-A-0215-0013, TASK NO. NR 306-076, MAY 1974
ABST STUDIES OF THE ENRICHMENT OF HYDROCARBONS AND FUEL OIL UTILIZING BACTERIA FOLLOWING A SPILL IN NARRAGANSETT BAY.
KEYW BIODEGRADATION, BACTERIA, HYDROCARBONS
CODE 29314F

AUTH TRAXLER R.W., BHATTACHARYA L.S.
TITL EFFECT OF A CHEMICAL DISPERSANT ON MICROBIAL UTILIZATION OF PETROLEUM HYDROCARBONS
PUBL ASTM SPECIAL TECHNICAL PUBLICATION 659
ABST THE DISPERSANT COREXIT 9527 WAS FOUND TO ENHANCE METABOLISM OF KUWAIT AND SOUTH LOUISIANA CRUDE OILS AS WELL AS PURE NON-MECHANICALLY AGITATED SEA WATER SYSTEMS.
KEYW PETROLEUM HYDROCARBONS, DISPERSANTS, BACTERIAL DEGRADATION, KUWAIT CRUDE
CODE 6597F

AUTH TRAXLER R.W., CUNDELL A.M.
TITL PETROLEUM DEGRADATION IN LOW TEMPERATURE MARINE AND ESTUARINE ENVIRONMENTS
PUBL URI DEPT. OF PLANT PATHOLOGY-ENTOMOLOGY, OFFICE OF NAVAL RESEARCH CONTRACT NO. N00014-68-A-0215-0013, TASK NO. NR 303-076, ANNUAL REPORT NO. 2, MARCH 1975
ABST STUDIES OF THE ENRICHMENT OF HYDROCARBONS AND FUEL OIL UTILIZING BACTERIA FOLLOWING A SPILL IN NARRAGANSETT BAY.
KEYW BIODEGRADATION, BACTERIA, HYDROCARBONS
CODE 29316F

AUTH TRINKS W., KLEIN J., BEMHOWSKI J.
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ABST LIMITATIONS AND EXTENSIONS OF THE ANALYSIS ARE DISCUSSED.
KEYW EVAPORATION, WET-BULB DEPRESSION, DROP-SIZE SPECTRUM
CODE 6053F

AUTH TRIMBLE L.
TITL OIL RECOVERY SYSTEMS, MARINE ENVIRONMENT OIL SPILL RECOVERY
PUBL LOCKHEED MISSILES AND SPACE CO. FOR USCG, SSIE NO. GZ-24713
CODE 0451P

AUTH TROY B., HOLLINGER J.
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PUBL NAVAL RESEARCH LAB., DEPT. OF TRANSPORTATION, REPORT NO. 3515, MAY 1977, DOT USCG 2-21081
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KEYW THICKNESS, VOLUME, SPREADING, DETECTION, AIRBORNE SYSTEM, REAL-TIME DETERMINATION
CODE 7629I

AUTH TUNN W.
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ABST THIS ARTICLE CONSIDERS SOME OF THE RECENT DEVELOPMENTS IN CARRYING OUT STUDIES OF OIL SPILLS AND MISCELLANEOUS AND DEALS WITH EQUIPMENT USED.
KEYW OIL SPILL STUDIES, EQUIPMENT, DEVELOPMENTS
CODE 3026R

AUTH TULIN A.
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PUBL HYDRONAUTICS INC. OFFICE OF NAVAL RESEARCH
ABST A THEORETICAL STUDY HAS BEEN UNDERTAKEN TO DEVELOP BASIC RELATIONS ALLOWING THEORETICAL CALCULATION OF DENSITY CURRENT BEHAVIOR ASCERTAIN THE PERTINENT PHYSICAL PHENOMENA AND THEIR RELATIVE IMPORTANCE.
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AUTH TULLY P.R.
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PUBL OIL ON THE SEA, PLENUM PRESS, 1969
ABST THIS ARTICLE DISCUSSES THE ADVANTAGES OF REMOVING SLICKS BY BURNING AND VARIOUS TECHNIQUES FOR DOING SO.
KEYW FLOATING OIL SLICKS, BURNING, TECHNIQUES
CODE 3036P

AUTH TUNSTALL F.
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PUBL SOHIO PIPELINE CO. 1973 CONF.
CODE 6113P

AUTH TYLER J.
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AUTH UEDA H., HINZE J.O.
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PUBL JOURNAL OF FLUID MECHANICS, VOL. 67, PART 1, 1975
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KEYW PLANE TURBULENT BOUNDARY LAYER, DISTURBANCE MECHANISMS, TURBULENCE
CODE 6313F

AUTH UPP E.L.
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PUBL PRESENTED AT THE WINTER ASME ANNUAL MEETING, HOUSTON, TX NOV. 30 - DEC. 4, 1975
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KEYW TANKERS, LOADING RATES, MEASURING PETROLEUM FLUIDS
CODE 2901F

AUTH URAM E.
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AUTH USA NATIONAL ACADEMY OF SCIENCES
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PUBL PHYSICAL REMOVAL
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KEYW RECOVERY, RECOVERY RATES, WAVES AND CURRENTS
CODE 0627F

AUTH WAGNERS J.
TITL OIL ON PUGET SOUND, AN INTERDISCIPLINARY STUDY IN SYSTEMS ENGINEERING
PUBL WASHINGTON SEA GRANT PUBLICATION, UNIV. OF WASHINGTON PRESS., SEATTLE 1972
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CODE 9087F

AUTH VALKOVIC V.
TITL TRACE ELEMENTS IN PETROLEUM
PUBL PETROLEUM PUBLISHING CO.
ABST PART 1: ORIGIN OF ELEMENTS AND THE ELEMENTAL COMPOSITION OF THE UNIVERSE, THE SOLAR SYSTEM, EARTH, SEAWATER, LIVING ORGANISMS, SEDIMENTS, AND CRUDE OILS ARE PRESENTED. PART 2: DISCUSSES IN DETAIL THE CONCENTRATIONS OF DIFFERENT TRACE ELEMENTS IN CRUDE OILS. IN PART 3, THE ENVIRONMENTAL ASPECTS OF PETROLEUM PRODUCTION, TRANSPORT AND USE ARE CONSIDERED. IN PART 4, THE METHODS AND TECHNIQUES USED FOR DETERMINING TRACE ELEMENT CONCENTRATIONS IN PETROLEUM ARE PRESENTED.
KEYW TRACE ELEMENTS, PETROLEUM, BIOLOGICAL EFFECTS
CODE 7762F

AUTH VAN DORN W.G., PAZAN S. E.
TITL LABORATORY INVESTIGATION OF WAVE BREAKING PART II DEEP WATER WAVES
PUBL UNIVERSITY OF CALIFORNIA, SAN DIEGO
ABST THIS STUDY REPRESENTS THE FIRST KNOWN ATTEMPT TO EXAMINE IN SOME DETAIL THE FLOW DYNAMICS OF THE TERMINAL GROWTH AND BREAKING OF PERIODIC SURFACE WAVES IN DEEP WATER, UNDER CONTROLLED AND REPRODUCABLE LABORATORY CONDITIONS.
CODE 7715 F

