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A SURVEY OF THE PROBLEMS AND RESEARCH NEEDS IN THE COASTAL ZONE

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ABSTRACT

This report presents the results of an interdisciplinary study made by a committee selected from the Old Dominion University science faculty. The purpose of the study was to establish the major problems and research needs in coastal zone oceanography. These are presented for the individual disciplines of biology, chemistry, geology, and physics, including coastal zone meteorology, with special emphasis on those problems and needs of an interdisciplinary nature.

Among coastal zone problems highest priority is assigned to pollution. The greatest need was found to be acquisition of more physical data for improving our knowledge of coastal water mixing processes.

Required ground truth measurements and possible application of Earth Resources Satellite (ERTS) sensory data for solution of specific problems are given.

Recommendations are presented concerning cooperation between NASA and NSF relative to ERTS application to the International Decade of Oceanographic Exploration.

PREFACE

Discussions were held in May 1970 between personnel of the Applied Materials and Physics Division, Aerospace Mechanics Branch, NASA - Langley Research Center, and the School of Sciences, Old Dominion University. As a result of these discussions it was agreed that a committee of the Old Dominion University faculty would do a survey of the problems in coastal zone oceanography and of the research needed to aid in solution of these problems. A task-order for this project became effective June 5, 1970, with a final report due on September 15, 1970. The Langley task description and the Old Dominion University proposal are attached in appendix. The organization of the study committee and the planned approach to the specific task responsibilities are outlined in the Old Dominion University proposal.

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INTRODUCTION

The comprehensive report (1) by the Commission of Marine Science, Engineering, and Resources includes a basic definition of the coastal zone. This area is described as "including seaward, the territorial sea of the United States and landward, the tidal waters on the landward side of the low water mark along the coast, the Great Lakes, port and harbor facilities, marine recreational areas and industrial and commercial sites dependent upon the seas or the Great Lakes". This description is accepted for the definition of the coastal zone in this report, with two significant modifications. The seaward limit shall extend at least to the margin of the continental shelf and the references to the coastal zone shall not be limited to the territorial waters of the United States.

The significance of the coastal waters to commerce, a source of natural resources, recreation, and national defense has been discussed in several recent reports on both national and internationallevels (1-23). There is common agreement in these studies regarding the importance of the coastal zones and their need for organized management and study. To the scientific and engineering community this position offers a rather formidable challenge to solve the myriad of problems associated with the coastal zone. There are additional industrial and economic interests concerned with the utilization of the living and non-living natural resources in these waters and the continental shelf. The growth of metropolitan centers along the coastline has created additional problems of pollution, the need for new recreational facilities, and have modified severely shore line structures in the coastal zone region. The overall physical and biological interrelationships that exist are vast and in most cases, little understood, or unknown.

Past efforts to study the coastal zones have been essentially isolated efforts, oriented to local, sometimes regional areas. It is important that these studies are not too limited in their scope and include input of information from all relevant sources, for these coastal current systems know no state or national boundary. Thus, there is a great need for broad coordinated studies of the coastal regions. In many cases, the solutions to these major but different problems depend on the acquisition and use of similar data. This relationship in the use of common data is apparent to the marine scientist who finds that an inter-disciplinary approach to oceanography is paramount. The solution of co-ordinated efforts by research teams has become the fundamental method in solving these needs in the coastal zone. However, each of these scientific groups, who are components of the coastal zone research community, have unique problems that call upon their innate expertise for solution. It is the purpose of this report to question the major groups of this community, and to note their respective areas of major concern and experimental needs. A common denominator is sought that may represent a need most useful to one or to all the groups. The results of this report includes the recommendation of an area of study mutually necessary to the problem solving requirements of the coastal community and specifies the environmental parameters this group requires and considers most significant.

PROBLEMS IN THE COASTAL ZONE

BIOLOGICAL NEEDS

Despite the comparative uniformity of the physical oceanic environment its biota exhibits a greater diversity of forms than all of the land and fresh water habitats combined. Among the nonparasitic types, only four of the total 59 usually recognized classes of animals lack marine representatives. Some 25 animal classes including the entire phylum Echinodermata (about 6,000 species) are wholly marine. This great diversity results in an ecological complexity unknown in the terrestrial realm.

The development of marine ecology has been hampered by an incomplete knowledge in the identity and complete life cycle studies of the oceanic flora and fauna. Many of the concerns of marine biology or ecology depend upon the accurate identification and census of the species encountered.

One needs to know not only what organisms are found where, and under what environmental conditions, but also in what absolute and relative numbers. These considerations will be influenced by the methods and frequence of sampling utilized. It is necessary that standard methods be employed, or that different methods be related to the same base, for comparable results. In addition to basic considerations, such as composition, distribution, and numbers of species; there is need for the measurement of the biomass contribution by each species and trophic level to the economy of each ecosystem. A more accurate knowledge of production at each trophic level would yield estimates of overall energy flow and ecological efficiency. Such knowledge would have practical and theoretical application in fishery biology.

There are several approaches to the study of ecology that may be useful in establishing feasibility and areas of prime importance in marine studies. One such division is, the autecological versus the synecological approach. Autecology deals with the extensive study of individual species in relation to environmental factors and is often indistinguishable from such disciplines as physiology. Autecology strives to determine the natural history of species and is intimately concerned with such aspects as reproductive potential, habitat requirements, tolerance ranges, behavorial responses, symbiotic relationships, longevity, mortality, recruitment, growth rate and food relationships. Though some autecological information is available for many members of the producer level, and a little more for the commerically important preditors and scavengers, virtually nothing is known about the intermediate organisms which link these two levels of the various marine ecosystems. An understanding of species interactions and interdependencies relies upon such information and is considered a major area where more investigations are needed.

Most aspects of autecological studies require the close examination of specimens which precludes the use of remote sensors. With the exception of possible application of sensors in studies of distribution, movement, and behaviour (providing individual species can be discriminated) the primary contribution of these devises to autecological studies appears to be in the examination of the physical aspects of the environment.

Synecology is concerned with the study of groups of interacting species (communities). Often the findings of autecology play a fundamental part in explaining the causes and processes of multiple interactions characteristic of communities and higher ecosystems and both approaches are essential to a full understanding of ecological phenomena. The major areas of concern in synecology include: the qualitative and quantitative study of population and community dynamics, prediction of future changes in succession, species interactions, biogeochemical cycling and production. The fundamental objective is the understanding of these entities under natural conditions with appropriate consideration and natural fluxuations. Mutual interdependences include predation and food chain inter-relationships. Biogeochemical cycling studies investigate the qualitative and quantitative movement of specific nutrients or elements between the biotic and non-living components of ecosystems. Production studies concerns the nutritional aspects of ecosystems and may deal with the numbers, biomass of energy component which is cycled from the producer level through subsequent trophic levels.

Synecological studies, by definition, are more broadly scaled than autecological studies and consequently offer a greater possibility for the utilization of remote sensor and satellite technology. It is impossible in a report such as this to set out ground truth requirements, sampling frequency, sensor resolutions, etc. for broadly conceived research programs. These requirements should be worked out between biologists and engineers during the formulation of specific research proposals from individuals or coordinated groups of investigators.

Neither the proposed ERTS A and B, nor the E and F instrument packages afford resolutions capable of any but the grossest of overviews from a biological point of view. None the less, the following possible applications do exist: 1) productivity estimates of various coastal zones based upon chlorophyll concentrations (e.g. salt marshes); 2) survey and charting of the habitat types of the world coastal zone; 3) physical oceanographic data of all types (e.g., currents, temperatures, upwellings, mixing, flushing rates, etc.) that would be related to the biological communities.

Analysis of a Questionnaire on Priorities in Biological Oceanography

Biological Oceanography represents one aspect of the marine sciences that engages a large number of investigators and participants in both applied and academic endeavors. These biologists are usually affiliated with educational institutions, state or federal fishery laboratories, or private industry. In an attempt to incorporate into this study the views of as many of our scientific colleatues as possible, a questionnaire was formulated (see appendix) and sent to 720 American and 83 foreign marine biologists and biological oceanographers. The recipients were selected from two major sources: 1) individuals recommended by the committee who were known to be actively engaged in major studies in coastal zone regions throughout the world and 2) names of marine biologists from academic institutions, state and federal fishing laboratories, and industry, as provided from membership lists of professional organizations.

A total of 171 (21.2%) of the questionnaires were returned (note table below). Of the foreign correspondence the return was 22.8%, with the response from the United States investigators 21.1%. Although replies are still being received, it is believed that the responses to date are a representative cross section of the opinions of the marine biologist regarding research in coastal zone oceanography.

Questionnaires

Scientists	Mailed	Returned	Percent Returned
U S A	720	152	21.1
Foreign	83	19	22.8
Total	803	171	21.2

The following table summarizes the results of the portion of the questionnaire which asked the recipients to place the listed major study areas in order of priority.

Major Study Area	Priority Rank				
	1	2	3	4	5
Coastal geography and cartography	5	9	22	38	16
Fisheries	27	72	39	10	4
Hazards to shipping and coastaline	3	6	19	39	30
Pollution	94	39	12	1	2
Other**	38	29	28	4	2

** Other includes a variety of subjects, but usually a more specific aspect of one of the other 4 areas.

The second portion of the questionnaire asked for a more detailed statement of specific problems. The information received in this part of the questionaire generally reflects the priority rankings given above. The responses reveal the following major points:

1. Pollution is the study area of primary concern in replies from both American and foreign respondents.

2. Estuarine studies, particularly those dealing with the pollution and degradation of estuaries are critical.

3. Fishery and shelf resource studies are greatly needed. Many fishery problems are closely related to the other major problems in the coastal zone.

4. Many responses emphasized the need for good hydrological information (e.g., current patterns, temperature and salinity distributions, etc.). Broad synoptic data was requested by many.

5. The need for basic ecological studies was stressed (e.g., life histories, productivity, biotic composition, ecosystem dynamics, etc.).

6. Specific geographical areas of concern were difficult to assess. Many problems were viewed on a worldwide basis; however, coastal areas near population centers were most frequently mentioned. Specifically mentioned by many respondents were Chesapeake Bay, San Francisco Bay, and the northern Gulf of Mexico. The mention of these three areas perhaps reflects a certain amount of bias reflecting the distribution of marine scientists as well as the distribution of major problems.

The questionnaire responses stated numerous specific problems and data deficiencies which will not here be enumerated. These, however, have been studied by the committee and are reflected in many portions of this report. The committee believes the emphasis placed on pollution and fisheries biology as major areas of concern warrants additional expansion and these have been discussed in more detail in the following pages.

Pollution

Americans and foreign biologists have both stressed the need for more study concerning the nature and effects of pollution on organisms of our bays and estuaries. Unfortunately, not enough study has been conducted to date on the basic biology and ecology of the organisms and regions subject to pollution. Today, pollutants need to be identified in relation to their presence and toxicity to the components of the marine community, their permanence in the local area, and their final dispersion in the environment.

Environmental pollution may be defined as the deletarious modification of our physical surroundings largely due to the direct, or indirect, by-products of human activities. These modifications may be to food supplies, energy patterns, radiation levels, chemical and physical factors, or to organismal abundance. Some of these changes may ultimately affect man through his supply of air, water, and food, or influence his opportunities for recreation and overall appreciation of the environment.

Generally, once the pollutant has entered the coastal waters, its full impact in the area will be influenced by a multiple of factors. These include (24): a) the dilution and dispersion of the pollutants by water masses, b) transport by currents and migrating organisms, c) concentration of the pollutant by biological processes in plant and animal tissue, and d) physical conditions leading to bottom precipitation and accumulation.

Pollution effects on the biota.

The most obvious effect of pollution is the direct mortality of the flora and fauna. In addition, reduced photosynthetic rates in phytoplankton, animal sexual impotency, embryonic defects, and carcinoma have also been attributed to various pollutants. The tolerance of organisms to specific pollutants appears to be highly variable, with juvenile stages and sedentary species often being more susceptable than adults and mobile species. Although the marine waters are vast, many of these pollutants will produce their effects in minute concentrations (e.g. less than a part per billion of DDT in some cases). It is therefore necessary to be able to identify the pollutant and monitor its concentrations for accurate correlations to toxicity effects on marine forms.

