NASA CR-144988

(NASA-CR-144988) SCME ASPECTS OF USER NEEDS FOR AN AIR-LAUNCHED, EXPENDABLE FREE-DRIFTING BUOY Final Report (Research Triangle Inst., Research Triangle) 26 p HC $4.00 CSCL 08C G3/48

N76-22862

Unclas 26877

FINAL REPORT

SOME ASPECTS OF USER NEEDS FOR AN AIR-LAUNCHED, EXPENDABLE FREE-DRIFTING BUOY

By

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RTI Project No. 41U-1077

Prepared under

Contract NAS1-13637

By

Research Triangle Institute
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For

NATIONAL AERONAUTICS & SPACE ADMINISTRATION

March 1976

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-144988		

4. Title and Subtitle	5. Report Date
Some Aspects of User Needs for an Air-Launched, Expendable Free-Drifting Buoy	March 1976
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Fred M. Vukovich	
9. Performing Organization Name and Address	10. Work Unit No.
Research Triangle Institute P. O. Box 12194 Research Triangle Park, North Carolina 27709	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Aeronautics & Space Administration Washington, DC 20546	Contractor Report
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Ten research objectives were determined based on user's needs in which an air-launched, free-drifting buoy would significantly contribute to the accomplishment of these objectives. The objectives were formulated through discussions with individuals representing federal and state agencies and universities. The most immediate need was in continental shelf oceanography which required data to characterize circulation in a localized mesoscale region.

A tentative plan for the North Carolina Outfall Study was presented. Data from air-launched, expendable free-drifting buoys would be used in this study not only to characterize the circulation off the North Carolina coast, but also to provide data by which a three-dimensional hydrodynamic model could be verified. Through the validated hydrodynamic model, long-term statistics on the circulation will be developed. These statistics will be used to determine optimum locations for ocean outfall systems off the North Carolina coast based on the minimizing the effect of the affluent on the coastal zone.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Lagrangian Buoy Lagrangian Data Continental Shelf Oceanography Outfall Study Expendable Buoy	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	24	$3.25

*For sale by the National Technical Information Service, Springfield, Virginia 22161

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SOME ASPECTS OF USER NEEDS FOR AN AIR-LAUNCHED, EXPENDABLE FREE-DRIFTING BUOY

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SUMMARY

A set of research objectives was determined based on user needs and in which an air-launched, free-drifting buoy significantly contributed to the accomplishment of these objectives. The objectives were formulated as a result of discussions and meetings with individuals representing federal and state agencies and universities. The research objectives fell into three categories: 1) continental shelf oceanography, 2) open ocean meteorology, and 3) dynamics in estuaries and in sounds. Of these, the most immediate need was in continental shelf oceanography due to the number of field experiments that are presently being performed or are planned for the near future, requiring data to characterize circulation in localized mesoscale regions.

A preliminary plan for the application of an air-launched, expendable free-drifting buoy in the North Carolina Outfall Study is presented. Outfall studies are subsets of the category designated as continental shelf oceanography. The buoy data would be used not only to characterize the cirulation off the North Carolina coast but also to yield data by which a three-dimensional hydrodynamic model for the continental shelf could be verified. It is through the hydrodynamic model that long-term statistics will be developed. From these, optimum locations of ocean outfall systems off the North Carolina coast can be determined.

1.0 INTRODUCTION

The objective of this project was to determine from stated user's requirements a set of research objectives to which the air-launched, free-drifting buoy would contribute significantly. In order to accomplish this objective, meetings were arranged with individuals representing various federal and state agencies and various universities to discuss their experimental requirements with regard to understanding ocean processes in the nearshore and in the open ocean and to determine whether and/or how an air-launched, expendable free-drifting buoy may satisfy some of these requirements. Information was compiled based on meetings and/or discussions with the following individuals:

a. Federal Agencies

Dr. J. O. Blanton	Division of Biomedical and Environmental Research Energy Research and Development Administration Germantown, Maryland
Mr. Lem Vallianos	District Office U. S. Army Corps of Engineers Wilmington, North Carolina
Mr. Thorndike Seville, Jr.	Technical Director U. S. Army Corps of Engineers Research Center Fort Belvoir, Virginia
Dr. Paul Teleki	U. S. Army Corps of Engineers Research Center Fort Belvoir, Virginia
Dr. Fran Stetina	Goddard Space Flight Center National Aeronautics and Space Administration Greenbelt, Maryland