AUTH VAN DYKE M., WEHAUSEN J.V., LUMLEY J.J.
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PUBL ANNUAL REVIEWS, INC.
ABST ANNUAL REVIEW OF FLUID MECHANICS BY VARIOUS CONTRIBUTING AUTHORS
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CODE 7721F

AUTH VAN FLEET E.S., QUINN J.G.
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PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
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KEYW HYDROCARBONS, CHRONIC POLLUTION, SEDIMENTS
CODE 2669F

AUTH VANDERKROOY M.
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PUBL REGIONAL ENVIRONMENTAL ENERGY COORDINATOR, SPILL TECHNOLOGY NEWSLETTER, VOL. 2, MAY-JUNE 1977
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KEYW EKOFISK FIELD, BLOWOUT, CLEANUP
CODE 7110F

AUTH VANDERMEULEN J.H.
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PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
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KEYW SYMPOSIUM, ENVIRONMENTAL RECOVERY, TIMESCALE FOR RECOVERY
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KEYW BIODEGRADATION, SEDIMENTS, CLEANUP
CODE 7149F

AUTH VARIOUS
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CODE 0547F

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KEYW TOXICITY, OIL CONCENTRATION, DISPERSANTS
CODE 2560F

AUTH VELANKER S.K., BARNETT C., HOUSTON C.W., THOMPSON A.R.
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PUBL DEPT. OF CHEMICAL ENGINEERING, BIOTECHNOLOGY AND BIOENGINEERING, VOL XVII, 1975
ABST A SIMPLE MECHANISM OF HYDROCARBON UPTAKE BY MICROORGANISMS IS EXAMINED
KEYW HYDROCARBONS, SURFACE ACTIVE AGENTS, GROWTH OF MICROBIAL CELLS
CODE 2936F

AUTH VEHARLE P.L.
TITL ERRORS IN ATOMIC ABSORPTION ANALYSIS FOR METALS IN SURFACTANT SOLUTIONS
PUBL MISSOURI WATER RESOURCES RESEARCH CENTER, UNIVERSITY OF MISSOURI, NO. A-090-MO, 14-31-0001-6320, 7/75-6/76
ABST THIS PAPER IS TO DEMONSTRATE THE MECHANISM BY WHICH THESE ERRORS WERE INTRODUCED AND SEARCH FOR WAYS TO PREVENT ERRORS.
KEYW IMPURITIES, SURFACE TENSION, ATOMIC ABSORPTION
CODE 6504F

AUTH VENDERMEULEN J.H., PENROSE W.R.
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PUBL JOURNAL OF THE FISHERIES, VOL. 35, NO. 5, MAY 1978
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KEYW ARYL HYDROCARBON HYDROXYLASE, AROMATIC HYDROCARBON, BIVALVE
CODE 2663F

AUTH VIERROCK H.
TITL FISCAL YEAR 1975 SUMMARY REPORT OF NOAA METEOROLOGY LABORATORY SUPPORT TO THE ENVIRONMENTAL PROTECTION AGENCY
PUBL NOAA TECHNICAL MEMORANDUM, ERL ARL-62, JULY 1976
ABST THIS REPORT OUTLINES THE STUDIES DURING THE FISCAL YEAR 1975.
KEYW MODEL DEVELOPMENT, EVALUATION, AND APPLICATION, AIR QUALITY AND METEOROLOGY, TECHNICAL ASSISTANCE
CODE 6594F

AUTH VOLLMERS, R.A., MUEHLENBECK C., WILEY L.
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PUBL USCG, OCT. 1977
ABST A NEW LOW COST TECHNIQUE HAS BEEN DEVELOPED TO PROVIDE SURFACE LAW ENFORCEMENT AND OIL CLEAN-UP CREWS WITH A NEAR REAL TIME MAP OF AN OIL SPILL AREA WHILE THE AIRCRAFT REMAINS ON SCENE FLYING OVER THE AREA OF INTEREST.
KEYW SURVEILLANCE, CLEANUP, AIRCRAFT
CODE 7654F

AUTH VONHOF J.A.
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PUBL HYDROLOGY RESEARCH DIVISION, DEPT. OF THE ENVIRONMENT, EPS 4-EC-77-1, 1977
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CODE 7148F

AUTH WALDMAN G., JOHNSON R., FANNELOP T.K.
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PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1548, MAY 1-3, 1972
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KEYW SPREADING, WIND AND CURRENT TRANSPORT, SURFACE TENSION
CODE 6300F

AUTH WALKER J.D.
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PUBL PROC. OF THE JOINT CONF. ON PREVENTION AND CONTROL OF OIL SPILLS
CODE 1097F

AUTH WALKER J.D., COFONE L., COONEY J.J.
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PUBL DEPT. OF BIOLOGY, UNIV. OF DAYTON, 1973 CONF.
ABST CLADOSPORIUM RESINAE IS PROBABLY THE MOST PREVALENT HYDROCARBON UTILIZING FUNGUS. IT UTILIZES ALIPHATIC AND AROMATIC HYDROCARBONS, AS WELL AS ALCOHOLS AND ACIDS. HIGH CONCENTRATIONS OF PESTICIDES OCCURRING IN OIL SLICKS WOULD NOT INHIBIT OIL DEGRADATION BY CLADOSPORIUM RESINAE.
CODE 6115F

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PUBL APPLIED MICROBIOLOGY, 27(1):285-287
CODE 1094F

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PUBL ENVIRONMENTAL SCIENCE AND TECHNOLOGY, VOL.11, NO.
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ABST A REPORT ON A SAMPLING DEVICE SUITABLE FOR
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     BEEN SUCCESSFULLY EMPLOYED IN MONITORING
     BIODEGRADATION OF PETROLEUM IN SITU AT A MARSHLAND
     SITE IN THE CHESAPEAKE BAY.
KEYW BIODEGRADATION, ENVIRONMENTAL IMPACT, AQUATIC
     ENVIRONMENTS
CODE 2653F

AUTH WALKER J.D., COLWELL R.R., HAMMING M.C., FORE H.T.
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     BAY SEDIMENT FATE OF AROMATIC HYDROCARBONS OF
     PETROLEUM SUBJECT  TO DEGRADATION BY FRESH, FROZEN
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PUBL J. GEN. MICROBIOL.
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TITL A STUDY OF THE BIODEGRADATION OF A SOUTH LOUISIANA
     CRUDE OIL, EMPLOYING COMPUTERIZED MASS SPECTROMETRY
PUBL UNIV. OF MARYLAND, GULF RESEARCH AND DEVELOPMENT
     CO., FOR EPA 1975 CONFERENCE
KEYW BIODEGRADATION, SOUTH LOUISIANA CRUDE OIL, MASS
     SPECTROMETRY
CODE 0156AP