The synergistic or side effects of pollutants frequently present a wide range of unforeseen events that may be more spectacular than the initial toxic effects. The composition of natural populations has been known to be modified by pollutants which in turn has resulted in changes in more extensive preditor-prey and host-parasite relationships. These changes can significantly alter the entire ecosystem balance and result in the destruction of important food species, or the movement of such species to different areas, which may subsequently affect their growth rate, disease susceptability, or the balance of life in the newly invaded areas. Pollutants such as specific crude oil fractions have been known to mask or mimic the natural role of pheromones to many marine forms. These chemical substances are secreted by species as attractants for mating and for the detection of preditors or prey. They are essential to the survival of the species. When this action is upset by such pollutants, large scale deaths may occur.

Areas of high oceanic productivity are usually localized due to unique and special circulation patterns. In the Indian, Atlantic, and Pacific oceans, the areas of high productivity are located near the boundaries of major current systems where active mixing and coastal upwelling brings the deeper, nutrient rich waters to the surface. The added significance of this upwelling is that along with the nutrients can also come pollutants, such as long-lived pesticides, heavy metals, and radioactive isotopes, which were deposited on the bottom. A major problem here, is that we are unable to predict such future consequences of these pollutants to the marine biota.

Many of the research needs of the biological community (responders to questionnaire) indicated problems associated with pollution. Examples of these major problem areas of high priority are: 1) knowledge of the pathways of chemical pollutants in biological systems and the tolerances of various organisms to each pollutant; 2) the importance of estuaries in the general ecology of the oceans and how different pollutants will effect this position; 3) the long term effects of industrial dumping, sludge barge unloading, and oil spills will have on coastal regions; 4) adequate instrumentation to measure and monitor pollutants at marine collection stations.

The general consensus is that basic ecological studies from which comparisons can be made are lacking. Without these base line studies it is impossible to know the extent of damage being caused by pollution. Many types of pollution have been cited; especially, thermal, pesticide, oil, nutrient (from domestic sewage, etc.), and radio-nucleotides. The lack of information on the direct and synergistic effects of pollutants is mentioned repeatedly by the responders to the questionnaire. The need for the detection and quantification of pollutants in relation to water circulation patterns is stressed. The need for monitoring environmental parameters and all pollutants is stressed. Studies to identify organisms or specific communities which can be used as pollution indicators also ranks high.

Types of pollutants.

The deletarious modifications of the marine environment may be brought about by a variety of agents. These agents may be broadly classified as chemical, thermal, and sediment pollution.

I. Chemical Pollutants - the chemical pollutants of greatest importance include the following: organic pesticides, heavy metals, crude oil and its derivatives, radio-nucleotides, and nutrients.

A. Organic Pesticides - these compounds can be generally separated into two types: 1) chemically unstable, and 2) chemically stable compounds (such as the chlorinated hydrocarbons). Though the first group can cause immediate mortality in a limited area, the unpredictability of their release limits our ability to detect their presence before their effects are manifested. The second group may cause immediate mortality, but its course of action is frequently by the phenomenon of biological magnification in the food chain which results in increased pesticide accumulation within organisms that eventually leads to death. The quantification of the stable organic pesticides is of paramount concern to many investigators. Comments by investigators reveal concern for the "high amounts" of chlorinated hydrocarbons being detected in both shell and fin fish. The usual methods employed to detect these substances require the analysis of animal tissue or water samples by gas chromatography. The instrumentation capabilities required for satisfactory investigation of these and other pollutants are presented in the section on chemical oceanography.

Organic pesticides are entering the continental shelf, and especially the estuaries, from areas of organized agricultural activities. The wide use of pesticides for control of insect vectors of human disease adds another source. Some of these chemicals are being carried into the oceans by fresh water streams, with additional quantities derived from air borne sources. The geographical significance of these pollutants is global in scope, with their presence noted throughout the world seas. The concern for the rising concentrations of these products is further substantiated by responders from Europe, Asia, Australia, and Central and North America.

B. Heavy Metals, Crude Oil and its derivatives - these groups appear to exhibit similar properties to those of the stable organic pesticides. The heavy metals enter the oceans from air borne sources (vehicular combustion), as industrial effluents, and in waterways derived from their use in human and agricultural disease control. The seriousness of lead pollution has been recognized longer than that from other heavy metals. However, recent concern with mercury pollution in fresh and marine waters indicates the whole class of heavy metals and related compounds should be evaluated.

The major areas of petroleum pollution include off-shore oil wells; the shipping lanes, and areas in and around international harbors. Billions of gallons of crude oil and its products are entering the marine environment annually, and large spills have become common. The seriousness of this type of pollution should receive a high priority for investigation. Current methods of detection and quantitative identification of petroleum products require the use of gas chromatography mass spectrochemical analysis, and nuclear magnetic resonance. Methods employed for the detection and quantitative identification of heavy metals require in situ sampling and includes titrimetry, colorimetry, gas analysis or spectrochemical analysis.

C. Radio-nucleotides - the well established dangers associated with radioactive substances make these products of special concern. At the present time their sources appear to be somewhat limited and offer a problem of regional concern. The increasing number of nuclear generating plants and atomic powered ocean vessels represent the major sources for these pollutants. The radioactive substances are the only class of pollutants whose effects have been extensively studied. However, less work appears to have been conducted on the effects and pathways of radioactive substances in marine ecosystems, than in terrestrial or fresh water systems. The usual method employed in the study of these materials include: concentration, and specialized preparation of samples for analysis in electronic radioactive detecting systems such as: Geiger-Muller detectors, gas flow counters, and liquid scintillation detectors. These analyses are difficult and often require extensive sample preparation.

D. Nutrients - excessive contributions of compounds containing nitrogen, potassium and phosphorus have been shown to cause undersirable shifts in aquatic ecosystems. The process of aquatic enrichment known as eutrofication has produced synergistic effects that have resulted in the destruction of commercially important species and the creation of conditions of potential human health hazards.

The major sources of such materials are outfalls from municipalities and industry. Additional secondary sources include septic systems and coastal shipping. The effects of this pollution is generally localized in areas of high population density and industrialization. The mouths of large river systems and large municipal outfalls, such as those that exist near Miami, San Diego and New York City, have been especially affected by this type of pollution. The delection of quantification of these materials utilizes standard chemical analyses.

II. Thermal Pollution. - thermal pollution, or the addition of water of higher temperatures than surrounding waters, is frequently derived from sources such as atomic generating plants and certain industries. This modification of the water has been demonstrated to have a profound effect on the composition of the local biological communities. There is general controversy as to the real significance of thermal pollution to the local biota. Some investigators feel that the effects caused by temperature increases are of little significance since they are essentially localized. Other workers contend that the effects are potentially far reaching and can significantly alter much of the biota in estuarine areas, with far reaching repercussions if the thermal change is located in coastal breeding grounds.

Any sensors capable of detecting temperature changes within half a degree centigrade would be useful in determining the presence and movement of heated waters.

III. Sediments - the continental shelf area is especially affected by coastal engineering projects such as damming, dredging and filling. The release and movement of sediments by these activities will influence coastal habitats and their inhabitants; these actions have steadily reduced salt marshes and other important coastal communities. Information is needed to determine the sources, amounts, and fate of these materials, as well as, the effects produced by their disposal. Due to the significance of coastal zone breeding marshes to marine ecology, this form of pollution is of special concern to biological oceanographers. Virtually all of the world's estuaries have been affected by human accelleration of the siltation process. The effects of this material on coastal organisms is determined by in situ sampling. This form of pollution is discussed in the section of geological oceanography.

Application of ERTS to Pollution Investigations.

The resolution of the ERTS space station payloads (300-600 feet ERTS-A, 200 feet ERTS-E and F) excludes the use of satellites for many of the problems associated with biologically related pollution studies. Most phenomena of interest are of too fine a dimension to be detected by this device.

Many important pollutants such as pesticides and heavy metals are deleterious in such minute quantities that their detection from a satellite platform is highly unlikely. Only polluting substances , such as large hot water effluents, oil spills, and large amounts of silt would be immediately detectable.

Refer to the section in this report on Chemical Oceanography for the resolution parameters required for detectable chemical pollutants.

One of the areas of pollution research most directly applicable to satellite sensing is the monitoring of the status of coastal marshes. Infra-red spectra can be used to indicate the presence and general vitality of this vegetational area. The basis for this type of application has already been demonstrated for agricultural crops. A decrease in vitality would indicate the effects of natural or human activities. A correlation of vitality change with satellite detected temperature or salinity changes would help to delimit the causative agent. Monitoring of carbon dioxide and/or oxygen flux by using appropriate spectral bands would yield values for productivity rates. These data would provide essential information for evaluating ecological efficiences, would contribute to our understanding of the coastal ecosystem energetics and changes from normal productivity rates, and could suggest pollution or other types of deleterious effects. Ground truth for these studies would utilize standard methods and techniques such as harvesting, gas analysis, or total chlorophyll determination on selected representative sites. Ground truth could be established by selecting appropriate areas or by the release of pollutants. The effects of the modification to the environment by engineering structures could be detected by changes in observed physical parameters. Alteration to the coastal biota could be observed by changes in the productivity rates, total chlorophyll composition, or perhaps by visable changes, such as on large algal beds. Gross changes in areas with extensive cover could be detectable with infra-red imagery. Ground truth might be established by direct sampling techniques or the use of relatively low airplane overflights. The use of airplane based sensors would seem to offer the greatest application for pollution related studies (13, 14). The studies by the Purdue University Agricultural Experiment Stations and the School of Electrical Engineering (15) demonstrates the feasibility of this approach. The frequency of data collection needed would depend upon the exact nature of the phenomena under study. Biologically selected phenomena would require frequent data due to the close relationships existing between life forms and their environment. For such studies, maximum and minimum values of these parameters are needed. Therefore it is necessary to collect data during different seasons, under different weather conditions, and at various times of the day. Many physically related phenomena such as the behaviour of sediments are greatly dependent upon weather conditions and would require a sufficient number of over flights to obtain rate values. Since tidal conditions are also significant, data should also be obtained during different tidal stages.

Fisheries

The ever increasing rate of world population growth has turned man toward the sea in search of a protein source. Whether the oceans will yield the hoped-for bonanza remains to be seen. At present, world fisheries produce about 57 million metric tons of unprocessed fishery products (10% of the total animal protein production). Estimates of potential annual ocean yields vary from 60 to 2000 million metric tons. Whatever the real potential may be, it appears certain that proper management and technological advance can significantly increase the ocean yield.

Many problems faced by the world fishing industry are political or socio-economic in nature and lie outside the scope of this study. These problems are, in large part, equally as complex and in need of resolution as the scientific and technical barriers.

Most of the world catch of marine fishes comes from continental shelf waters at depths less than 200 fathoms. Though shelf waters constitute only 8% of the ocean area they account for approximately 90% of the marine fish catch. Due to micing and nutrient run off from land areas, the shelf waters are several fold more productive than the open ocean. The only significant high-seas fishery (since the demise of whaling) is the fishery for tuna and tuna-like species. Though there are, no doubt, numerous potentially exploitable high-seas stocks of marine organisms, the real fishery potential still lies in the continental shelf waters. Unfortunately, these waters are also most vulnerable to degradation by human activity since nearly 70% of the world shelf area lies in the northern hemisphere, the most industrialized portion of the earth.

Fishery Research Needs.- the report of the IDOE Committee (5) discusses the idealized series of stages through which fisheries studies in a region may be considered to pass. These are as follows: 1) an <u>exploratory</u> stage which consist of finding potentially exploitable stocks; 2) the <u>descriptive</u> stage in which constituent species are determined and life histories and stock assessments are worked out; 3) the <u>dynamic</u> stage where the parameters of the population response to the environment and to fishing pressure are determined; 4) the manipulative stage where the knowledge acquired in the previous stages is used for management and yield prediction of the resource.