Dr. Michael J. Hall	NOAA Data Buoy Office National Oceanic and Atmospheric Administration Bay St. Louis, Mississippi
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Dr. Neal Frank	National Hurricane Research Laboratory National Oceanographic and Atmospheric Administration Miami, Florida
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b. <u>State Agencies</u>

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Mr. Ernie Carl	Director Office of Marine Affairs North Carolina Department of Natural and Economic Resources Raleigh, North Carolina
Mr. Stan Hecker	Office of Marine Affairs North Carolina Department of Natural and Economic Resources Raleigh, North Carolina

c. <u>Universities</u>

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Dr. Larry Atkinson	Skidaway Island Research Institute University of Georgia Skidaway Island, Georgia
Dr. Donald Francisco	Wastewater Research Institute University of North Carolina Chapel Hill, North Carolina
Dr. John Reizecki	Virginia Institute for Marine Sciences Gloucester Point, Virginia
Dr. Paul Hyer	Virginia Institute for Marine Sciences Gloucester Point, Virginia
Dr. Chris Welch	Virginia Institute for Marine Sciences Gloucester Point, Virginia
Professor Dean Bumpus	Woods Hole Oceanographic Institute Woods Hole, Massachusetts
Professor Charles Parker	Woods Hole Oceanographic Institute Woods Hole, Massachusetts
Professor Philip Richardson	Woods Hole Oceanographic Institute Woods Hole, Massachusetts
Mr. Bill Vachon	Massachusetts Institute of Technology Boston, Massachusetts

The following narrative summarizes in detail the net result of the discussions.

2.0 POTENTIAL APPLICATIONS OF FREE-DRIFTING BUOYS

2.1 Applications on the Continental Shelf

In recent years, an urgent need has developed to understand the nearshore circulation and exchange processes on the continental shelf off the coast of the United States. This need grew out of the potential danger to the biological, chemical and geological nature of the nearshore environment resulting from several factors. The most prominent of these factors are the following.

2.1.1 Coastal Zone Gas and Oil Exploration

By 1978 there will be widespread exploration for and exploitation of gas and oil off the United States coast due to the increasing need for petroleum products.[1] The primary areas of interest are the Gulf of Alaska, regions off the California coast, the Gulf of Mexico, and regions off the northeast and southeast coasts of the United States. Due to the potential danger of the biological, chemical and geological nature of the marine environment on the continental shelf, the Bureau of Land Management (BLM) of the Department of the Interior will be performing environmental impact studies in those regions. The overall objectives of these studies is to provide data that will serve to characterize a baseline for the status of the marine environment in order that changes may be measured or predicted. By baseline is simply meant the existing or present state of the chemical, physical, geological and biological character of the marine environment. The following specific objectives which are needed to satisfy the overall objective, are of interest.

1) Determination of the circulation and dispersion patterns in the oil and gas lease areas because of the potential hazard to the marine environment downstream as a result of the surface advection and diffusion of hydrocarbons and bottom transport of heavy metals.
2) Determination of the relationship between surface currents (in the first meter) and the movement of surface oil spills.
3) Determination of the nature of transport by waves.

The most common technique used to determine the dynamic properties of water in regional nearshore studies is to establish an array of Eulerian current meters and collect data over an adequate time period.[2] The cost of such systems generally makes this approach economically unfeasible when the scale of the phenomena to be studied is large or the area of interest is large (i.e., a large number of stations are required fro the array). Generally, the lease areas for gas and oil exploration incorporate an area of the order 10^5 square miles on the continental shelf.[1] However, the concensus of opinion is that a much smaller number of current meter stations are required for proper analysis of transport if Lagrangian data obtained using free-drifting buoys are combined with Eulerian data from current meters.

In many instances, the time scales of some coastal perturbations are short. In the time it would take a ship to deploy a system of free-drifting buoys in their proper locations, the phenomena of interest may have a) progressed to a stage where a large portion of the life cycle has been missed, b) dissipated completly, or c) moved to a different location. Because of these factors, it was considered extremely important to have the capability to launch buoys from an aircraft.

The position of the buoy must be observed with a frequency which depends on the scale on the scale of the phenomena investigated. For example, studies of microscale phenomena such as motion associated with tida idal effects or dispersion need a high frequency of observation on the order of one observation every few minutes to one each hour, whereas mesoscale phenomena need observations on the order of one every few hours to one each day. In the case of the BLM studies, both mesoscale and microscale phenomena are to be studied.