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CODE 5044P

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PUBL API, PROJECT NO. OS-6, CONTRACT NO. 212B00083,
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ABST TO PROVIDE A SINGLE SOURCE ON AVAILABLE OIL SPILL
     TREATING AGENTS.
KEYW TREATING AGENTS, WAREHOUSED MATERIALS, PRODUCTION
     RATES, READY REFERENCE
CODE 4039B

AUTH WALKUP P.C., SMITH J.D., PETERSON P., POLENTZ L.M.
TITL STUDY OF EQUIPMENT AND METHODS FOR REMOVING OIL
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ABST THIS STUDY WAS PERFORMED TO IDENTIFY AND DESCRIBE
     THE COST EFFECTIVE AVAILABLE SYSTEMS CONSISTING OF
     PRESENT OR NEW COMBINATION OF EXISTING EQUIPMENT,
     MATERIALS, AND TECHNIQUES.
KEYW REMOVAL, MECHANICAL RECOVERY AND CONTAINMENT,
     CHEMICAL DISPERSANTS
CODE 0517F

AUTH WALLACE S.A.
TITL LEGAL ASPECTS OF THE 1973 MARINE POLLUTION
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PUBL EPA, 1975 CONVENTION
KEYW LEGAL ASPECTS, CONVENTION, COMMENTS
CODE 8070A

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PUBL CMS-RANN-1-76, OCEAN ENG. RPT NO. 5, MARCH 1976,
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ABST PROGRAM DESIGNED TO DELINEATE THE EFFECTS ON
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CODE 3510A

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TITL MODELING OF OIL EVAPORATION IN AN AQUEOUS
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PUBL COLLEGE OF MARINE STUDIES, UNIV. OF DEL.,
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ABST RESEARCH ON THE EFFECTS OF  CRUDE OIL TRANSFER AND
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     TO PROVIDE INFORMATION ON THE INPUT OF OIL
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     MAKERS.
KEYW NUMERICAL MODEL, CHARACTERISTICS OF OIL, WIND,
     TEMPERATURE, SIZE
CODE 6515F

AUTH WANG H.P.
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PUBL URI , MARINE TECHNICAL REPORT NO. 40, MECH. ENG. &
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ABST THE OBJECTIVES OF THIS REPORT ARE TO INVESTIGATE
     THE EFFICIENCY OF DIFFERENT NUMERICAL INTEGRATION
     SCHEMES AND TO DEVELOP A SUITABLE FINITE ELEMENT
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KEYW NUCLEAR POWER STATION, ENVIRONMENTAL RESEARCH,
     HYDRODYNAMICS
CODE 2674I

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     OIL SPREADING AND TRANSPORT AND ITS APPLICATION
     FOR PREDICTING OIL SLICK MOVEMENT IN BAYS.
PUBL USCG, DEPT. OF TRANSPORTATION,TT-D-365-74-1, FEB.
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ABST A COMPUTER MODEL FOR SIMULATING OIL SPREADING AND
     TRANSPORT HAS BEEN DEVELOPED. THE MODEL CAN BE
     UTILIZED AS A USEFUL TOOL IN PROVIDING ADVANCE
     INFORMATION AND THIS MAY GUIDE DECISIONS FOR AN
     EFFECTIVE RESPONSE IN CONTROL AND CLEANUP ONCE AN
     ACCIDENTAL SPILL OCCURS.
KEYW NUMERICAL MODEL, OIL SPREAD AND TRANSPORT,
     PREDICTING MOVEMENT
CODE 7566I

AUTH WANG S., HUANG E.
TITL A NUMERICAL MODEL FOR SIMULATION OF OIL SPREADING
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PUBL NTIS REPORT NO:AD786 424
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CODE 2590F

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PUBL JOURNAL OF SHIP RESEARCH, MARCH 1971
ABST THIS PAPER PRESENTS A SOLUTION OF THE TWO
     DIMENSIONAL POTENTIAL PROBLEM ASSOCIATED WITH
     HARMONIC OSCILLATION OF A TWIN HULL BODY IN A FREE
     BODY SURFACE.
KEYW OIL BARRIER DYNAMICS, HYDRODYNAMICS, OSCILLATION
CODE 0510F

AUTH WARD A.P. DAVIES J.M.
TITL A COMPARISON OF THE RATES OF TRANSPORT OF OIL,
     FROM SURFACE SLICKS AND FROM OIL DISPERSED INT.
     THE WATER COLUMN TO THE BOTTOM SEDIMENTS
PUBL INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE
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     NO. CM 1976/E:15
ABST OIL SLICKS WERE PUT ONTO THE SURFACE OF TWO LARGE
     PLASTIC ENCLOSURES AND ONE TREATED WITH
     DISPERSANT. THIS EXPERIMENT HAS CLEARLY SHOWN HOW
     TWO FACTORS, MIXING AND DISPERSANT, CAN
     SIGNIFICANTLY EFFECT THE DECAY OF AN OIL SLICK.
KEYW DISPERSANT, DYE EXPERIMENTS, MIXING
CODE 7651F

AUTH WARD D.M.
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PUBL THIS THESIS IS IN PARTIAL FULFILLMENT OF THE
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ABST THIS THESIS IS COMPRISED OF FIVE MANUSCRIPTS
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     ENVIRONMENTS. EACH PAPER IS INTRODUCED AND THE
     RESULTS DISCUSSED IN RELATION TO PERTINENT
     LITERATURE SEPARATELY WITHIN EACH MANUSCRIPT.
KEYW MICROBIAL DEGRADATION, ENVIRONMENTAL EFFECTS,
     BIODEGRADATION
CODE 7181F

AUTH WARNER D.G.
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ABST THIS PAPER REVIEWS SPILL PREVENTION EQUIPMENT AND
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ABST A CALCULATION PROCEDURE IS DESCRIBED TO REPRESENT
     THE DISPLACEMENT OF SURFACE OIL SPILL UNDER THE
     ACTION OF TIME VARYING SURFACE WIND STRESS
     COMPONENTS
KEYW DISPLACEMENT, WIND STRESS, SURFACE VELOCITY
CODE 0503F

AUTH WARNER J.S.
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ABST IT IS SHOWN THAT THE FINGERPRINT OF SULFUR-CONTAINING COMPONENTS CAN BE MORE DEFINITIVE THAN THE CORRESPONDING HYDRO-CARBON FINGERPRINT.
KEYW FINGERPRINTS, SULFUR-CONTAINING COMPONENTS, MARINE SAMPLES
CODE 00818