Few, if any, fisheries have ever developed in this idealized fashion. In practice, new fisheries move from the exploratory stage to an exploitive stage. The descriptive and dynamic stages which provide the basic scientific information for sound management and yield prediction are postponed or ignored until the fishery declines to the alarm point. After-the-fact studies designed to provide basic information on a declining fishery all too often accomplish little more than to monitor the demise of the fishery. The ineffectiveness of many marine fishery mangement practices is clearly the result of too little basic information on the exploited stocks. The numerous current attempts at aquaculture are suffering from these same information shortages. If sustainable increases in ocean yields are to be accomplished, studies through all of the stages must be completed for all the major fisheries.

The data needs of fisheries are shared in large part with those of the rest of marine science. The following is a list of arbitrarily arranged, high priority, fishery needs, which should be investigated simultaneously. Included are comments concerning what appears to be the most feasible, and in some cases the only, approach to these problems.

1) Physical Oceanographic Studies. Information on the tides, current patterns, salinity and temperature distributions, mixing, exchange rates, bottom types, etc. are greatly needed.

The need for synoptic data along with the high cost and short supply of research ships makes these types of studies particularly attractive for study by remote sensing devises. The optimum sampling interval varies with the phenomenon under consideration as well as with the area being covered. In some near shore areas, especially bays and estuaries. the physical features of the environment are highly variable with tidal, diurnal, seasonal and annual fluctuations, and continuous monitoring may be necessary. Broad scale studies of surface water temperatures for shelf areas appear to be particularly feasible. Isotherm charts should be compiled at intervals no greater than one month. The present research fleet would be hard pressed to provide ground truth data for any large scale program; however, for biological purposes, relative temperatures are better than no information at all.

2) Systematic Studies. There is need for much "alpha level" study of the identification and differentiation of exploitable species and stocks and their forage organisms. Many fisheries currently utilize mixed and undifferentiated species. Sound management obviously cannot be carried out under these conditions. Systematic studies require the collection and close examination of specimens.

3) Life History Studies. The life histories of most exploited species are incompletely known. We know little about the migration, distribution, place of spawnimg, time of spawning, fecundity, growth rate, longevity, behaviour, food relationships, larval and juvenile development and general ecological requirements for most commerically utilized species. Our knowledge of forage organisms is even more primitive.

Many aspects of life history studies require the collection of specimens and most demand in situ examinations, but there is some possibility for the application of remote sensing devices. Movements and migratory patterns of marine organisms are particularly expensive and difficult to attack. The conventional method of tagging and releasing specimens yields bias data due to the non-random distribution of fishing vessels, and additionally provides no information on movement between release and recapture. Previous attempts at remote tracking of marine organisms have had only limited success, however in light of alternate methods remote tracking shows promise.

Remote sensing devices (TV, photography, etc.) are frequently used in studies of animal behaviour as they allow the observer to remain outside the experimental framework. These devices offer many additional possibilities for both laboratory and field studies of behaviour.

4) Population Dynamics. The fact that the size and limits of most fishery stocks are at best poorly known is indicative of the work required in this area. Studies of recruitment, year class success, mortality, energy flow through the food web, predation rates, effects of fishing pressure, etc.are needed. Most of these studies require direct sampling of the population and experimental or statistical treatment. Additionally there is need for refinement, standardization and increase coverage of the catch data, especially in the area of sportfish harvests.

5) Effects of Environmental Alternation. Pollution studies are discussed in detail in a separate section of this report, however the importance of such studies to coastal-zone fisheries is such that it merits reemphasis. The acute lethal toxicity to marine organism of only a few agricultural and industrial pollutants are known. We have virtually no knowledge of the chronic effects of sublethal dosages or the synergistic effects of the milieu of pollutants which pour daily into our coastal waters.

Estuaries and coastal marshlands are of particular concern. These highly productive areas are the primary habitat of numerous commercial species, serve as the nursery area for the juvenile and young stages of many others and are utilized by anadromus species which spawn up rivers. The National Estuary Study Report (17) indicates that nearly one-quarter of our estuaries have been severely modified. In addition to being bombarded with pollutants, these areas are being drained, filled, and bulkheaded at an alarming rate. Detailed study and continued monitoring of these areas is of vital impottance.

6) Exploratory Studies. There is need for exploratory fishing and survey

studies to reveal unutilized or underutilized stocks. It would be most efficient to concentrate in areas found by some broader survey to be the most productive and potentially exploitable portion of the world coastal zone. Such broad surveys might be carried out by remote sensing of chlorophyll content from an aircraft or satellite. The ground truth would be that provided by the exploratory fishing vessels as a sequential part of the survey.

Many problems facing the fishing industry are those whose solution would lead to short-term gains, but not significantly increase the sustainable yield, unless accompanied by the aforementioned basic research and consequent sound management. These studies mostly include ways to increase the catch per unit effort (e.g., location of fish concentrations by remote sensing; development of more efficient and selective fishing gear, etc.). If we are to efficiently harvest the oceans we must solve these technical problems; however, it is apparent that even with our primitive fishing techniques we are presently capable of overfishing many stocks, some to the point of extinction.

Regional Potential - In addition to estuaries and coastal marshes, the following regions and species have been singled out by the Marine Resources Panel of the Commission on Marine Science, Engineering and Resources (2) as offering the greatest growth potential:

Herring-like fishes - Arabian Sea, waters off California, Chile, Argentina, Venezuela, Northern Brazil, West Africa, Gulf of Alaska, Gulf of Mexico.

Hakes - Waters off Chile, Peru, Mexico, Argentina, West Africa.

Clams - Worldwide coastal regions.

Flounders - Northeast Pacific, Patagonian Shelf, New Zealand waters.

The Ponza Report (6) lists the following world coastal areas to be of major significance and in need of additional study.

The Arabian Sea	Caribbean and Gulf of Mexico
The Gulf of Alaska	Indonesian and New Zealand shelves
The Antarctic Sea	Northwest African Shelf and Gulf of Guinea
The Argentine and Chilean shelves	

Application of ERTS to Fishery Development - The solution to most fishery problems appears to lie more toward a greater commitment of manpower and money in conventional approaches than in the development of sophisticated tools. The primary application to fisheries of the proposed ERTS A, B and E, F. systems appears to be in the area of physical oceanographic studies with an additional possibility in identifying potentially productive coastal areas to be further explored by conventional methods.

CHEMICAL OCEANOGRAPHY

Chemical oceanography has been defined as the application of chemical techniques, laws and principles to the scientific study of the oceans (25). It attempts to provide an accurate description of the chemical nature of seawater as well as an understanding of the processes that produce and alter the distribution of all chemicals within the sea. It also strives to elucidate the effect of these chemicals upon the biological, geological and physical processes occurring in the ocean.

Therefore, the majority of a chemical oceanographer's effort has been and will continue to be in the area of analytical chemistry with most of the data obtained used in support of other scientific disciplines, such as biology, geology and physics, that are concerned with the study of the oceans. To fulfill his function, the chemical oceanographer must determine or develop techniques for determining many of the chemical constituents of seawater as well as in related sediments, sea spray and air. The complex nature of coastal waters relative to open ocean waters complicates the problems of the analyst. Concentration levels of the chemical constituents in the coastal waters is of a much greater range than in the open ocean and changes within these levels occur over much shorter distances and time span. Obviously, many measurements within limited time and space are needed if the chemistry of coastal waters is to be understood.

Measurements Required

Among the more important measurements required are the following:

Salinity - Salinity is defined in terms of the total dissolved salts in seawater and is expressed in parts per thousand. It varies in different ocean areas with approximately 90% of seawater falling between 34 and 36 parts per thousand. However, in estuarine and coastal waters, salinity may vary from near zero in areas of excessive continental runoff to as high as several hundred parts per thousand in restricted, subtropical embayments where evaporation rates are high.

Salinity is one of the most important measureable parameters in oceanography since it, along with temperature and pressure, influences the basic physical properties of seawater. One of the more important of these properties is density which serves as one of the main driving forces in establishing ocean currents. In addition, the physical oceanographer uses salinity and temperature to characterize and identify different water bodies. Obviously, salinity measurements are necessary if the dynamic mixing processes which play such an important role in coastal oceanography are to be determined. Furthermore, salinity distribution both spatial and temporal may have profound effects upon the activity and distribution of marine organisms. Indeed, sudden salinity changes in estuarine waters have resulted in catastrophic loss of marine life. The influence of salinity upon the flocculation of suspended material as it moves from fresh water into a seawater environment is discussed in the section on geological oceanography.

Temperature - Although not a chemical parameter, temperature is extremely important in understanding the chemistry of coastal water. Not only does it, along with salinity, determine density of the water and therefore currents and mixing, but it is also important in controlling the solubilities and reaction rates of various chemicals. In addition, temperature has a direct influence upon toxicity of certain chemicals; a rise of 10°C may halve the survival time of some marine organisms. Temperature changes in the ocean usually result from natural climatic phenomena; however, thermal pollution from industrial sites may be critical in coastal waters.

Nutrients - Phosphorous, nitrogen and silicon represent inorganic elements that are essential to the life processes within the ocean, especially phytoplankton productivity. The fertility of any given body of seawater will depend upon the amount of these nutrient elements present. In extremely low concentrations, the elements can be limiting to biological productivity; however, in large quantities, they can lead to excessive plant growth which upon decay causes depletion of dissolved oxygen and subsequent loss of animal life. Such excessive nutrient pollution may occur in coastal regions from aqueous runoff of fertilized lands as well as industrial and municipal waste discharges. Therefore, monitoring of nutrient levels will be required in estuarine and coastal waters to establish 1) fertility of the water and 2) presence of excessive waste nutrients. These elements are usually determined in their anion form, i.e., as phosphate, nitrate and silicate. Nutrient nitrogen may also occur to a lesser degree as nitrite and ammonia and these forms should also be determined.

Hydrogen Ion Concentration (pH).- The pH value of seawater is mainly determined by the carbon dioxide content. As a result, it can be affected by any processes involving salinity and temperature changes, photosynthesis and respiration, deposition of carbonate ions and gaseous exchange with the atmosphere. Measurement of pH is useful in studying these processes as well as others in which the reactions are pH dependent. The pH observed is usually between 7.8 and 8.3 in surface waters, but in estuaries, values as high as 9.0 have been observed during periods of high photosynthesis (26). Furthermore, when increased biological activity results in carbon dioxide librration, pH values as low as 7.5 may be found. Also near the shore, pH may drop sharply due to introduction of fresh water streams carrying large quantities of decaying vegetation and organic matter derived from land. pH measurements may be useful in detecting organic waste and pollutants in coastal waters.

Oxidation-Reduction Potential (Eh) - Oxidation potential in the ocean is determined by the oxygen half-cell reaction. As a result, organic matter has a great effect upon the Eh of seawater. At the sea surface, Eh is usually +300 millivolts or more. However, this decreases with depth and at or below the sediment surface values as low as -300 millivolts may be found due to oxygen consumption by decaying organic matter. Obviously, Eh measurements are useful in tracing the effects of organic pollutants in seawater. Because the ionic states of many metals depend upon Eh, measurements are also needed in studying geochemical processes in the marine environment. Eh and pH are often interrelated in their affects upon chemical processes and their measurements used in conjunction with each other.

Dissolved Gases - Although dissolved gases constitute only about 0.25% by weight of seawater, several are of prime importance to oceanographic studies. The two most important are oxygen and carbon dioxide. Both gases participate in the basic biological processes of photosynthesis and respiration and their measurements are essential to most biological and pollution studies. Dissolved oxygen measurements are used to establish the quality of marine waters and their suitability for sustaining marine life.

In addition, carbon dioxide is involved in the carbonic acid system which serves to buffer the oceans' pH. Measurements of CO_2 are needed for studies of this complex dynamic system which involves air, sea and sediments.

Additional trace gases, such as CO, O_3, CH_4, SO_2, NO_2, and H_2S, may have importance from a pollution aspect but more studies are needed to establish this.