The time scale will influence the technique by which the location of the buoy is determined. The Random Access Measurement System (RAMS)[3] used on the orbiting satellite NIMBUS 6 can determine the position of a free-drifting buoy once each orbit (approximately once every twelve hours) over the region of interest, which would satisfy the mesoscale needs of the BLM studies. The data are not sufficient for studies of diffusion processes. Geosynchronous satellites, such as the SMS satellites, could determine the position of the buoy with whatever frequency would be required if the buoy were in the range of the satellites. However, location systems are not yet available for these types of satellites. High frequency observations for the location of a free-drifting buoy can be determined through navigational systems such as LORAN and OMEGA. The data could be stored aboard the free-drifting buoy and transmitted later to either a geosynchronous satellite or an orbiting satellite. This technique offers the greatest flexibility with respect to the frequency of observation, since it has the capability of satisfying both the large-scale advective transport problem and the diffusion problem.

The expendability of the buoy will depend on a trade-off between the cost of the buoy and the time of usage. A free-drifting buoy, which can interface with a satellite, can be developed at a cost comparable to the cost of operating an ocean-going oceanographic vessel for one day. Based on this constraint, it would be feasible to consider a buoy expendable when used in a study whose duration is greater than a few days [discussion with Professor Bumpus].

Though the primary data requirement from an air-launched, expendable free-drifting buoy in shelf studies would be accurate position data through which Lagrangian motion could be determined, it has been suggested that other instrumentation should be placed on the buoy. Instrumentation which could obtain surface and subsurface temperature and salinity data following the motion of the buoy is compatible with BLM's baseline data requirement. Of these parameters, reliable instrumentation does exist for the acquisition of surface and subsurface temperature; however, the conductivity sensors used to measure salinity have a very short lifetime relative to the temperature sensors (approximately two weeks in the open ocean and seven to ten days on the shelf). The short lifetime is due to contamination by algae and other foreign materials in the ocean.

With regard to the BLM objective to determine the relationship between surface currents and the movement of surface oil spills, past experience has suggested that surface oil spills do not always move in the direction of surface currents due to imposed surface wind stress effects. In order to study this problem, a free-drifting buoy may possibly be employed which has the capability of measuring the surface wind. However, in medium to heavy seas, the wind direction sensor would not yield reliable data. Alternative techniques such as synoptic weather analysis hould be used to obtain wind direction.

In order to satisfy the third specific objective treating wave transport, wave statistics (wave height, wave period, wave direction, wave speed, etc.) must be obtained in the lease areas. It may be possible to obtain wave data from a free-drifting buoy, but this would require that the buoy be a realtively stable platform.

2.1.2 Energy Production

With the increasing need for energy, the Energy Research and Development Agency (ERDA) is examining the potential for locating energy producing complexes such as nuclear power plants and ocean thermal systems on the continental shelf region. As in the case of exploration and exploitation of oil and gas, there is a high potential of producing detrimental environmental effects. Therefore, ERDA is examining the potential impact of nuclear power plants and other energy-related activities located on the shelf. ERDA intends to develop its capability to predict the effects of coastal and offshore nuclear reactors on the coastal zone. The present research sponsored by ERDA deals with processes within 20 km of the coast. Though the principal effort is nearshore, there are attempts to gather data at mid-shelf and near the shelf break in order to determine dynamic processes and predict potential impacts in these regions. The maximum area covered by the individual ERDA studies is about 10^4 square miles as opposed to approximately 10^5 squares miles involved in the BLM study. [4]

The principal objective of the ERDA study in physical oceanography is to provide a solution for problems assocaited with siting, operation and environmental impact of energy-related activities. The basis of the solution lies in understanding transport and dispersion of heat and chemical discharges into the environment, and corollary transport and dispersion of organisms into areas where these activities occur. This requires an understanding of the circulation processes in an area smaller than that associated with the BLM study. (This study is presently completing its first year of funding and is a three-year study).

Current meter arrays were used exclusively in the first year to obtain data which, through time series analyses, can characterize circulation processes in the area designated by ERDA to be of interest. It is highly probable that the application of the current meter arrays employed in ERDA studies combined with Lagrangian buoys would greatly enhance the results of the studies. Field programs using free-drifting buoys in the nearshore should primarily be devoted to near-surface currents. However, at mid-shelf and at the shelf break, both surface and subsurface currents should be examined.