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PUBL EPA, CONTRACT NO. 68-01-0017
ABST A SURVEY TO ASSESS THE BIOLOGICAL DAMAGE RESULTING FROM THE APRIL 26, 1971 DIESEL SPILL AT ANACORTES, WA. WAS CONDUCTED BETWEEN 5/9/71 AND 5/12/71.
KEYW BIOLOGICAL SURVEYS, DIESEL FUELS, SEDIMENTS
CODE 01498

AUTH WEATHERFORD D.J.
TITL BOAT FOR COLLECTING OIL SLICKS AND OTHER CONTAMINANTS FROM THE SURFACE OF WATER
PUBL US PATENT NO. 3862904, JAN. 28, 1975, OFFICIAL GAZETTE OF US PATENT OFFICE
ABST A NEW OIL COLLECTION CRAFT IS A MANEUVERABLE SELF-PROPELLED BARGE EQUIPPED WITH A FRONT-END SURFACE SKIMMER WITH A FLOATING BOOM TO DRAW CONTAMINANTS.
CODE 3116P

AUTH WEBSTER C.A.
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PUBL FLUID MECHANICS, VOL. 19, AUG. 1963.
ABST THIS PAPER CONCERNS AN INVESTIGATION OF TURBULENCE IN THE DENSITY STRATIFIED SHEAR FLOW OF A SPECIALLY DESIGNED WIND TUNNEL.
KEYW TURBULENCE, DENSITY, VELOCITY
CODE 2103F

AUTH WECHSLER A.E., STEVENS J.I., HUSKA P.A., LITTLE A.D.
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PUBL PREPARED UNDER CONTRACT 14-20-950 FOR DIV. OF OIL AND HAZARDOUS MATERIALS, OCT. 1971
ABST REGULATIONS, PRACTICES AND PLANS FOR PREVENTION OF SPILLS OF POLLUTING NATURE.
CODE 6063P

AUTH WEEDEN S.L.
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PUBL OCEAN INDUSTRY, MAY 1977.
ABST REPORT ON A NEW AMERICAN PETROLEUM INSTITUTE BOOKLET "LARGE TANKERS - OUR ENERGY LIFELINES"
KEYW SUPERTANKERS, DEEPWATER PORTS, COST REDUCTION
CODE 2665F

AUTH WEICHART G.
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PUBL AMBIO 2(4):99-106
CODE 1098R

AUTH WEINSTEIN B., TREYBAL R.E.
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PUBL AICHE JOURNAL VOL. 19, NO. 4, JULY 1973
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KEYW TWO-PHASE LIQUID, AGITATED MIXING VESSEL, DISPERSED LIQUID
CODE 5071F

AUTH WEINSTEIN B., TREYBAL R.E.
TITL LIQUID-LIQUID CONTACTING IN UNBAFFLED, AGITATED VESSELS
PUBL AICHE JOURNAL, VOL 19, NO. 2, MARCH 1973
ABST DROP SIZE AND DISPERSED-PHASE HOLDUP WERE MEASURED FOR LIQUID DISPERSIONS, UNBAFFLED AGITATION VESSELS WITH NO GAS-LIQUID INTERFACE AND HENCE NO VORTEX FOR BATCH, AND CONTINUOUS FLOW.
KEYW DROP SIZE, LIQUID DISPERSIONS, UNBAFFLED AGITATED VESSELS
CODE 5072F

AUTH WEINSTEIN N.J.
TITL WASTE OIL RECYCLING AND DISPOSAL
PUBL EPA TECHNOLOGY SERIES, AUG. 1974
ABST INFORMATION WAS DEVELOPED ON SOURCES AND QUANTITIES OF WASTE OIL, CURRENT AND POTENTIAL RECYCLE AND DISPOSAL METHODS AND THE ENVIRONMENTAL IMPACT OF THESE MATERIALS.
KEYW WASTE DISPOSAL, MATERIALS RECOVERY, TREATMENT.
CODE 0086P

AUTH WEISS F.T.
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PUBL UNKNOWN
ABST SEVERAL EXTENSIVE PROGRAMS HAVE BEEN INITIATED BY THE PETROLEUM INDUSTRY TO DEVELOP A BIOLOGICAL AND ANALYTICAL FOUNDATION TO INCREASE OUR UNDERSTANDING OF THE FATE AND EFFECT OF OIL IN THE MARINE ENVIRONMENT.
KEYW NATURAL OIL SEEPS, EFFECT ON MARINE LIFE, HYDROCARBONS
CODE 2013F

AUTH WELCH R.H.
TITL AERIAL SPILL PREVENTION SURVEILLANCE DURING SUB-OPTIMUM WEATHER
PUBL EPA, REPORT NO. R2-73-243
CODE 2096R

AUTH WELCH R.L., MARMELSTEIN A.D., MAUGHAN P.M.
TITL SPILL PREVENTION SYSTEM
PUBL OFFICE OF RESEARCH AND MONITORING, CONTRACT NO 68-01-0145, JAN. 1972
CODE 6375P

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PUBL OFFICE OF RESEARCH AND MONITORING, EPA, PROJECT NO. 15080HOC, CONTRACT NO. 68-01-0145, JAN. 1973
ABST ACQUISITION AND INTERPRETATION OF MULTISPECTRAL AERIAL PHOTOGRAPHY AND THERMAL INFRARED IMAGERY WERE PERFORMED TO EVALUATE THEIR UTILITY IN AN AERIAL SURVEILLANCE SPILL PREVENTION SYSTEM.
CODE 3111R

AUTH WELLBAUM E.W.
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PUBL ALASKA PIPELINE SERVICE CO. 1973 CONF.
ABST THE TRANS-ALASKA SYSTEM IS CONCERNED WITH THE PREVENTION OF OIL SPILL INCIDENTS ASSOCIATED WITH TANKER AND PIPELINE OPERATIONS, REFINERIES, AND TRANSFER AND STORAGE TERMINALS.
CODE 6110P

AUTH WERTENBAKER W.
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PUBL MARINE TECHNOLOGY SOCIETY JOURNAL
CODE 0327R

AUTH WESTLAKE D.W.S.
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PUBL CANADIAN JOURNAL OF MICROBIOLOGY 20(7):915-928
CODE 1096A

AUTH WESTMAN W.E.
TITL BIOASSAYS AND BIOLOGICAL MONITORING
PUBL A COMPILATION OF AUSTRALIAN WATER QUALITY CRITERIA, AUSTRALIAN WATER RESOURCE CONTROL, TECHNICAL PAPER NO. 7:275-281
CODE 1030R