Radioactive Isotopes - Public concern, coupled with extensive research, has successfully prevented harmful pollution from radioactive substances produced by nuclear devices and reactors. However, in coastal waters, some monitoring for radioactivity must be carried out in areas where accidental release could occur. If the anticipated large increase in nuclear power reactors over the next few decades takes place, additional monitoring and studies will be required.

Dissolved Organic Compounds - Our knowledge of the kinds, distribution and significance of organic compounds in seawater is currently undergoing rapid change. The amount of total organic carbon in seawater varies from 0.1-5 ml/l with highest values occurring in coastal waters, especially those with high phytoplankton productivity. Individual types of organic compounds naturally occurring in seawater number into the thousands and serve almost as many functions. They may serve as a food for many organisms, as growth stimulants (vitamins and hormones) for others and, in some cases, as growth inhibitors (toxins, antibiotics etc.). Some are capable of chelating heavy metals in seawaterthereby reducing or increasing toxicity of the metals to organisms (27). Others can retard or enhance flocculation of clays and other suspended material in the water.

To fully understand the chemistry and role of naturally-occuring organic compounds, we will need to know not only values for total organic carbon but also those for the individual compounds. This need also exists in the case of man-made organic compounds which are polluting our coastal waters in ever increasing amounts. Degradation of these compounds often leads to oxygen depletion with resulting loss of marine life. Pollution studies are requiring increased use of total organic carbon measurements as indicators of the chemical oxygen demand being made upon a given body of water.

Pesticides - Pesticides may contaminate estuarine, bay and coastal waters as a result of aerial spraying, runoff from treated areas, waste discharge by pesticide producers, misuse, and other means. Determining the precise amounts present is difficult since pesticides are retained in water in many different states. They may be found in soluble form, attached to suspended material, incorporated into organisms and complexed with other organics. Available data does indicate they occur in the parts per billion (ppb) or less range (28). Unfortunately, this is approximately the level at which they may become toxic to many marine organisms. Consequently, frequent monitoring of the pesticide content of these waters will be needed.

Heavy Metals - Knowledge of the concentrations of heavy metals dissolved in seawater is essential in establishing water quality for biological use. In low concentrations, a few ppb more or less, these elements act as essential micro-nutrients but in slightly higher concentrations they may be toxic to marine life. In addition, they enter into complex geochemical processes that involve their solution, transportation and deposition within various parts of the hydraulic regime.

Heavy metal inputs into coastal and estuarine waters usually occur from normal erosion and runoff and from mine, industrial and municipal waste discharges.

Suspended Solids - The size, chemical composition and distribution of suspended solids is needed. These materials may act as scavengers, transporters and sources of many chemicals. Clays are known to absorb pesticides, hydrocarbons and other organics, as well as radioisotopes and heavy metals, and to transport them from one area of the environment to another before their release. Suspended solids also serve as mineral sources for nearshore wediments and their geochemical study is of importance to the geologist.

Organic Films and Slicks - Many organics are known to be only slightly water soluble and, as a result, form surface films or "slicks". Among these are fish oils and hydrocarbons. It has been suggested that these may be sensed or measured remotely and used to detect fish schools and oil spills, respectively (29). In addition, naturally occurring hydrocarbon "seeps", as films or vapors, might be used to detect sources of oil or gas. Organics are also known to form as slicks or "windrows" along the line of convergence of internal waves. Possibly, detection of the slicks could be used to study these underwater waves.

Although not necessarily a film constituent, chlorophyl pigments dissolved in surface and near surface waters have also been suggested for remote sensing; the data to be used as an indicator of plant productivity in the ocean. These observations may be of potential value in open ocean studies, but the complexity and dynamics of coastal waters would appear to restrict their use there. If, however, they could be used for the open ocean, then their application to coastal oceanography should be investigated.

Summary - The major chemical parameters whose measurements are required in coastal oceanographic studies are present in Table 1. It should be noted that the range of expected values presented here are those that might be encountered in estuarine and coastal waters rather than those often reported for open ocean waters. No attempt has been made to present spatial and temporal resolution requirements at this time, since they involve too many unknown variables such as nature and source of the chemicals, dynamic mixing processes, etc. Time requirements may vary from continuous to one month, distance from zero to 0.5 miles, and depth from zero to 600 ft. with interval between depths of 10 - 50 ft.

Analytical Methods

In most cases, chemical measurements of seawater require collection of water samples and their subsequent analysis in shipboard or land-based laboratories. The specific analytical technique employed will depend upon the constituent being determined as well as the use for which the data is to be employed (30, 31). Generally, inorganic species will be subjected to conventional chemical analyses such as titration and colorimetry. For analysis of organic compounds more sophisticated techniques are required; i.e., gas chromatography and infrared, mass, and NMR spectrometry (32).

Continuous Sensing Devices - Although the above methods have provided us with much of our knowledge of ocean chemistry, they do not provide sufficient sampling or data points for studying environments as complex and fast changing as estuaries, bays and coastal waters. New techniques are required to permit rapid, continuous *in situ* analyses of the most important chemical constituents within the marine environment (3, 28). Where such techniques have been available, closer observations

Table 1. Chemical/Physical Measurements Required in Coastal Oceanographic Studies

	Parameters	Range	Accuracy
1.	Salinity	0-40°/oo	± 0.01°/oo for density calc. ± 1°/oo for other uses
2.	Temperature	0-25°C	± 1°C
3.	Dissolved Gases		
	O_2	0-10 ml/1	± 1 ml/1
	CO_2	0-0.3 ml/1	± 0.05 ml/1
	N_2	0-20 ml/1	± 1 ml/1
	CO	trace	unknown
	O_3	trace	unknown
	CH_4	trace	unknown
	NO_2	trace	unknown
	SO_2	trace	unknown
	H_2S	trace	unknown
4.	pH	6.7-9.0	± 0.1 pH unit
5.	Eh	-0.30 to +0.45 volts	± 0.01 volts
6.	Nutrients		
	nitrate	1-600 ug/1	± 1 ug/1
	nitrate	0-50 ug/1	± 1 ug/1
	ammonia	0-75 ug/1	± 1 ug/1
	phosphate	1-60 ug/1	± 1 ug/1
	silicate	20-4000 ug/1	± 10 ug/1
7.	Heavy metals, Pb, Hg, Cu, etc.	ppb level	± 1 ppb
8.	Total Dissolved Carbon	0.1-5 mg/1	± 0.1 mg/1
9.	Pesticides	ppb level	± 1 ppb
10.	Radioactivity	picocurie/1 level	unknown
11.	Chlorophyll	0.05-40 ug/1	± 0.1 ug/1
12.	Hydrocarbons	- -	- -
13.	Fish oils	- -	- -
14.	Other organic compounds too numerous to mention	occur at ppb level or less	unknown

in both time and space have revealed details in chemical distribution not previously known or even suspected (25).

At present, devices are fairly well established for continuous, in situ sensing of salinity, temperature and radioactivity. These devices may be lowered from ships or attached to buoys, can be used in waters of any salinity and at any depth, and may be left unattended for some length of time.

Selected physico-chemical parameters such as Eh and pH can also be measured continuously in surface waters using electro-chemical probes. Specific element or ion probes are also available for oxygen, alkali, alkaline earth and some trace or heavy metals as well as for a number of anions, particularly the halides. However, surfaces tend to foul over a period of time and none, with the exception of oxygen probes, work well in water of varying salinity or at depth. Maintenance of calibration of these probes is also a problem.

Remote Sensing - The only properties in Table 1 that appear capable of being remotely sensed and measured are surface salinity and temperature, near surface chlorophyl and radioactivity, and surface films such as petroleum and fish oils. All other parameters will probably have to be measured by in situ sensors or have samples brought back to a laboratory for analysis.

Future Needs and Priorities

It is now apparent that the highest priority for chemical studies within coastal zone waters must be given the problem of water pollution. Future requirements and priorities within this field can best be presented by consideration of the report by a subcommittee appointed by the American Chemical Society to evaluate the chemical improvement of our environment (25). Among the recommendations of this subcommittee are:

1. "More emphasis should be placed on investigations of the transport and long-term deposition of pollutants in the oceans... . The initial requirement is improved analytical methods for identifying and measuring specific chemical compounds".

2."Emphasis should be placed on the development of analytical methods for specific organic pollutants at all concentrations and in all waste sources and receiving waters, including estuaries and the oceans".

3. "Analytical methods for gathering basic data, monitoring, research, and treatment control should be actively and continuously upgraded... ".

4. "Comprehensive investigations of naturally occurring and pollutant particles in water should be undertaken to determine such characteristics as size, charge, composition and absorptive properties. Expanded knowledge of particles would be important in studies of sedimentation, erosion, ... as well as in work on transport".

5. "Research on improved mathematical descriptions of natural water systems subject to pollution should be strongly supported. The chemical-biological complexity of those systems requires that such research be highly interdisciplinary, involving scientists from disciplines such as chemistry, chemical engineering, civil engineering, biology, and ecology".

Second highest priority should be assigned to those chemical studies related to establishing the fertility of coastal waters and their suitability for fisheries use. Both priorities require acquisition of the measurements listed in Table 1.

GEOLOGICAL PROCESSES AND PROBLEMS

The geological problems in coastal zones are unique and important for a number of reasons. The coastal zone areas are where a majority of men live, work, and play. Transporatation, food supplies, mineral resources, and recreational opportunities are some of the attractions of the edge of the sea for man. The geological problems of the coastal zones are related to interactions between land, sea, and air. Only in the coastal zones are energy transfers between land, sea, and air so rapid, so vigorous, and so immediately effective on man.

In the coastal zones the rates of many geological processes are more rapid than in most other areas. The subsidence or uplift of the land resulting from tectonic movements and changes in sea level with changes in climate are most evident in the coastal areas. Shore lines are continually changing as a result of erosion by waves and tides, and by deposition of transported sediments. Man needs to measure, inventory, and monitor the geological processes and changes in the coastal zones. By so doing he may better understand the processes and thus improve and prolong the use of all the resources of the coastal zones to his benefit.

Harbor Shoaling and Waste Disposal

The study of the erosion, transportation, and deposition of marine sediments is amenable to a twofold division, into the analysis of bed-load sediments, and the analysis of suspended-load sediments. Bed-load sediment consists of particles whose terminal velocity in moving water is greater than the vertical velocity component of turbulent flow. In most hydraulic situations, bed-load materials fall into the size categories designated as gravel (particle with diameters greater than 2 mm.) and sand (2- .062 mm.). Except in such anomalous, high energy zones as the surf zone, or tide-swept sand shoals, where sand is thrown into suspension, most marine suspended sediments are in the categories designed as silt (62-3 microns) and clay (3 microns to colloidal size).

These size-determined categories of marine sediment differ in composition as well as in grain size. Sand and silt consist primarily of the relatively inert mineral quartz (SiO_2). Clay consists mostly of complex aluminosilicate minerals referred to as clay minerals. These fine, platy mineral particles tend to have higher surface charges than quartz, and their behaviour is determined by eletrical forces, as well as by inertial and hydraulic forces. In fact, they generally appear in the marine environment as low density, multiparticle flocs. In addition to interstitial water, these flocs carry absorbed water, base-metal cations, and organic compounds. Recent experiments suggest that while clay minerals form electrically generated flocs under controlled laboratory conditions, such flocs under natural conditions in coastal waters are strongly effected by biological activity. Indeed, most flocs in coastal waters may be formed primarily as fecal pellets by such animals as oysters, whelks, clams, or fish; or may have been pelletized in part by the agglutinizing action of algal or bacterial slime.

The Coastal Zone discussed in this report falls into two geographic provinces. The intracoastal zone consists of estuaries and lagoons. Genetically, estuaries are drowned river mouths. Geometrically, they are intracoastal water bodies whose long axis is normal to the main coastline. An example is Chesapeake Bay. Genetically, lagoons are intracoastal water bodies cut off from the open sea by the growth of spits and barrier islands of sand. Their long axes are generally parallel to the coast, as for instance Pamlico Sound. The second province of the Coastal zone is the open water of the continental shelf, extending from the ocean beach out to the shelf edge, generally at about 420 meters depth. Suspended sediments form a significant part of the sediment transport system in both these provinces, and the environmental engineer faces problems in both sectors relating to suspended sediment transport.