As in the case of the BLM study, it is important to have the capability to launch the buoy from an aircraft because the time scale of some coastal dynamic processes are short. Furthermore, since the objective is to characterize the transport and dispersion properties, navigational systems such as LORAN or OMEGA should be used to locate the free-drifting buoy. Data should be stored on board the buoy for transmission at a later time to either a geosynchronous or an orbiting satellite. As indicated earlier, this technique offers the greatest flexibility with respect to frequency of observations, so that both mesoscale and microscale processes can be accounted for by the same experiment. Since the space scale is small, the time scales involved with the regional circulation processes should also be small (the order of one to three days). For a free-drifting buoy whose cost is comparable to the operation of an ocean-going oceanographic research vessel for one day, the expendability is borderline. Since the area of interest is small, relatively inexpensive ships may be used to recover the buoys.

The application of free-drifting buoys in this experiment would be event-oriented, since economics would not allow a continuous study using free-drifting buoys similar to that performed using the current meter array. However, case studies are economically and logistically feasible, and should provide data which can be used to enhance the time series studies using the current meter arrays.

The ERDA program also has an objective to determine transport by waves in the coastal zone.[4] The ERDA objective is more immediate than that of BLM since ERDA's operation will be for the most part, within 20 km of the coast and BLM's operation will be conducted from 20 km oceanward.

2.1.3 Ocean Outfalls

Communities have indicated a need to improve their waste water disposal facilities to support increasing demands of development and expanding populations. In many regions, the prospect is that soils will be unable to accept additional volumes of waste water discharge without incurring a high probability of endangering health and well-being of local residents. Therefore, an urgent need exists to discover alternative techniques for waste disposal in this country. One solution available to coastal states is development of an ocean outfall system. This solution has been applied in the State of Florida and is currently being applied by the State of Virginia.[5 and 6]

Optimization of the location of ocean outfall systems is primarily based on two criteria. The first is to minimize the impact on the coast. This requires the determination of the probability that the effluent will not be transported back to the coastal regions; if such an adverse event did occur, tremendous social and economic impact upon the region would result. The second is to minimize the impact on the marine environment which requires the determination of the effect of the effluent on the biological and chemical structure of the marine environment.

One of the principal requirements, therefore, in optimization of location of ocean outfall systems is to acquire an indepth knowledge of the circulation and dispersion processes off the coast where the outfall systems are to be developed. Literature surveys reveal a scarcity of scientific data on which existing conditions off the coast of the United States might be evaluated for optimization. Additionally, this lack of adequate background information prevents development of prediction techniques and models to test the adequacy of the proposed systems such as discharge rate, length of outfall pipe, etc.

Therefore, studies are necessary to determine the environmental impact of ocean outfalls to serve the coastal regions in order to initiate the optimization process. These studies would provide data for an appraisal of the present condition of the nearshore environment, and the temporal and spatial response to forces to which it may be subjected. The results of data analysis should provide an envelope of parameters within which proposed waste water disposal systems may be evaluated and their impacts assessed.

For one aspect of the optimization process, long-term statistics on the circulation processes must be obtain for the coastal region. The cost of a long-term field program prevents this technique from being feasible for the acquisition of data. However, one solution is to develop a three-dimensional hydrodynamic model to obtain circulation data. A short-term field program would be required to obtain data 1) by which the hydrodynamic model may be evaluated, 2) by which the dispersion processes in the regional area may be evaluated, and 3) by which a supporting empirical model of the circulation processes in the regional area may be developed. The validated hydrodynamic model will provide a basis to determine expected error and refine the model to minimize error. After this is done, the model may be used to develop long-term statistics on the circulation. When the model developed statistics are combined with the empirical model of the circulation, the optimum location for ocean outfall systems may be determined.

An air-deployable, free-drifting buoy can provide necessary circulation data for the short-term field program. Navigational systems such as LORAN or OMEGA should be used to locate the free-drifting buoy since the time frequency at which the location of the buoy can be determined satisfies both the mesoscale and microscale requirements of this study. Since the experiments will deal with mesoscale processes having periods from one to fourteen days, the expendability of the buoy will depend on which time scale is studied. In a fourteen-day experiment, a buoy whose cost is similar to the cost of an ocean-going research vessel for one day is expendable; however, in the one-day experiment, it is not.