AUTH WHEELER R.B.
TITL THE FATE OF PETROLEUM IN THE MARINE ENVIRONMENT
PUBL EXXON PRODUCTION RESEARCH COMPANY
ABST THIS REPORT OUTLINES PROGRESS TOWARD UNDERSTANDING THE FATE OF PETROLEUM SPILLED IN THE MARINE ENVIRONMENT. THE REPORT UPDATES THE 1975 NATIONAL ACADEMY OF SCIENCES REPORT "PETROLEUM IN THE MARINE ENVIRONMENT" AND EMPHASIZES THE FATE OF OIL IN THE HIGHER LATITUDES. THE PHYSICAL, CHEMICAL, AND BIODEGRADATIVE PROCESSES THROUGHOUT THE HISTORY OF AN OILSPILL ARE COVERED IN THIS REPORT. AN ATTEMPT IS MADE TO IDENTIFY PROCESSES DOMINATING MOVEMENT AND WEATHERING AT VARIOUS TIMES AFTER THE SPILL.
KEYW EVAPORATION, DISSOLUTION, SEDIMENTATION DISPERSION, CLEANUP
CODE 7729F

AUTH WHITE F.M.
TITL ANALYTICAL PHYSICAL MODEL
PUBL URI, SSIE NO. GBP-69-2
CODE 0650P

AUTH WHITE G.P., ARECCHI A.V.
TITL LOCAL AREA POLLUTION SURVEILLANCE SYSTEMS: A SUMMARY OF THE COAST GUARDS RESEARCH AND DEVELOPMENT
PUBL USCG, FOR EPA 1975 CONFERENCE
ABST PAPER SUMMARIZES THE DEVELOPMENT AND EFFECT OF OIL SPILL SENSORS AND PRESENTS AN OVERVIEW OF WORK STILL TO BE ACCOMPLISHED.
KEYW SUMMARY, DEVELOPMENT, OIL SPILL SENSORS
CODE 0384P

AUTH WHITE J.R., FREEZER D.R., VOLLNERS R.B.
TITL USCG UTILIZATION OF REMOTE SENSING TECHNIQUES FOR OCEAN SURVEILLANCE
PUBL UNKNOWN
ABST THIS PAPER DISCUSSES SOME RECENT COAST GUARD RESEARCH AND DEVELOPMENT PROGRAMS IN REMOTE SENSING.
KEYW SURVEILLANCE, SEARCH AND RESCUE, ICE RECONNAISSANCE
CODE 76598F

AUTH WHITTINGTO, J.W.C., MAYER J.F., TINGLE G.O.
TITL OIL ABSORBENT FOAMED SILICATE FOR OIL POLLUTION CONTROL

PUBL OFFICIAL GAZETTE OF US PATENT OFFICE, VOL. 927, NO. 4, 10-22-74
ABST A POROUS ALKALAI METAL SILICATE FOAM HAVING OLEO-PHILIC-HYDROPHOBIC PROPERTIES IS PROVIDED FOR USE ON OIL SPILL CONTROL AND REMOVAL. PARTICLES CAN ABSORB THREE TIMES THEIR WEIGHT, OIL CAN THEN BE RECLAIMED.
CODE 3133P

AUTH WICKS M.
TITL FLUID DYNAMICS OF FLOATING OIL CONTAINMENT BY MECHANICAL BARRIERS IN THE PRESENCE OF WATER CURRENTS
PUBL UNKNOWN
ABST THE OBJECT OF THIS WORK IS TO PRESENT CURRENT EXPERIMENTAL RESULTS AND THEIR INTERPRETATION ON THE EFFECTS OF WATER CURRENTS ON OIL CONTAINMENT WITH BOOMS.
KEYW CONTAINMENT, BOOMS, BARRIERS
CODE 0570F

AUTH WIDAWSKY A.
TITL DEVELOPMENT OF HARBOR OIL SPILL REMOVAL RECOVERY SYSTEMS: PHASE I
PUBL CONFERENCE ON THE PREVENTION AND CONTROL OF OIL POLLUTION
ABST COMMERCIALLY AVAILABLE SUBSYSTEMS USED IN HARBOR OIL SPILL RECOVERY WERE ANALYTICALLY EVALUATED. BASED ON THE EVALUATION, SIX CONTAINMENT BOOMS, TEN SKIMMERS, THREE PUMPS, TWO TOWABLE STORAGE TANKS, AND THREE OIL WATER SEPARATORS WERE TESTED IN RIVERS, WAVE TANKS AND ON LAND.
KEYW CONTAINMENT, RECOVERY, STORAGE, TRANSFER, REMOVAL
CODE 5113F

AUTH WILCOX J.D.
TITL A HYDRODYNAMICALLY EFFECTIVE HORIZONTAL OIL BOOM
PUBL CONFERENCE ON THE PREVENTION AND CONTROL OF OIL POLLUTION
ABST THIS PAPER DESCRIBES THE BOOMS STRUCTURAL AND FUNCTIONAL CHARACTERISTIC AND THE OVERALL EFFECTIVENESS CONCEPT FOR CONTAINING OIL SPILLS IN MEDIUM TO FAST CURRENTS.
KEYW CONTAINMENT, HYDRODYNAMICS, RECOVERY
CODE 0525F

AUTH WILDISH D.J.
TITL ARRESTANT EFFECT OF POLYOXYETHYLENE ESTERS ON SWIMMING IN THE WINTER FLOUNDER
PUBL WATER RESEARCH, VOL. 8, NO. 8, AUG. 1974
ABST THIS PAPER DISCUSSES THE SUBLETHAL EFFECT OF DISPERSANTS ON THE SWIMMING OF THE FLOUNDER.
KEYW DISPERSANTS, ARRESTANT EFFECTS, SWIMMING AMPLITUDE
CODE 2174P

AUTH WILDISH D.J., LISTER N.J.
TITL THE ACUTE TOXICITY OF THE OIL DISPERSANT GULF AGENT 1009 LS/3712 TO AQUATIC FAUNA
PUBL MANUSCR. REP. SER. FISH. RES. BD. CAN., 976, 8P., 1971
CODE 1029R

AUTH WILKINSON D.L.
TITL DYNAMICS OF CONTAINED OIL SLICKS
PUBL JOURNAL OF HYDRAULICS DIVISION, ASCE, VOL. 98, NO. HY 6, JUNE 1972
CODE 0722R

AUTH WILKINSON D.L.
TITL LIMITATIONS TO LENGTH OF CONTAINED OIL SLICKS
PUBL AMERICAN SOCIETY OF CIVIL ENGINEERS, HYDRAULICS DIVISION
CODE 0361R

AUTH WILLIAMS A.S., BRUNDAGE S.C., ANDERSON J.R., HARRIS D., SMITH C.
TITL SAVING OILED SEABIRDS
PUBL INTERNATIONAL BIRD RESCUE RESEARCH CENTER, AMERICAN PETROLEUM INSTITUTE, JAN. 1978
ABST THIS MANUAL IS INTENDED FOR THE VOLUNTEER. THE METHODS IT DESCRIBES ARE BASED ON SEVEN YEARS OF FULL TIME WORK. THIS MANUAL SPECIFICALLY EXCLUDES THE USE OF SOLVENTS, AS THEY POSE UNNECESSARY RISKS FOR BOTH VOLUNTEERS AND BIRDS. SAFER AND EFFICIENT DETERGENT CLEANING METHODS ARE THUS RECOMMENDED.
KEYW OIL STRESSED BIRDS, CLEANING TECHNOLOGY, MIGRATORY BIRDS, DETERGENTS
CODE 7650F