Suspended sediment circulation in intracoastal water bodies - Intracoastal water bodies such as estuaries, lagoons and harbors are generally floored by mud (watery silt and clay) and their waters are quite turbid, with values ranging from 60 mg/l of suspended solids to 1 g/liter under certain circumstances.

This is not simply the consequence of rivers pouring their muddy waters into such basins as originally supposed; turbidities generally show little relationship to the volume of freshwater input. Instead the physical structure and circulation patterns of those water bodies renders them efficient fine-sediment traps. The particles observed to be suspended in the water are mainly scoured from the bottom during the tidal cycle, and many of them return to the bottom during slack water. The amount of sediment permanently gained from rivers or lost to the sea is only a very small part of sediment movement during each tidal cycle.

The most significant hydraulic mechanism trapping sediment in estuaries is their density-driven circulation. The light river water runs out to sea over a wedge of denser sea water. As it does so, it entrains salt water, and gradually attains normal marine salinity. More seawater flows landward to replace the salt-water thus consumed. Suspended sediment particles which settle through the fresh effluent into the salt influx are returned by this influx to the fresh water, to cycle again. Thus most estuaries have in their throats a turbidity maximum, more tubid than either the lower estuary or the entering river. Supplementary mechanisms such as scouring lag, settling lag, and the time-velocity asymmetry of the tidal wave cause a secondary turbidity maximum to occur in the waters bordering the marshes and mud flats of the estuaries margin.

Problems directly relating to suspended sediment transport in intracoastal waters are twofold; problems relating to shoaling, and problems concerning trace elements, nutrients and pollutants carried by the suspended sediment.

The second group of problems will be considered elsewhere, under the heading of chemical oceanography. However, resolution of these problems like those of first group will to a large extent depend on knowledge of the suspended sediment budget, a concept that will be discussed below.

In order to consider shoaling problems in estuaries, it is necessary to consider the evolution of the world's coasts during the past 15,000 years. During this period, since the last great ice advance of the Pleistocene ice age, sea level has risen in response to the melting of the ice sheets and polar caps. As a result, most of the mouths of the world's rivers are drowned and have the form of estuaries; only a few have sufficiently high output of river sediment to build out as deltas. But because estuaries are such efficient sediment traps they are ephemeral features which can only last a few thousand years more before filling up, and closing down to narrow channels (33).

Shoaling problems in these intracoastal water bodies are keyed to the two major zones of deposition; the marginal zones of mud flats and salt marshes, (mangrove forests in low latitudes), and the central zone of submarine mud shoals which have grown up beneath the tubidity maximum in the zone of salinity-stratified water, or "salt wedge". The "wetlands" or salt marshes and mangrove swamps are generated as the intertidal margins of estuaries build upward and outward to the level of mean low tide. These areas are initially valuable because they serve as nurseries for the larval stages of many commerically valuable species of fish and shellfish. By diking or by natural processes they will ultimately become permanently dry land, capable of sustaining agriculture and other human activities. The present widespread concern with natural resources will necessitate much more concern with, and monitoring of, the growth and maintenance of wetland.

Shoaling in the central estuary is a primary concern of harbor authorities. All of the ports on both sides of the North Atlantic are on "ephemeral" estuaries which must, in future millenia, close down to small channels, and the approaches to these ports must be constantly dredged, at considerable expense. The case of the ports of the Atlantic seaboard of the United States is especially instructive. North of Cape Hatteras the estuaries (Chesapeake Bay, Delaware Bay, New York Harbor, Naragansett Bay, Boston Harbor, Penobscot Bay) have barely begun the shoaling process.

South of Cape Hatteras, however, the rivers carry a higher sediment load from the deeply weathered, subtropical hinterland, and the estuaries of this sector have in many cases already closed down to tide-maintained channels, in equilibrium with their tidal prism (34). Artificial deepening of these channels has tended to upset this equilibrium, often with disasterous results. The penetration of the salt wedge up the deepened channels has in some cases shifted the turbidity maximum, and with it the locus of most intense shoaling so that formerly "open" harbors have had their rates of shoaling increased by an order of magnitude or more (35).

Suspended sediment transport on the open shelf - Mineral particles do not generally dominate open shelf waters. On most open shelves, surface turbidities are on the order of a few milligrams per liter, and ignition losses indicates that the material is mainly of an organic origin. However, turbidities and mineral content are locally higher near the beach and near the bottom, especially during storms. On coasts down-current from such major deltas as the Mississippi and the Orinoco, where suspended sediment input is very high, mud flats form beneath intertidal turbidity maxima on the open coast. On most coasts with lower suspended sediment input, a weak nearshore tubidity maximum is still present, perhaps, because a weak salinity-driven circulation, with landward flowing bottom water is generally present, and probably also because new fine sediment is being released from the bottom by surf erosion. On some low energy shelves with high suspended sediment input, such as the Northwest Gulf of Mexico shelf, a blanket of mud is forming on the shelf. But ultimately much of the suspended sediment delivered to shelves is bypassed to the deep ocean floor.

Problems concerning fine sediment transporatation of the continental shelf relate to 1) pollutants and nutrients carried by the fine sediment as in the case of intracoastal fine sediment transport, and 2) disposal of fine particulate waste that, introduced into the shelf, will circulate as does the natural material. Pollutants and nutrients carried by suspended sediment will be discussed as a problem of chemical oceanography. Some examples of fine waste disposal that will enter the internal dispersal system are 1) the sewage of New York and Philadelphia that is presently transported in barges to the open shelf and dumpted, leaving a bottom sludge some centimeters thick over square kilometers of the bottom (36), and 2) a proposed conduit to transport copper mine tailings as a slurry from mainland Puerto Rico to the edge of the island shelf, and 3) a proposal to build a new water-level Panama Canal by means of atomic explosives, which will spread contaminated fine waste over coastal waters on either side of the isthmus.

Sampling plans - In order to be able to solve problems relating to suspended sediment transport in the coastal zone, it is necessary to determine the suspended sediment budget. The suspended sediment transport system must be conceptualized as a series of reservoirs (for instance, 1) the mud bottom of an estuary which exchanges sediment with 2) the overlying turbid water mass), and paths of transfer (for instance, the sediment exchange between 1 and 2 above, sediment exchange between 2 and the open sea). The concentration of suspended sediment in each reservoir must be known, and the net rates of transfer along each path must be established. This is a far more difficult task than it sounds, for suspended sediment concentration is highly variable in both time and space. Time variables consist of 1) seasonal, and long term climatic variables in fluvial sediment input, and in the ability of waves to resuspend fine sediment in shallow water, 2) semidiurnal, diurnal, semimonthly, and yearly variations in the strength of tidal currents, and 3) random, small - to large-scale variation in dediment concentration due the inherently tubulent nature of tidal and wave generated flow. In order to resolve such time variability in suspended sediment transport, it is necessary to patiently develop an adequate time series of data, usually over a period of years.

Space variability is a consequence of the systematic large scale structure of coastal water masses, and also to small- to large-scale random variations due to turbulence. Space variability in suspended sediment transport is resolved by collecting large numbers of synoptic (synchronous) samples. An illuminating discussion of the problems of measuring suspended sediment discharge in tidal watereays has been presented by Wicker (37). He has calculated that in order to obtain meaningful values for the mean flow of suspended sediment through a single cross section of a tidal waterway, it would be necessary to make between 12,000 and 40,000 point determinations of suspended sediment concentration through the water column over a period of a year, depending on the methods used. When it is realized that many such cross sections must be monitored in order to determine the sediment budget of a given region, the difficulties associated with this sort of study become apparent. In practice, many simplifying assumptions are made and a rigorous synoptic approach is not utilized. The standard technique divides the study area into a series of cross sections of perhaps fifteen stations each. The stations are located such that each is at the centroid of an area of equal discharge. Current velocity and suspended sediment concentrations are determined at the bottom, mid-depth, and surface at intervals throughout the tidal cycle. Selected areas are also monitored through successive tidal cycles, at spring and neap tides, and during times of abnormal river discharge and wave activity.

Parameters observed, and sensing methods - The major parameters measured to determine a coastal zone suspended sediment transport system are suspended sediment concentration, its size frequency distribution; and temperature, salinity, and current velocity, in three dimensions.

For reconnaissance determinations of suspended sediment concentration, secchi discs have been utilized. These white plates are lowered until invisible. The depth of extinction is used as a measure of turbidity, which in turn is a function mainly of grain size, concentration, and refractive index. The classic method of analysis of sediment concentration and size distribution has been by filtration of a water sample of known volume and microscopic inspection of the filtrate. The results are expressed as milligrams per liter, in the range 5 to 100 mg/l $\pm$ 1. Newer methods include the Coulter counter (38), which senses conductivity of a water sample, and photoelectrical determinations of turbidity. Shiptowed, _in situ_ turbidometers with deck readout have greatly simplified and expedited surveys of suspended sediment transport systems. High altitude serial photography has proved a very valuable accessory technique, in areas of high turbidity, for delineating gross surface patterns of turbidity distribution and large scale turbulence (39). Airborne lasers, presently being developed for bathymetric surveys, will be used for sensing turbidity in the near future (40).

In areas where suspended sediment transport is significantly effected by salinity and temperature gradients, these parameters are measured by means of _in situ_ induction salinmeters which read salinity in the range of 5.0 to 40.0 $\pm$ .1 parts per thousand and temperature in degrees centigrade in the range 0 to 40 $\pm$ .1.

Current measurements fall into two general categories. In _Eulerian_ measurements, the meter is fixed relative to the frame of reference, so that flow past the meter is measured. A host of current meters of this type sense current flow by means of impellers. More recent fixed point meters sense the flow as changes in the rate of propogation of sound, as distortions of a magnetic field, or as the rate of cooling of a hot wire. With these techniques, element response time is negligable. In _LaGrangian_ measurements the meter moves with the currents with respect to a fixed frame of reference. A typical device is the parachute drogue, in which a weight is attached to a float of small wind resistance by means of a line. A parachute is attached to the line at the depth at which current information is desired. Rhodamine B and other dyes are also used for La Grangian measurements. An especially interesting photogrammetric technique employes stereo pairs of a water surface with drogue buoys on it; the apparent height above the water or depth below it of the buoys in the stereoscopic projection is a function of their velocity (41). Currents are generally measured in cms/sec, range 0 to 400, ± .5.

Coastal Erosion and Shelf Floor Resources

The nature of "coarse sediment" (sand and gravel) and its mode of transport (as "bed load"; by rolling, dragging or bouncing) has been discussed in the previous section. Hereafter the category "sand and gravel" will be referred to as "sand", its dominant component. It remains to 1) summarize the mechanics of the transport of marine coarse sediments, and 2) to outline applied problems associated with them.

Domains of sand transport - It was pointed out in the previous section that the modern shelf surface has been shaped by its past 15,000 - 19,000 years of history. At the beginning of that period, during the climax of the ice age, so much of the sea's water was locked up in continental ice sheets that sealevel was lowered 125 meters or more, and the world's shelves were exposed as dry land. During this time streams brought sand to the exposed shelves, and the surf of the retreating shoreline has, since then, spread and reworked this material. At about 4,000 to 7,000 years ago, the rate of sealevel rise slowed, and the modern shorelines were built. Wave attack truncated projecting headlands, and longshore currents carried the resulting sand and debris laterally, to form spits and barrier islands across the mouths of adjacent estuaries. These features are retreating landward under the impetus of the continued slow rise of sealevel (perhaps 4 mm per century).