The validation of the hydrodynamic model will require data on both the dynamic and the physical structure of the nearshore marine environment. Therefore, it would be advantageous to have instrumentation placed on the buoy through which surface and subsurface temperature and salinity data may be obtained following the motion. Wind speed measurements will also aid the model validation since surface wind stress, which can be computed using the wind speed, is one of the major forcing functions influencing the currents on the continental shelf.

2.2 Meteorological Applications for Free-Drifting Buoys

The Global Atmospheric Research Program (GARP) has two objectives The first is to improve and extend weather forecasting by developing a better understanding of the atmospheres' transient response, and the second is to improve our knowledge of factors determining the statistical properties of the general circulation.[7] These kinds of objectives are fundamental. In order to meet such objectives, large amounts of weather data will be required on a global basis. Difficulties arise in efforts to collect weather data in remote oceanic regions. However, some of these difficulties may be overcome by using satellite-borne remote sensing systems such as the High Resolution Infrared Sounder (HIRS) and the Tropical Wind Energy Conversion at Reference Level Experiment (TWERLE).

The infrared sounder can yield data on the vertical distribution of temperature through the atmosphere. The accuracy of this system is depen-ent, to a certain extent, on the accuracy of the surface temperature (sea-surface temperature in oceanic regions). The surface temperature is derived by the sounder system itself since it has a water vapor window radiation band. However, alternative techniques for obtaining accurate surface temperatures are needed in order to insure that the infrared sounder system will yield accurate data for programs such as the First GARP Global Experiment schedule to begin in 1978.

One possible solution to the problem of observing sea-surface temperature in remote oceanic regions is the use of air-launched, expendable free-drifting buoys as a meteorological sensing platform. The air-launched capability reduces the economic burden of delivery of such vehicles to remote ocean regions, particularly in such regions as the southern hemispheric oceans. Inexpensive thermistors are available which will yield temperature accuracies the order of one-tenth of a degree centigrade (0.1°C). This appears to be adequate since satellite-derived temperatures have an accuracy of five tenths of a degree centigrade (0.5°C).[8]

It may also be possible to place a barometer on the free-drifting buoy and to collect surface pressure data along with the sea-surface temperature data. However, the instrumentation required must have an accuracy of the order of $\pm$ 1 mb in the vicinity of the North American continent. In the open ocean, the accuracy must be of the order of $\pm$ 0.5 mb. Since programs such as GARP require that both wind direction and speed be obtained at the surface, the use of wind systems on the free-drifting buoy would not be of any advantage due to its limited capability. All data collected by the buoy should be telemetered to a satellite.

It has been indicated that the most important factor required for the application of the meteorological data from a free-drifting buoy is the determination of accurate position data. Experience has shown that this area of endeavor gives the most difficulty.

2.3 Studies in Estuaries and in Sounds

Free-drifting buoys may be used to support studies characterizing the nature of circulation and dispersion processes in estuaries and sounds The objectives of such studies are 1) to understand the role of sediment and sand transport in the development of shoals (Army Corps of Engineers), 2) to understand distribution of currents as they apply to navigational problems (Army Corps of Engineers), and 3) to understand transport and dispersion as these processes apply to waste water research (State and Federal Agencies). At present, dye techniques are being used to characterize circulation and dispersion processes in these regions. These techniques have yielded adequate results, but produce extremely complicated logistics and analysis problems. Alternative techniques for determining transport in sounds and estuaries have been desired for many years. Considerable attention has been paid to the prospect of using free-drifting buoys to replace the dye techniques.

Due to the shallow water involved in these regions (less than 10 m on the average) and the need simply to locate these buoys, a small drogueless surface drifter is required whose position can be determined remotely and continuously. Satellite-compatible buoys with OMEGA or LORAN location systems containing a digital data sorted system may suffice, provided the satellite can discriminate one buoy from the next since a large number of buoys are required. Small radar buoys are also applicable. Sounds as well as estuaries can be rather large. Therefore, the air-launch capability should be maintained.

2.4 Concluding Remarks

The following is a set of research objectives based on user needs derived from the previous discussions of the three major categories, 1) continental shelf oceanography, 2) open-ocean meteorology, and 3) dynamics in estuaries and in sounds, in which air-deployable, free-drifting buoys can play a major role.

A. Continental Shelf Oceanography

1) The determination of the three-dimensional characteristics of horizontal transport associated with meso-circulation systems on the continental shelf. This would include transport associated with Gulf Stream induced eddies, meteorologically induced eddies, tidal motion, etc.

   a) As a corollary to the shelf circulation studies, surface and subsurface temperature and salinity data should be acquired following the motion of the buoy. These data would be used as an aid in the interpretation of the motion of the buoy.