AUTH WILLIAMS G.N., HANN R., JAMES W.P.
TITL PREDICTING THE FATE OF OIL IN THE MARINE ENVIRONMENT
PUBL TEXAS A & M UNIV. FOR EPA 1975 CONFERENCE
ABST PAPER INCLUDES: PROJECTED MOVEMENT OF OIL SPILLS, ANALYTICAL MODELS, THE SLICK MODEL, AND RESULTS.
KEYW MOVEMENT, MODELS, SLICKS, RESULTS
CODE 01494R

AUTH WILSON B.W., FELDHAUSEN P.H., CHAKRABARTI S.K.
TITL HINDCAST OF DEEP-WATER WAVE ENERGY SPECTRA HURRICANE AUDREY OF 1957
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 1833, APR. 29-MAY 2, 1973
ABST A NUMERICAL PROCEDURE TO PREDICT WIND WAVES TRAVELING WITH AND THROUGH STORMS, HAVING IRREGULAR PROPAGATION RATES AND PATHS, IS USED TO HINDCAST THE DEEP WATER WAVES AND WAVE SPECTRAL ENERGY DENSITIES GENERATED BY HURRICANE AUDREY.
KEYW NUMERICAL PROCEDURE, WIND WAVES, HINDCASTING, WATER WAVES, WAVE SPECTRAL ENERGY, HURRICANE AUDREY
CODE 0046F

AUTH WILSON D.P.
TITL LONG TERM EFFECT OF LOW CONCENTRATIONS OF AN OIL SPILL REMOVER (DETERGENT) STUDIES WITH THE LARVAE OF SABELLARIA SPINATOSA
PUBL J. MA. BIOL. ASSOC., U.K., 48:177-182, 1968
CODE 1049R

AUTH WILSON J., NADEAU P., PREMACK J.
TITL NAVY HARBOR OIL SPILL CLEANUP: A PROGRESS REPORT
PUBL CONFERENCE ON THE PREVENTION AND CONTROL OF OIL POLLUTION
ABST THIS PAPER DISCUSSES THE PROGRESS IN DEVELOPMENT OF EQUIPMENT AND TECHNIQUES FOR NAVY OIL SPILL PROGRAMS.
KEYW CLEANUP, DETECTION AND SURVEILLANCE, CONTAINMENT, REMOVAL, STORAGE, TRANSFER, DISPOSAL
CODE 0017F

AUTH WILSON J.R., BAIRD W.F.
TITL A DISCUSSION OF SOME MEASURED WAVE DATA
PUBL THIRTEENTH COASTAL ENGINEERING CONFERENCE, JULY 1972, VOL. 1, CHAPER 3, VANCOUVER BC, CANADA
ABST THE SIGNIFICANT WAVE HEIGHT AND PEAK AS DERIVED FROM THE SPECTRAL ANALYSIS OF 171 MEASURED WAVE RECORDS TAKEN IN THE OCEAN OFF WESTERN HEAD, NOVA SCOTIA ARE COMPARED TO THE MORE CLASSICAL PARAMETERS DERIVED FROM INDIVIDUAL WAVE HEIGHTS AND THE TUCKER METHOD.
KEYW SPECTRAL ANALYSIS, WAVE HEIGHT, ZERO CROSSING PERIOD
CODE 0516F

AUTH WILSON K.W.
TITL THE ABILITY OF HERRING AND PLAICE LARVAE TO AVOID CONCENTRATIONS OF OIL DISPERSANTS
PUBL THE EARLY LIFE HISTORY OF FISH PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM, OBAN, SCOTLAND, MAY 1973, 17-23, PP 589-602
CODE 1030R

AUTH WILSON M.P.
TITL THE ASSESSMENT PROBLEMS OF WHETHER OR NOT TO TREAT OIL SPILLS
PUBL DEPT. OF MECHANICAL ENGINEERING, CONTRACT ERDA, URI
ABST THIS PAPER DISCUSSES VARIOUS INPUTS IN DECIDING TO TREAT OR NOT TO TREAT OIL SPILLS.
KEYW DISPERSANTS, TREATMENT, ENVIRONMENT, ASSESSMENT
CODE 0602F

AUTH WILSON M.P.
TITL ASSORTMENT OF VARIOUS ARTICLES PERTAINING TO THE PROPOSAL
PUBL DR. MASON P. WILSON
CODE 2642F

AUTH WILSON M.P.
TITL ECOSYSTEM IMPACTS BY OIL SPILLS - A NEED FOR AN INTEGRATED APPROACH, PRESENTED AT THE ECOLOGICAL DAMAGE ASSESSMENT CONFERENCE NOV. 12-14,1979 ARLINGTON, VIRGINIA
PUBL ECOLOGICAL DAMAGE ASSESSMENT CONFERENCE ARLINGTON, VIRGINIA
ABST A COMBINATION OF EXPLICIT AND IMPLICIT APPROACHES TO THE ASSESSMENT OF ENVIRONMENTAL IMPACTS CAUSED BY OIL SPILLS IS PRESENTED. THE ASSESSMENT REQUIRES A WELL INTEGRATED TEAM FROM VARIOUS DISCIPLINES.
KEYW ECOSYSTEM IMPACTS, INTEGRATED APPROACH, CLEAN-UP, DAMAGE ASSESSMENT
CODE 7773F

AUTH WILSON M.P.
TITL ENVIRONMENTAL ASSESSMENT OF TREATED OIL SPILLS VERSUS UNTREATED OIL SPILLS
PUBL U.R.I., APRIL 1976
ABST PROPOSAL FOR RESEARCH ON ENVIRONMENTAL ASSESSMENT OF TREATED OIL SPILLS VERSUS UNTREATED SPILL.
KEYW ENVIRONMENTAL IMPACT, TOXICITY, SEEPAGE AND SPILLS
CODE 2593F

AUTH WILSON M.P.
TITL WHAT ARE WE DOING ABOUT OIL SPILLS?
PUBL MARITIMES, U.R.I., AUG. 1976
ABST THIS REPORTS ON LEGISLATIVE RECOMMENDATIONS FOR CONTAINMENT AND CLEANUP PROCEDURES.
KEYW LEGISLATURE, CONTAINMENT, CLEANUP
CODE 2576F