Marine geologists recognize two seafloor dormains with respect to the disposition of marine sand (42). A shore face extends at a slope of up to 8m/km from the low tide line to the edge of the more gently sloping (1m/km) inner shelf floor. The slope of the shore face is generally not constant, but is more nearly exponential with the steepest portion near shore. This is an equilibrium surface, adjusted by wave action to absorb the energy of shoaling waves. It is furfaced by "modern" sand, whose size frequency distribution is fully adjusted to the modern hydraulic regime. The shore face may be primarily a constructional feature, building seaward in areas of abundant supply of sand from rivers, or it may be a wave-cut surface, only thinly mantled by "modern sand" derived from wave erosion. The latter type is more common, as a consequence of the continuing rise of sea level, since except where its effects are overcome by an abundant supply of fluvial sand, a sea level rise results in erosion of the shore face, and concommittant aggradation of the sea floor.

Seaward of the break in slope, the shelf floor is veneered with a sheet of "relict" sand, shore-line deposits relict from lower stands of the sea. This material is being reworked by the modern shelf hydraulic regime, but much more slowly than are the shore face sands.

Dynamics of sand transport - In order to understand problems of coastal sand transport, it is necessary to briefly consider the hydraulic regimes of the continental shelf.

The hydraulic regimes of the shore faces are twofold. The beach and surf zones comprise high energy zones of rapid and transport, both parallel with and normal to the beach. The basic phenomena behind longshore sand transport or littoral drift is the wave-driven longshore current. Most wave trains approaching the beach do so at an angle oblique to the shore. They rotate into near parallelism as a consequence of wave refraction (successive sections of a wave slow as they "feel" the bottom) but a residual angle commonly remains. As the waves "break" and are transformed from oscillation waves to waves of translation (bores), water is thrown obliquely up the beach, and restores under the influence of gravity obliquely down the beach, in the direction in which the wave angle opens. The consequence is a resultant coastwise "longshore current" between the beach and the surf, which may reach velocities of 50 cms/sec or higher. Such currents may transport many thousand of cubic meters of sand past a given point on a coast per year.

Onshore-offshore transport is a result of the interaction of oscillatory wave surge, the slope of the beach face, and the range of grain sizes available. During fair weather, the relatively flat swells approaching the beach generate a landward bottom surge which is much stronger than the seaward surge associated with the adjacent wave troughs. Consequently course sand moves landward to build the beach. Fine sand is thrown into suspension, to be swept seaward by intermittant mid-depth currents associated with "wave set-up", or the pile-up of water by waves between the surf and the beach. This fine sand is deposited as a well-sorted mantle extending into deeper water toward the foot of the shore face. During the stormy weather of winter, however, most of the available sizes of sand are thrown into suspension and the beach is eroded back. Thus beaches undergo a yearly cycle of summer build-up and winter retreat. Net loss or gain over a year depends on interaction of onshore-offshore transport with longshore transport, plus the extent to which fresh sand is being supplied by nearby rivers. But because of the slow, world wide rise of sealevel, most beaches appear to undergo an inexorable, long-term retreat, at rates ranging from centimeters to meters per year.

Two special cases require further comment, since their hydraulic regimes are more complicated, and furthermore, have a direct bearing on problems of harbor engineering. These are the regimes prevalent at tidal inlets, and at the mouths of large bays. Tidal inlets are the passes between barrier islands, which separate small estuaries and coastal lagoons from the open oceans. They are maintained by tidal currents which equalize the water level of the intracoastal water body with that of the open shelf. Equilibrium inlets have cross-sections in square feet equal to the volume of water passing through them on a half tidal cycle (tidal prism) in acre-feet. Attempts to maintain them at navigable depths greater than equilibrium cross-sections in the face of vigorous littoral drift require constant costly dredging. Furthermore, tidal inlets tend to migrate down the direction of littoral drift, and the work of coastal engineers is to a large extent concerned with inlet stabilization.

The situation is a little different at the mouths of such large estuaries as the Chesapeake Bay. Here changes in the area of equilibrium cross-section are over-shadowed by complex changes in channel configuration. Bay mouth shoals are generated by littoral drift as the slow infilling of back-estuary areas by fine sediment reduces the tidal prism. Such shoals develop complex topographies as a result of a phase lag between the shelf tidal wave and the friction-retarded tidal wave reflected from the back of the estuary. The estuary tide commonly ebbs for some fraction of an hour after the shelf tide has started to flood. The flooding shelf tide tends to push in on either side of the main jet ebbing from the estuary mouth, or may interdigitate with it in a complex way, with the result that a series of interlocking ebb- and flood-channel systems form, separated by hazardous shoals. These shoals evolve and migrate according to as yet poorly understood rules.

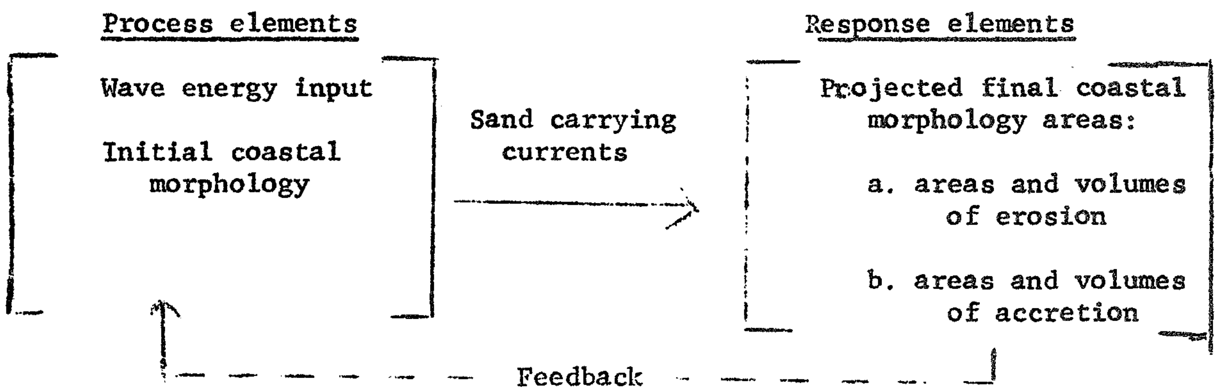
Vigorous sand movement ceases at the foot of the shore face. Sand movement continues seaward across the shelf, but except on tide-dominated shelves such as those of western Europe, it transpires at a far slower rate, driven by the surges of rare cataclysemic storms. While such movement is of considerable theoretical interest, it does not directly affect the more pressing practical problems of coastal ocenography.

Coastal Erosion - The preceeding discussion of the dynamics of coastal sand transport has fore-shadowed some of the major problems of coastal zone engineering. Foremost among these is the problem of coastal erosion (U. S. Army Coastal Engineering Research Center, Rept. 4).

The low unconsolidated coasts of the world are undergoing general erosional retreat, at the rate of centimeters to meters per year. The Atlantic coast of the United States from Cape Cod to Cape Sable, Florida, and the Gulf Coast (with the exception of the Mississippi delta) fall into this category. Hundreds of thousand of property owners on these coasts, plus the U. S. Army Corps of Engineers, have exhibited steadily increasing concern over this problem since the period of the Civil War. No certain remedy for this problem has been developed, aside from the expensive processes of local beach stabilization, and replenishment with material pumped from offshore. Examples of resort areas on the Atlantic seaboard which have in the past or are now experiencing costly erosion problems are Miami Beach and Daytona Beach, Florida; Myrtle Beach, South Carolina; Wrightsville Beach and the outer banks of North Carolina; Virginia Beach, Virginia; Ocean City, Maryland; and the New Jersey, Long Island and Cape Cod resorts.

The remaining problem of considerable significance to coastal engineering is harbor-mouth maintenance for ports located in lagoons behind tidal inlets, and ports located on major estuaries. Harbor-mouth maintenance is necessitated mainly by the littoral drift of sand. Examples of ports on America's east coast which experience inlet stabilization problems are Daytona Beach and Jacksonville, Florida. Beaufort, North Carolina, and Atlantic City, New Jersey. The major commercial ports of this coast are situated on estuaries whose mouths must be dredged. These include Savannah, Georgia; Charleston, South Carolina; Norfolk, Virginia; Baltimore, Maryland (Chesapeake Bay), and Philadelphia (Delaware Bay).

The same initial step is necessary to solve problems of both coastal erosion and harbor mouth shoaling in these diverse portions of the Atlantic Coast, and in similar areas around the world. It is necessary to develop a process-response model for sand transport in the area of concern capable of quantitification. Elements of such a model for coastal erosion are as follows:



This model may be entered in one of two ways. Either the transform elements may be directly measured, and the response predicted, or the process elements may be measured, the currents computed, and the response accordingly predicted. Since in many cases, basic process data is already available, much work has been done by the Corps of Engineers in the development of empirical formulas which will predict coastal response from measured process elements.

Measurement of coastal process elements - The fundamental energy measured in coastal sedimentation studies is wave energy. Wave parameters, are amplitude (.5-2 m, $\pm$ 1), period (4-20 sec, $\pm$ 1) and direction (0 - 360° $\pm$ 5). They are, at a given instant, fairly consistent offshore along many tens of kilometers of coastline, but vary with the periodicity of local weather, and also with the evolution of storms many thousand of miles distant. Locally generated waves occur as a broad spectrum, of wave lengths and heights, and wave trains from several generating areas frequently arrive at the same point. Consequently, statistical methods are used to develop wave data. One method assesses reports of deep water wave characteristics by ships at sea, compiled by the U. S. Navy Oceanographic office, and published as sea and swell charts. The second applies wave forecasting techniques to produce wave statistics for the study area from historical synoptic weather maps (44). Both methods provide statistical data on wave heights and directions in deep water. The latter method also provides wave periods associated with height and direction, enabling energy evaluation. Attempts are presently being made to directly measure these parameters by remote sensing (45).

Since shallow-water wave velocity varies with depth, wave energy is concentrated along some sectors and rarified along others by wave refraction, due to irregularities in the shore face. Wave refraction patterns and resultant littoral drift for a coast under study may be calculated by computer. Input consists wave parameters of the most frequent wave regimes, their relative yearly durations and the bathymetry of the shore face. The latter information is usually determined by contouring the smooth sheets from which U. S. Coast and Geodectic survey charts are prepared. The charts themselves are less suitable, because they have approximately 20% of the original cata. The output includes daily wave energy transmitted forward, its longshore component, and (based on various empirical relationships) the daily and annual littoral sand transport rate in cubic meters per year. The com½arison of transport vectors for successive coastal segments of perhaps 5 km length indicates net erosion or accretion due to littoral driaft for these segments.

The results of such calculations may be checked by comparison with time series of aerial photographs (Langfelder and others), (46) or of historical charts for rates of coastal erosion or accretion, and with annual volumes of accumulation and accretion in the vicinity of wrecks, grains and other artificial obstacles.

Harbor maintenance measurements - In the mouths of tidal inlets, additional measurements must be made, and in the mouths of large bays, these additional measurements predominate. The process-response model may be correspondingly modified, as follows:

Process elements

1. initial morphology
2. grain size distribution
3. rate, and grain size of sediment input
4. rate and grain size of sediment output
5. current structure

→

Response elements

Projected final morphology

a. areas and volumes of erosion
b. areas and volumes of accretion

← - - - - feedback - - - - -

In this model for the sediment budget of a bay mouth or inlet, the preceeding mode for longshore transport appears as Items 3 and 4 of process elements, with the additional proviso that the grain size frequency distribution is now critical. In small inlets, sand is bypassed across the inlet mouth, via a lunate (cresentic) bar, hence both sediment input and output is of concern. Hugh bay mouths are more efficient sand traps, and sand may not be bypassed.

The initial morphology of the bay or inlet mouth must now be known in greater detail than can be indicated on most charts, and is usually mapped in the course of the study by means of acoustic fepth sounders. Vertical resolution of ± 15 cms and electronic precision navigation systems horizontal reduction of ± 5 m. In clear water, laser bathymetry may be feasible (see reference in preceeding section to air borne laser surveys of water masses). The bottom profiling methods should be sufficient resolution to detect such micromorphologic features as sand ripples and sand waves. In the strong tical currents of bay mouths, these bed forms are important mechanisms of bedload sand transport.

The bottom of the study area is grab sampled commonly at the same time that the bottom morphology is mapped. Density of the sample net is a function of the wavelength of the bottom topography, and the logistics of the survey, but spacing between survey lines is commonly several hundred meters or less. Acoustic profiles are continuous, while grab sample stations may be spaced 100 meters or less apart. Up to 3 dm^3 are obtained at a station, for grain size analysis in the laboratory.