2) The determination of dispersion processes on the shelf.

3) The determination of the movement of a surface contaminant relative to surface currents in oceanic regions.

4) The establishment of surface wind-stress analysis over shelf regions for model validation.

5) The acquisition of wave statistics on the continental shelf in order to develop an understanding of transport processes associated with waves and to predict potential flooding in estuaries.

B. Open-Ocean Meteorology

6) The determination of sea-surface temperature in support of satellite infrared sounder analyses.

7) The acquisition of sea-level pressure measurements over remote oceanic regions for an accurate sea-level pressure analysis.

C. Dynamics in Estuaries and in Sounds

8) The establishment of sediment and sand transport processes in estuaries and sounds in support of activities studying the development of shoals.

9) The establishment of a distribution of currents in estuaries in support of studies of navigational problems.

10) The acquisition of data in estuaries and in sounds to study transport and dispersion processes as they apply to waste water research.

3.0 EXPERIMENT DESIGN FOR NORTH CAROLINA OCEAN OUTFALL STUDY WITH APPLICATIONS OF FREE-DRIFTING BUOY

As indicated earlier in Section 2.1.3, ocean outfall studies on the continental shelf is an experiment in which free-drifting buoys can play an important role. In the following section, a preliminary experiment design for the North Carolina Outfall Study is presented which demonstrates the role of air-deployable free-drifting buoys.

3.1 Objectives of North Carolina Outfall Study

The primary objective of the North Carolina Outfall Study is to determine the optimum location or locations for ocean outfalls along the North Carolina coast from the Virginia border to the South Carolina border. Optimization will depend on minimizing the effect of the effluent on the coastal and marine environment. The following specific objectives will be accomplished.

A three-dimensional hydrodynamic model of the shelf region off the North Carolina coast will be developed. This model will include forcing functions such as the surface stress, the Gulf Stream, bottom topography, and coastal topography. The model will be used to develop long-term mesoscale circulation data which will be used to determine the optimum location of the ocean outfall systems based on minimizing the effect of the effluent on the coast.

However, before the long-term mesoscale circulation data are developed using the hydrodynamic model, the model will be evaluated and refined. In order to accomplish this, special experimental studies will be initiated employing satellite data, free-drifting buoy data, and various in-situ data to determine the characteristics of the circulation off the North Carolina coast. The data from these studies would be used to evaluate the hydrodynamic model and to develop an empirical model on the circulation processes off the coast. Along with the circulation data, baseline marine chemistry and marine biology data will also be obtained which will be used in the second phase of the optimization analysis.

After the hydrodynamic model has been evaluated and refined, long-period mesocirculation data developed, and the empirical models completed, the first step in the optimization program will be initiated. This step determines the optimum location of ocean outfall systems based on minimization of impact on the coast; that is, the determination of regions with low probability of having effluent transported back to the coastal region. After this criteria has been imposed and these locations, if any, determined, then the second minimization criteria will be imposed; that is, minimization of impact on marine environment. The second criteria will be used to determine if the locations based on the first criteria are regions where there is a high probability of significant impact on the marine environment in terms of its chemistry and its biology. If there is a high potential, then this location will be dropped. However, if the potential is low, the location will be sustained, completing the theoretical optimization process.

The final stage in the determination of optimum location for ocean outfall systems will be a site evaluation study. The purpose of this study will be to determine the suitability of the locations for ocean outfall systems determined by the theoretical technique mentioned above through a microscale study.

3.2 Logistics for Oceanographic Field Program

3.2.1 Mesoscale Oceanographic Field Program

The primary purpose of the mesoscale oceanographic field program will be to obtain data to be used to evaluate and refine the three-dimensional hydrodynamic model and to establish an empirical circulation model. Because of the high cost of performing such a field program, the program design specifies special studies for approximately three to four-week periods in each of the four seasons, rather than long-term continuous effort. Figure 1 shows the preliminary current meter array. The nearshore station will have at least one current meter which will be positioned near the surface. Those stations near the shelf break will have at least three current meters: one at the surface, one at mid-level, and one near bottom. At each of these stations, temperature data will be collected at various levels using thermistors. The spacing between thermistors will be at most ten meters. Data will be stored on strip charts at each station and collected by a ship, or digitally at the station and telemetered to a satellite.