AUTH WILSON M.P., BROWN G.P.
TITL A DIFFERENTIAL VISCOSITY FILTER OIL RECOVERY SYSTEM FOR OIL SPILLS AND BILGE EFFLUENTS
PUBL URI, COLLEGE OF ENGINEERING, 1971
ABST A PROPOSAL FOR RESEARCH THAT DESCRIBES A TWO YEAR RESEARCH PROGRAM FOR OBTAINING BASIC INFORMATION ON THE FLUID DYNAMICS PROCESSES.
KEYW DIFFERENTIAL VISCOSITY FILTER, CONTAINMENT, RECOVERY, FLUID DYNAMICS

CODE 2996F

AUTH WILSON R.P., CECE J.R.
TITL ENVIRONMENTAL ASSESSMENT OF TREATED VERSUS UNTREATED OIL SPILLS. PRESENTED AT THE DEPARTMENT OF ENERGY ENVIRONMENTAL CONTROL SYMPOSIUM, NOV 28-30,1978 WASHINGTON,D.C.
PUBL DOE ENVIRONMENTAL CONTROL SYMPOSIUM NOV. 28-30,1978
ABST SHOULD OIL SPILLS BE ALLOWED TO DISPERSE BY NATURAL MEANS OR SHOULD THE DISPERSION PROCESS BE AIDED BY THE USE OF CHEMICAL DISPERSANTS? AN INTENSE ANALYSIS OF THE FATE AND EFFECTS OF THE UNTREATED SPILL COMPARED TO THE TREATED, IS REQUIRED. THE PRACTICABILITY AND FEASIBILITY OF USING DISPERSANTS TO MITIGATE THE IMPACT IS STUDIED.
KEYW TREATED VS. UNTREATED OIL. DISPERSANTS.
CODE 7772F

AUTH WILSON R.D., MONAGHAN P.H., OSANIK A., PRICE L.C., ROGERS M.A.
TITL NATURAL MARINE OIL SEEPAGE
PUBL SCIENCE, VOL. 184, NO. 4139, MAY 24, 1974
ABST THIS PAPER DISCUSSES THE DIRECT DISCHARGE OF OIL INTO OCEAN WATERS DUE TO SUBMARINE SEEPAGE.
KEYW SUBMARINE SEEPAGE, SEEPAGE RATES
CODE 2102F

AUTH WILSON R.L., SHIRLEY D.J.
TITL A DUAL PROGRAM FOR PREVENTION OF OIL SPILLS IN OFFSHORE DRILLING AND PRODUCING OPERATIONS
PUBL SHELL OIL CO. 1973 CONFERENCE
ABST A PROGRAM FOR ACCIDENT PREVENTION, EQUIPMENT FAILURE AND HUMAN ERROR. IT IS FULLY IMPLEMENTED THROUGHOUT SHELL OIL CO. OFFSHORE OPERATIONS IN THE GULF OF MEXICO.
CODE 6112A

AUTH WILSON R.W., COWELL E.B., BEYNON L.R.
TITL THE TOXICITY TESTING OF OILS AND DISPERSANTS A EUROPEAN VIEW
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST THIS PAPER REPRESENTS A REVIEW OF EUROPEAN APPROACHES TO THE PURPOSE AND PROBLEMS OF TESTING THE TOXICITY OF HYDROCARBONS AND DISPERSANTS.
KEYW DISPERSANTS, TOXICITY, SAMPLING, EUROPEAN VIEWS
CODE 6114F

AUTH WILWERDING J.S.
TITL US IMPORTS: THE CHALLENGE OF THE 70'S - A SHIPPER'S PERSPECTIVE
PUBL UNKNOWN
ABST DISCUSSES KEY ITEMS THAT SHIPPERS WILL BE SEEKING.
KEYW MARINE TRANSPORT, DEEPWATER PORTS, INDUSTRY
CODE 7199F

AUTH WIMPRESS D.S.
TITL OIL/WATER SEPARATION SYSTEM WITH SEA SKIMMER
PUBL GARRETT CORP., AIRESEARCH MANUFACTURING DIV., OCT. 1970
CODE 6061A

AUTH WITMER F.E., GOLLER A.
TITL DETERMINATION OF OIL CONCENTRATION AND SIZE DISTRIBUTIONS IN THE BALLAST WATERS: METHOD AND REPRESENTATIVE RESULTS
PUBL ENVIRONMENTAL SCIENCE AND TECHNOLOGY
CODE 0419A

AUTH WOLFE D.A. (EDITED BY)
TITL FATE AND EFFECTS OF PETROLEUM HYDROCARBONS IN MARINE ORGANISMS AND ECOSYSTEMS
PUBL PERGAMON PRESS
ABST THIS VOLUME PRESENTS MOST OF THE PAPERS WHICH WERE PRESENTED NOVEMBER 10-12, 1976 AT AN INTERNATIONAL SYMPOSIUM BY THE SAME TITLE HELD AT THE OLYMPIC HOTEL IN SEATTLE WA. TOPICS : INPUTS AND PHYSICAL TRANSPORT PROCESSES, BIOACCUMULATION AND METABOLISM OF HYDROCARBONS BY MARINE ORGANISMS AND BIOLOGICAL AND ECOLOGICAL EFFECTS OF PETROLEUM EXPOSURE IN MARINE SYSTEMS.
CODE 6196B

AUTH WOLFE J.W.
TITL HOW CLEAN GULF COMBATS OIL SPILLS
PUBL OIL AND GAS JOURNAL
CODE 0318P

AUTH WOOD P.C.
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PUBL MINISTRY OF AGRICULTURE, SSIE NO. WDO-51C
CODE 0497A

AUTH WOODWARD J.B.
TITL SOURCES OF OIL AND WATER IN BILGES OF GREAT LAKES SHIPS
PUBL EPA, JULY 1974, CONTRACT NO. R-802475
ABST SOURCES OF BILGE WATER AND OF OIL IN BILGE WATER WERE SURVEYED ABOARD FIVE SHIPS OF THE CLEVELAND CLIFFS IRON CO.
KEYW TANKER SHIPS, GREAT LAKES, BILGE WATERS
CODE 0154P

AUTH WOOLEVER G.F., REDD L.A., WELSH J.P., MCINTOSH J.A., FARMER L.D.
TITL UTILIZATION OF REMOTE SENSING TECHNIQUES FOR USCG MISSIONS
PUBL USCG RESEARCH AND DEVELOPMENT CENTER, GROTON, CT.
ABST THE USCG IS IMPLEMENTING A VARIETY OF REMOTE SENSING TECHNIQUES IN THE PERFORMANCE OF SEVERAL MISSIONS, SUCH AS FOR POLLUTION SURVEILLANCE, ICE CLASSIFICATION, ICEBERG DETECTION AND CLASSIFICATION, VESSEL TRAFFIC SYSTEM DEVELOPMENT, AND SEARCH AND RESCUE. RECENT ACTIVITIES ARE BRIEFLY DESCRIBED.
KEYW REMOTE SENSING TECHNIQUES, SURVEILLANCE, ICE CLASSIFICATION
CODE 7654A