Side scanning sonar techniques are presently being developed which have limited application in determining the nature (grain size distribution) of bottom sediment (47)

The final parameter measured is the current system. For bay and inlet mouths this is primarily tide-driven rather than wave driven, as in the case of littoral drift. It is further complicated by density (salinity) driven currents, and is complexly structured in three dimensions. Consequently it must be measured directly.

In the determination of flow systems of tidal estuaries the primary parameter to be measured is current velocity in the range 10-400, ± 15 cms/sec. This must be sampled for perhaps 3 minutes every 30 at least through a 12 hr. semidiurnal tidal cycle, and if logistics permit, the diurnal and longer term components should also be assessed. The sample net might consist of 20 stations, strategically situated in channels and on shoals with in situ, one month, recording or telemetering. Ideally each station has bottom, mid-depth and surface meters moored to an anchor. Salinity in 5-40 parts per thousand, ± .1 and temperature (0-40°C ± .1) are also significant in that the current system is partly driven by the fresh water input of rivers. In situ, one month recording or telemetering salinometer thermometers might therefore be attached to the current meters. In addition density profiles at 2 meter to 5 meter depth intervals should be taken at quarter-tide intervals for at least a semi diurnal cycle.

Adequate resolution of the current system, plus a detailed map of the grain size distribution will permit estimation of the rates and directions of sediment transport in the estuary mouth, through a variety of empirical formulas, and prediction of the areas and volumes of sediment erosion and accretion.

Mineral Resources of the Continental Shelf

The greatest present concern for the continental shelf involves not its more slowly paced patterns of sediment movement, nor the storm-induced shifts in bottom topography, but the mineral resources contained in its relict sand sheet. These are first and foremost merely sand and gravel. The demand for these construction materials is increasing off east coast metropolitan areas to the extent it is becoming economically feasible to dredge them. Sand is also being pumped landward from immediately offshore of large resort beaches to replinish areas of severe erosion (48).

Secondly, the modern beaches, and the drowned beaches and stream channels of former lower stands of sealevel have hydraulically concentrated certain rare minerals such as ilmenite (titanium ore), cassiterite (tin ore), zircon (zirconium ore), gold, and diamonds, to the extent that it is locally econically feasible to dredge for these materials.

Finally the bottom morphology distribution of bottom materials controls the distribution of bottom fauna and is of considerable importance to the fishing industry. Bottom sediment distribution on U. S. continental shelves is presently being mapped by several federal agencies, including the Bureau of Commercial Fisheries, the U. S. Geological Survey, and the Coastal Engineering Research Center. The procedure is a simple one, where a ship traversing a rectillinear sample grid samples the bottom once per 10 sq. km. and submits the sample to laboratory analusis for grain size and mineral composition.

Subsurface geology

Previous sections of this discussion of Geological Processes and Problems have been concerned with phenomena outside the surface of the solid earth. Shore line erosion, sediment deposition, water circulation, and so on, occur at the interfaces of land, sea, and air, or within the fluid bodies of the sea and air. Many of the answers to the geologic questions of current interest are to be found beneath the solid surface. In most land areas there are exposures of features giving clues to subsurface geology. In coastal zones, and beneath the open seas, the water and often thick layers of sediment hide most of the visible clues to the subsurface. Resources of petroleum and mineral ores, and secrets of the earth's history, even the origins of the ocean basins, are hidden here.

The present methods of finding, delineating and interpreting structures within the earth may be divided into two main categories: 1) direct observation of exposed crustal material; and 2) indirect observation of the subsurface. In the first category such features as faults, folds, intrusions, and flows are found, studied, and correlated by field mapping and observation of exposed features, and by interpretation of aerial photographs and side-scanning radar imagery. Drilling into the subsurface and examining recovered samples of the earth is a transitional method of studying the subsurface. It is used as a supporting method to either the direct or indirect procedures. The second category, that of stydying buried features, is more complicated for it entails a variety of sophisticated equipment for investigating different aspects of the subsurface. For example, in the correlation of subsurface rock units, and the delineation of faults and folds, seismic surveys can be conducted. In this process an explosive charge is detonated which generates shock waves. These waves are reflected and refracted as they pass through rock of differing rigidity and density. Wherever there is a change in the elastic properties of the rock, part of the energy is reflected back toward the surface while the remainder passes through to the next discontinuity. The recording of these reflected waves along with calculations of time and distance functions enables the geologist to determine depths, configuration, and, in a general way, rock type of these reflecting horizons or discontinuities. By comparing the recorded data, interpretations pertaining to correlation and structure can be obtained. Accuracy and depth of penetration depends on the sensitivity of the equipment, the size of the force generated shock wave, and the placement of the explosive charge with respect to the earth's surface. A similar process is used by stationary seismograph stations which record earthquake waves, calculate their point of origin and use these wave records in the study of the earth's deep interior.

Another indirect method of studying the subsurface is by a gravity measuring instrument which at present, can have an accuracy of approximately one part in 50 million. Information pertaining to the structure of the earth's crust and interior comes from interpretation of area where the force of gravity deviates from the calculated normal. These deviations or anomalies can be obtained by correcting the observed value for the effects of latitude, terrain, the Bouger effect (attraction of a mass of material between sea level and point of measurement), freeair, elevation above sea level, and the sun and moon. The observed value is consequently reduced to what it would be at sea level at that position if the effects of all the terrain above sea level as well as the effects of the sun and moon were removed. If the corrected value still deviates from the calculated theoretical norm, then an anomaly exists, which may be either positive or negative. Negative anomalies exist where there is less dense material surrounded by more dense material. For example, negative anomalies are found over salt domes under the Gulf of Mexico and along the Gulf Coast. Typically these plugs are about a mile in diameter, roughly circular, shaped somewhat like a spindle or carrot and are located generally a few hundred feet to a few thousand feet beneath the surface of the crust. Positive anomalies are found where a more dense area such as a metallic ore body is surrounded by less dense country rock. Anomalies are also used to help locate faults and folds where high density rocks have been offset.

Unlike seismic methods, gravity measurements do not give detailed information about the depth or shape of the buried rock masses. For example, a small body of high density ore buried at a shallow depth might give the same anomaly as a mucy larger but more deeply buried mass. Consequently other geologic methods must be employed to gain further insight into the anomaly.

For mapping on a scale of 1:1000000, the minimum resolution required probably should be on the order of lo milligals. For mapping on a scale of 1:24000 the maximum resolution should be on the order of tenths of a milligal.

A third basic method of indirect observation of the subsurface is by magnetism. In geological magnetometric surveying the unit of measurement is the gamma, 1/100,000 of a gauss. The quantities usually measured in magnetometric surveying for geologic structure either on the ground or by air-borne or ship-borne instruments are the horizontal and vertical components of the earth's magnetic field. These values must be corrected for the influence of a number of cyclic and irregular variations in the magnetosphere, and for the normal or terrestial regional change in the vertical intensity. The result of these reductions is an anomaly value, which may be related to geological structural conditions in the subsurface. Geologic magnetic survey work is based upon the fact that rock masses and rock types differ from one another in their magnetic quality or susceptibility. For example, some ores, such as those of iron, are highly magnetic. Some igneous and metamorphic rocks contain a relatively large proportion of magnetite. Local anomaly values can probably be attributed to the form, size, and distribution of rock bodies (igneous, metamorphic, sedimentary) which are comparatively rich in their content of magnetically susceptible minerals.

Interpretation of magnetic anomalies for their geologic significance is by no means simple. In some cases there is a definite relationship between the magnetic anomaly and a subsurface lithologic or structural feature, while in other cases there is no known correlation between very pronounced magnetic anomalies and subsurface lithology or structure down to drilled depths of several thousands of feet. Here the effects may be from deeper lying causes.

As in the case of gravity mapping, second (or greater) derivitive maps may be made to secure better resolution of the magnetic anomaly.

For mapping on a scale of 1:1000000. the minimum resolution needed for general surveying would be on the order of hundred of gammas. The maximum resolution will depend on technological advances, but in a detailed ground survey tens of gamma are used.

Another method for indirect observations of the earth's subsurface is that for thermal measurements. Surface temperatures and heat flow are often excellent clues to subsurface phenomena. The use of thermal monitoring of areas of volcanic activity is obvious. More subtle temperature differences may be associated with faylts and other subsurface features. Synoptic measurements as from high altitude platforms carrying infra red sensors are usually necessary to recognize such features.

In coastal zones the published information on subsurface geology is scanty. Reasons for lack of publication are several. As indicated above, the subsurface features of the coastal zones are not readily visible for study due to flat relief and/or coverage by water and sediments. Instruments for indirect observations of the subsurface with much precision and accurace are relatively recent, and their use somewhat expensive. Measurements by public agencies in most coastal countries, therefore, have been limited. Computers with the easy capacity to do the numerous mathematical manipulations on data derived from indirect observations, required for interpretation of subsurface features, are only recently available. A large portion of the indirect subsurface observations which have been made were done commerically in the search for petroleum, including natural gas, and mineral resources. Such information is thus closely held.

There is need in many coastal zone areas for public information on the subsurface where there is crustal activity and danger to life and property from unforeseen earthquakes, earth slides, and volcanic eruptions.

Application of Satellite Data to Geological Problems

Snynoptic measurements of magnetic anomalies have been made from polar-orbiting satellites (49). Large-scale gravity anomalies have been inferred from satellite observations (50). Repeated coverage of various coastal areas will provide imagery from satellite borne sensors such as in the middle Atlantic seaboard. This will allow interpreting and correlating coastline modifications with respect to wind and current directions, storms intensities and direction, the affects of normal climatic conditions between periods of storms, and the type and size distribution of involved sediment.

To date it has been impossible to obtain repeated coverage on a day-by-day; week-by-week; or month-by-month basis over considerable lengths of time and covering large geographic areas. Recent investigations have generally dealth with changes occurring in small geographic areas and covering short lengths of time. (51, 52). Many of these are profile studies which give little insight into the processes and modification occurring outside the profile area. In addition many are confined to either the beach and near shore areas or to off shore studies. A few investigations have looked at geographically small area over considerable periods of time (years to 100 or more) using available arial photographs, charts, maps and sketches (53). This type of investigation gives a net change in shape for the area but is of little aid in interpreting these changes as to why they occurred, how they occurred, when they occurred, and the relative energies needed to produce these changes. In addition it is of little help in understanding the interactions of various tides and currents occurring in the area.

Synoptic satellite imagery coupled with ground truth data on winds, currents, tides and sediment load could give much insight into the processes and energies involved in coast line modification. Rate of sediment transfer, and the shape and rate of development of shoals both off shore and in protected bodies of water could be monitored and predicted. Repeated satellite imagery in several narrow wave bands, as well as composite color for selected areas is needed. Ground truth investigations would include measurements pertaining to wind and current directions and velocity, tidal fluctuations, longshore drift direction and velocity; selected lines of profile from beach to offshore; and an analysis of sediment type and size distribution.

Synoptic multi-channel imagery coverage of all or part of an emerged coastal province for the purpose of delineating and mapping vegetation types, soil types and relative availability of near surface ground water over a large area would provide a valuable ground truth experiment.

Such investigations would give for the first time, a detailed composite understanding of the distribution patterns of coastal plain vegetation, soil and water. Such information would be of great value in future local, state, and federal planning programs pertinent to the development and management of these areas. In addition this information would serve as a base for future studies dealing with changes due to natural phenomena including drought, flooding and human activity such as large scale drainage, filling, dredging, and expansion of residential areas.

Ground truth investigations will be needed to correlate imagery with actual vegetation types and quality, soil types and location of the water table.

Study of shallow water sediment transport and deposition with respect to time, wind, currents, and tidal variations would be productive from satellite imagery.

Beach erosion is most active during periods of high energy release such as storms and hurricanes. The eroded beach material may be moved in the direction of dominant long shore currents; offshore to form a submerged bar; and out on the continental shelf if the sediment size is fine and trapped in strong seaward moving rip currents.