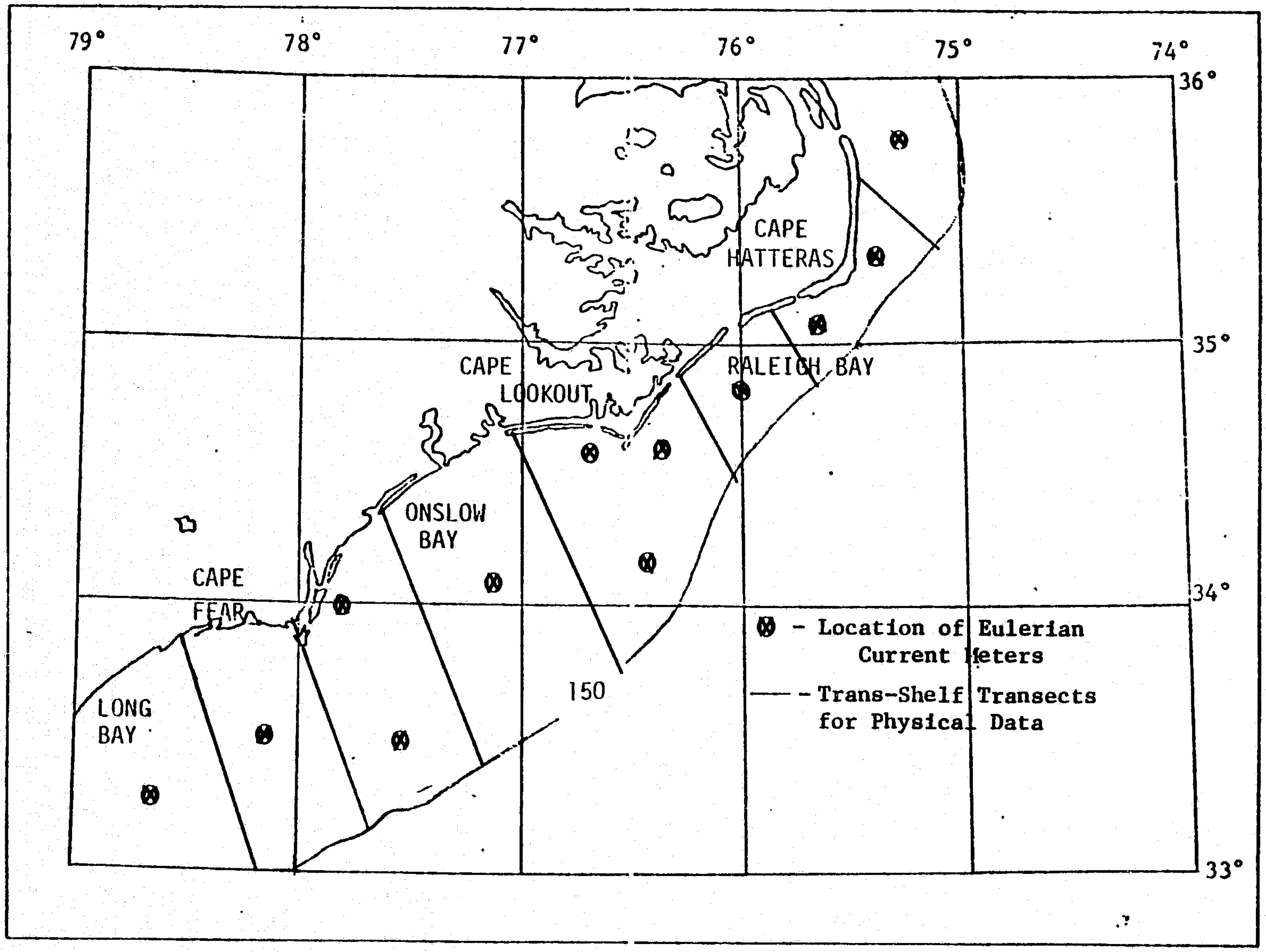
79°
78°
77°
76°
75°
74°
36°
35°
34°
33°
CAPE HATTERAS
RALEIGH BAY
CAPE LOOKOUT
ONSLOW BAY
CAPE FEAR
LONG BAY
150
- Location of Eulerian Current Meters
- Trans-Shelf Transects for Physical Data

Figure 1.

Also shown in Figure 1 are preliminary positions for trans-shelf transects at which physical data, chemistry data and biological data will be obtained during the course of the field program. Two ships, or possibly helicopters, will be employed to obtain these data. If ships are used, it has been estimated that it will take approximately five days to complete the entire grid. However, if helicopters are employed, only two days will be required.