AUTH WORLEY D.C.
TITL MECHANICAL CONTROL OF OIL SPILLS UTILIZING A STREAMLINED BOOM
PUBL CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT
ABST THE WORK DESCRIBED IN THIS PAPER INVOLVES THE INITIAL DESIGN AND PRELIMINARY TESTING OF A STREAMLINED OIL RETENTION BOOM.
KEYW BOOMS, RETENTION, CONTAINMENT
CODE 0541F

AUTH WRIGHT C.
TITL BAILING SYSTEM FOR SPILL CONTROL
PUBL WORLD PORTS 1973
CODE 0317P

AUTH WU J.
TITL LABORATORY STUDIES OF WIND-WAVE INTERACTIONS
PUBL J FLUID MECHANICS, 1968, VOL. 34, PART 1, JAN 15, 1968
CODE 2130A

AUTH WU J.
TITL SEA-SURFACE DRIFT CURRENTS
PUBL OFFSHORE TECHNOLOGY CONFERENCE, PAPER NO. 2294, MAY 5-8, 1975
ABST WIND AND WAVE INDUCED SURFACE DRIFT CURRENTS AT VARIOUS FETCHES WERE SEPARATELY ESTIMATED ON THE BASIS OF EXISTING WIND AND WAVE DATA.
KEYW SURFACE DRIFT CURRENTS, WIND/WAVE, WIND FETCH
CODE 2534F

AUTH WU J.
TITL WIND-INDUCED TURBULENT ENTRAINMENT ACROSS A STABLE DENSITY INTERFACE
PUBL J. FLUID MECH. VOL. 61, PART 2, 1973
ABST INTRODUCTION OF TURBULENT ENTRAINMENT ACROSS A DENSITY INTERFACE IS STUDIED IN A LAB. WIND/WAVE TANK.
KEYW TURBULENCE, ENTRAINMENT, STRATIFICATION
CODE 2105F

AUTH WU J.
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PUBL THE PHYSICS OF FLUIDS, VOL. 13, NO. 8, AUG.
CODE 2137A

AUTH WURTZ-ARLET J.
TITL LABORATORY STUDY OF THE TOXICITY OF CERTAIN SYNTHETIC DETERGENTS TO THE RAINBOW TROUT
PUBL VORTRAGE ORIGINAL FASSUNG INTERN. KONGR., GRENZFLAECHENAKTIVE STOFFE, 3 COLOGNE VOL. 3, CHEM. ABS. VOL 57, 1962
CODE 1023P

AUTH YATES B.A.
TITL THE MAKING OF A LOCAL CONTINGENCY PLAN
PUBL USCG, COOS BAY, OREGON
ABST THIS PAPER CHRONICALS THE UTILIZATION AND NINE MONTH DEVELOPMENT OF THE COTP PORTLAND OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN.
KEYW CONTINGENCY, UTILIZATION, DEVELOPMENT
CODE 0111P

AUTH YEUNG R.W.
TITL DOCUMENTATION OF FOUR OCEAN RELATED COMPUTER MODULES
PUBL MIT SEA GRANT PROGRAM, REPORT NO. MITSG 76-10, INDEX NO. 76-310-NRC
ABST THIS REPORT CONTAINS THE DOCUMENTATION OF A SERIES OF OCEAN RELATED COMPUTER PROGRAMS DEVELOPED AT MIT.
KEYW RESEARCH, COMPUTER PROGRAMS, DOCUMENTATION, MODULES
CODE 6129F

AUTH YORK J.L., STUBBS H.E., TEK M.R.
TITL THE MECHANISM OF DISINTEGRATION OF LIQUID SHEETS
PUBL TRANSACTIONS OF THE ASME, OCT. 1953
ABST THE DISINTEGRATION OF A PLANE SHEET OF LIQUID OF FINITE THICKNESS MOVING TANGENTIALLY RELATIVE TO A SURROUNDING FLUID IS SUBJECTED TO MATHEMATICAL AND EXPERIMENTAL ANALYSIS.
KEYW INTERFACIAL TENSION, AERODYNAMIC FORCES, DISINTEGRATION
CODE 2575F

AUTH YOUNG G.K., WARNER L.S., JETTMAR R.U.
TITL FINAL REPORT - MAJOR OIL SPILLS FROM TANKERS AND BARGES AND OTHER VESSELS IN THE US WATERS/ANALYSIS OF RECENT TRENDS AND PATTERNS
PUBL COUNCIL ON ENVIRONMENTAL QUALITY GKY AND ASSOCIATES, REPORT NO. EQ7AD235, MAY 1, 1977

ABST AN INVESTIGATION OF OIL SPILLS DURING THE WINTER OF 1976-1977 AND COMPARISON WITH SPILLS SINCE 1969.
KEYW TANKERS BARGES VESSELS TRENDS
CODE 7213F

AUTH YU T.S., VENTRIGLIO D.R.
TITL SHIPBOARD OIL POLLUTION CONTROL SYSTEM FOR BALLAST AND BILGE
PUBL NAVAL SHIP RESEARCH AND DEV. LAB.
ABST AN INVESTIGATION WAS UNDERTAKEN TO PROVIDE NAVAL COMBATANT SHIPS AT THE CAPABILITY OF AVOIDING OIL POLLUTION IN EXCESS OF 100 PARTS OF OIL/ 1 MILLION PARTS OF SEAWATER IN THEIR DISCHARGES OF BALLAST AND BILGE WATERS.
KEYW BALLAST, BILGE SHIPBOARD OIL POLLUTION
CODE 6103F

AUTH YUEN K.
TITL PROJECT OIL, TOXICITY TESTS FOR OIL DISPERSANTS
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16. Abstract

~~This report describes~~ the results of a series of studies conducted to determine the practicability and feasibility of using dispersants to mitigate the impact of an oil spill on the environment are described. The method of approach is holistic in that it combines the physical, chemical, microbial and macro-fauna response to a spill treated with dispersants and compares this with spills that are left untreated. The program integrates mathematical, laboratory, meso-scale (three 20 foot high by three feet in diameter tanks~~, described in Section I~~), in-situ experiments and analyses to determine if the use of dispersants is an effective oil spill control agent.

In summary, it appears viable to use dispersants as determined on a case by case basis. The case for using dispersants has to be based on whether or not their use will mitigate the environmental impact of the spill. In the case of an open ocean spill that is being driven into a rich inter-tidal community, the use of dispersants could greatly reduce the environmental impact. Even in the highly productive George's Bank area at the height of the cod spawning season, the impact of the use of dispersants is well within the limits of natural variability when the threshold toxicity level is assumed to be as low as 100 ppb, a level which is often found in the open ocean. Thus, it appears that dispersants can and should be used when it is evident that their use will mitigate the impacts of the spill. Their use in areas where there is poor circulation and therefore little possibility of rapid dilution is more questionable and should be a subject of future studies.

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