The case studies will be event-oriented; that is, the case studies will be initiated based on different types of meteorological forcing or forcing due to Gulf Stream eddies. In order to determine whether Gulf Stream eddies are playing an important role on the transport on the continental shelf off the North Carolina coast, this region will be monitored using the IR data from one of the applications satellites (the NOAA series). Standard weather data will be used to determine the nature of the meteorological forcing (wind stress distribution) on the continental shelf. The sea-surface thermal distribution from satellite IR data will also be used to determine if perturbations are developed as a result of the meteorological forcing.

For the most part, the deployment of the air-deployable, free-drifting buoy will depend on the analysis of the IR data and on the meteorological analysis. If an event is detected, a grid yielding the positions at which the buoys are to be deployed in order to study the event, will be determined. Generally, air-deployable buoys will be drogued to determine near-surface currents in the coastal zone and multiple buoys will be deployed near the shelf break to obtain surface and mid-level currents. Depending on the location of the event, five to ten buoys may be deployed per grid.

3.2.2 Site Evaluation Study

The site evaluation study will take place after the optimum locations for ocean outfalls have been determined using theoretical procedures. Short-period seasonal field programs are planned through which tidal motions, microscale motions, and plume motions will be studied. Physical, chemical and biological data will also be acquired during the site evaluation study to examine more closely the baseline state of the region.

Free-drifting buoys will be used to study tidal motions and dispersion processes. Essentially, clusters of buoys will be released in the region and the position of the buoy will be determined at fifteen (15)-minute intervals during a period of three to four days, depending on the meteorological regime. The buoys will be drogued at different depths in order to classify the processes in various modes of dynamic activity. Some attempts may be made to employ remote sensing techniques for plume tracking. The final decision on the applicability of the location for ocean outfall systems will rest on the results of the site evaluation study.

3.3 Concluding Remarks

The above describes the present state of planning for the North Carolina Ocean Outfall Study. The experiment design is in a very preliminary stage. The nature of all data to be acquired has not been determined as yet. However, certain field programs under the direction of personnel from the various universities in the state of North Carolina have been initiated to collect chemical and biological data in support of this program. It is expected that these programs will provide a basis for determining the types of biological and chemical data to be collected.

For the most part, the preliminary plans have been based on the physical oceanographic nature of the continental shelf region off the North Carolina coast and the various modes of circulation that characterize that region. It is expected that air-launched, free-drifting buoys, combined with Eulerian current meter data, will play a major role in establishing the nature of the circulation off that coast.

4.0 CONCLUDING REMARKS

Ten research objectives were determined from the series of discussions and meetings with individuals representing various state and federal agencies and universities. These research objectives fell into three categories: 1) continental shelf oceanography, 2) open ocean meteorology, and 3) dynamics in estuaries and in sounds. Of these categories, the need for an air-launched, expendable free-drifting buoy in continental shelf oceanography appears to be immediate. This is due to the significant number of studies presently being performed (BLM and ERDA studies) and the large number of studies being planned (the expected comprehensive outfall studies) which require detailed knowledge of the circulation and dispersion patterns in the localized regions. It appears that when data from air-launched, expendable free-drifting buoys are integrated with conventional data, there will be a significant improvement in the spectrum of scales of motion which can be studied. This would result in a lower cost than would otherwise be necessary if conventional techniques were applied to obtain the same spectrum.

However, it should be pointed out that though improved analyses of circulation properties on the continental shelf can be obtained by combining buoy data with conventional data, significant improvement must be made in analysis techniques using Lagrangian data, as well as the combination of Lagrangian and Eulerian data. The application of free-drifting buoys in oceanographic studies have been small compared to the application of Eulerian current meters. Very little has been done to develop analysis techniques.

ACKNOWLEDGEMENTS

This report was prepared by the Geosciences Department of the Research Triangle Institute (RTI), Research Triangle Park, North Carolina under Contract NAS1-13637, sponsored by the Langley Research Center (LRC), National Aeronautics and Space Administration (NASA). The author wishes to acknowledge the support and interest of Mr. Jimmy Usry (NASA/LRC), who was the contract monitor and Mr. John McFall (NASA/LRC). Special thanks to the many people who took time out from their busy schedules to discuss their underlying needs with respect to free-drifting buoys.

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