By observing the relation of sediment transport over a long period of time to a variety of wind, current, and tidal conditions an understanding will be attained as to 1) where the sediment is being transported; 2) areas of possible shoaling and their predicted growth or destruction; and 3) prediction of spread or entrapment of waste products now being dumped at sea by coastal metropolitan cities.

A great deal of ground truth investigations will need to be conducted to correlate observed imagery with the physical factors operating in the area. Such items as character and configuration of the bottom surface and below surface current directions and velocities, sea state, tidal fluctuations and velocities, and wind directions and velocities must be determined before any meaningful interpretation can be applied to the satellite imagery. Some ground truth experiments which would contribute to the ERTS-A & B, or ERTS-E & F programs are suggested below. This list does not exhaust the possibilities which will result from these programs.

Littoral Zone Ground Truth Experiment - An investigation confined primarily to the beach and surf zone. Parameters to be evaluated, using ERTS-A sensors will be beach configuration and modification, temperature patterns on the beach as an indication of grain size (sand or gravel) and composition (quartz, organic mats, etc.), temperature in the surf zone as in indication of energy release, and temperature distribution patterns between the beach and surf zone as a means of determining direction and perhaps magnitude of long shore currents. The area of study should be easily accessible during all types of weather, such as the coast line from Virginia Beach, Virginia to Ocracoke Island, North Carolina. Because it is difficult to simultaneously monitor the entire area sensed by a single satellite pass, selected sites of reference would be used for the actual taking of measurements and calibration while the intervening areas would be used as areas of interpretation. It is thought that sites spaced at 10 to 15 kilometers apart in 15 to 20 meters of water would be adequate for monitoring waves outside of the surf zone and 3 to 10 kilometers apart in the surf zone with closer spacing in areas of known activity and rapid change such as False Cape, Cape Hatteras, Hatteras Inlet and Ocracoke Inlet. There would be approximately 4 stations per site except in the above mentioned areas. Station 1 would record beach width, beach composition, grain size and temperature of beach surface; station 2 would record current velocity and direction, temperature, and amount of suspended meterial between the beach and the surf zone; station 3 would record temperature, velocity of incoming waves, direction of wave, period of wave, wave height at breaking depth, breaking depth, angle of surf of a particular wave regime with respect to coast line in the surf zone; station 4 would record temperature, wave direction, period, and height and topography of the bottom seaward of the surf zone.

Ground truth sensing equipment needed for this experiment would be wave gauges, suspended sediment samplers, such as the Coulter counter, bed-load samplers, such as the Arnhem bed-load sampler, and smooth sheet marine charts, while the imagery needed to conduct the satellite phase of this experiment would be from all ERTS-A channels.

A great deal of important information concerning not only short term beach erosion and accretion but also long-term effects on the coastal area can be obtained from such an experiment. Such long-term information would play a vital role in the prediction of beach modification and consequently be an important tool in the evaluation, planning and development of coastal lands for best use.

Observation of Offshore and Bay-mouth Shoaling - Horizontal and vertical water circulation patterns are often influenced by bottom topography, while the bottom topography is the result of current patterns. This interaction could be used as a means to detect, plot, and establish growth and migration of offshore shoals.

The area of study should be the off-shore area from Cape Charles, Virginia to Octacoke Island, North Carolina because this area has a history of shipwrecks due to shoaling conditions. Selected areas such as the Chesapeake Bay mouth and Diamond Shoals off of Cape Hatteras will be measured using shipboard bottom profile equipment. Monitoring will be done during satellite passes as well as prior to and after storms. In addition, sea state parameters such as wave height, direction, and period as well as temperature, salinity, current directions and velocities, and amounts of suspended and bed-load will need to be determined.

Apparatus similar to that in the preceding littoral zone experiment will be needed with regional spacing of about one station per 15 to 20 square miles and several areas of detailed observation having a spacing of one station per square mile in 5 to 10 square mile blocks.

Ground-determined shoal position and migration will be collated with the satellite imagery. The other measured parameters will not only provide a good basis for predicting future buildup, destruction and/or migration of shoal conditions but these measurements also can be correlated with satellite imagery for future satellite observation interpretation in other areas.

Economically, an understanding of shoal positions and shoaling causes would lend important information to maritime industries for navigation, and would also help delineate possible new sources of sand and gravel for future construction needs.

Analysis of Sediment Transport: Lagoon to Open Marine - This experiment is designed to observe, collate, and calibrate suspended sediment load egressing from protected lagoons to open marine conditions.

Little is known about the sediment load being transported through tidal channels such as Hatteras and Ocracoke Inlets from protected bays, sounds, and lagoons to open marine waters. Yet in many instances such knowledge is of economic importance because this sediment contributes to shoaling of navigable channels, development of offshore bars and sediment supply of the beach.

Ground truth investigations for this experiment would include studies of: 1) tidal fluctuation. 2) volume of water entering and exiting from the selected inlet; 3) current velocities, distribution, and patterns; 4) salinities of entering and exiting water; 5) temperature of entering and exiting water; 6) refractive index, size distribution, and concentration of suspended sediment being transported through the inlets; 7) size and concentration of bed-load being carried through the inlet; 8) areal extent distribution patterns, dispersal directions, and sediment characteristics of transported material seaward of the inlet.

Ground truth monitoring equipment necessary would consist of tidal gauges, current meters, Coulter counters Arnhem bed-load samplers, and smooth sheet marine charts. Spacing of this equipment depends on channel and sedimentary plume configuration. In general though the numer of stations will range from 10 to 30 for each cross section through the inlet or sedimentary plume with approximately 10 to 20 cross sections being needed.

The configuration of the sedimentary plumes can be delineated by satellite imagery. Imagery density, shading, and color patterns and distribution will be related to such ground determined characteristics as transported sediment volume concentration currents, bottom topography and salinity.

Determination of River Run-off: Fresh Water and Sediment Volume - This experiment would test the feasibility of determining estimates of fresh water and sediment volume being discharged by rivers. Few rivers have accurate flow metering equipment and consequently little is known about the total runoff of fresh water from land. In addition, the total rate of sediment supply to the oceans is also unknown. By doing a pilot study of a few selected rivers and calibrating imagery color density and patterns with ground measurements, it seems possible that in the future a standard reference file can be developed. River discharge patterns on a world-wide basis then can be compared to the standard reference file and reasonably accurate estimates of total fresh water and sediment discharge to the world oceans can be attained.

The discharge data of a few selected rivers such as the Susquehanna, James and Savannah Rivers, which are now being monitored, should be correlated with some features of satellite imagery. This information should then be applied to a second set of selected, monitored rivers to determine the accuracy of satellite estimates of river discharge.

River discharges can usually be identified in photographs taken from above because they are characterized by muddy water, differences in color or shading, and/or lines of foam or floating debris. They often are characterized also by water temperatures different from that of the surrounding sea water. Ground truth measurements will be made to determine the shape of the river discharge wedge as well as its volume and quantity of suspended material. The three dimensional shape of the discharge wedge, in general, is a function of amount of river runoff, bottom topography in the discharge area, wind and wave conditions, currents, tides, and ice. These parameters, consequently, must be measured. Equipment needed for this study, then would consist of tide gauges, wave gauges, current meters. suspended sediment samplers, and bottom profiles. Depending on discharge width and configuration the number of cross sections needed to monitor the area will range from 10 to 20, with 10 to 30 stations per cross section.

Additional benefits from such a study would be 1) data for assessing the effects of floods and hurricanes, 2) increased knowledge of river effluent dynamics, and 3) considerable insight into the processes of delta deposition.

Surface Phenomena and Submarine Canyons - Submarine valleys exert an important influence on adjacent water masses and currents. For example there are periodic upwellings of cold deeper waters near canyons, there are differences in water color and shading paralleling the valley margins, and streaks of foam have been found running parallel to the valley boundaries. In addition mass movements and turbidity currents along the axis of the valley stir mud into surface water. Another phenomena which needs to be studied is the surface expression of canyon controlled currents. For example ships positioned over the axis of a submarine canyon will remain over the axis during extended periods of drift, yet there is little evidence that these valley influenced currents have surface expression.

Besides the delineation of known submarine valleys and the discovery of additional such features, repeated coverage would build a record of canyon flushing occurrences. Such a record would shed considerable light on the causes for these movements. In addition high altitude imagery could be of great value in detecting and delineating the surface expression of canyon directed currents.

Ground investigations would include such apparatus as wave current wind and suspended sediment gauges. At least three cross sections of the canyon are needed, dividing the area into 1) canyon head; 2) lower erosional canyon; amd 3) canyon fan. Station spacing should be on the order of every 3 to 5 miles across the canyon head and every 10 miles across the remaining two cross sections.

Opinions of Others

A short questionnaire with a covering letter (see appendix) was sent to about 50 selected persons who are working in marine geology and closely related fields. Replies were received from some 50 per cent of addressees.

The replies reflect a wide range of interests and opinions. Most replies contained additional suggestions of problems and needs than were listed on the questionnaire. Several persons made comments of particular value such as:

> "The important thing is to slow man's inroads down while we still have a chance to make baseline studies of everything. But to be realistic we need to know the environmental bases. What is the physical, chemical, biological, geological environment on the shelf and coast not only daily, but what are the rare events that may be most important? (54) and

> "Importance of problems is determined by need, potential gain, etc., and may be quite different in the short-term sense from the long-term aspect. Your list, to which I have added a few items, is far from comprehensive in each of its three categories, I feel, particularly when viewed in global terms." (55).

The opinions expressed in the replies to the survey showed about equal concern for two general problems of the coastal zone. These were "pollution" and "shoreline processes". The effects of pollution on marine ecology in general, and on food fish in particular were emphasized. The increasing dangers to man from pollution were indicated. Problems associated with interactions between land and sea in shore line processes were considered of high priority. Beach erosion, channel silting, and data on sedimentary environments were recognized as such problems. Petroleum and mineral resources of the coastal zone, and the legal and political problems in the use of the coastal zones were not rated as urgent questions.

Geodesy

Geodetic measurements and surveys are made with the best possible precision and extremely fine resolution. The objectives of these measurements include determination of the exact shape of the earth and the absolute horizontal and vertical location of any spot on the surface of the earth, either land or sea. Such geodetic data serve as the bases for the construction of most maps and charts. Geodesy includes measurements of the gravity and magnetic fields associated with the earth. Small scale anomalies in these fields are of particular interest to geologists in delineating subsurface crustal structures and in locating mineral ore bodies.

The need for geodetic measurements of high precision and accuracy is obvious in a number of geological problems related to the coastal zone. Vertical movements in land and sea of low magnitude during relatively long time periods are evidences of tectonic activity and/or changes in liquid water volumes in the seas. Apparent movements may result from shore line modifications due to erosion and deposition of sediments. Short term changes in vertical position of moderate to large magnitude are infrequent and when they do occur are usually catastropic to man and his works. Horizontal movements of low magnitude over long time periods may be evidence of sea-floor spreading and continental drift.

Some comments, which seem to adequately describe satellite geodesy are quoted directly from the report of Panel 13 on Geodesy - Cartography of the 1967-78 "Summer Study" (50).

"End Products of Dynamic Satellite Geodesy

"So far in this discussion of dynamic satellite geodesy, the approach has been that of an ongoing activity evolving toward new and more valuable results. This is the point of view of the producer of the geodectic information. An alternative approach can equally well be followed, emphasizing the products of dynamic geodesy from the user's point of view. In this aspect, typical products of dynamic geodesy are:

"1. Long-wave structure of the gravity field, obtained from tracking data, and the shorter-wave structure of the gravity field obtained from satellite altimetry over the oceans.

"2. More detailed knowledge than is now available for time-varying components of the gravity field (such as tidal effects)

"3. Absolute coordinates in a geocentric system for stations tracking the geodetic satellites

"4. Very precise satellite positions as a function of time, especially for satellites carrying geodetic instrumentation

"5. Precise elevations of many points on the earth's surface, both ocean and land

"6. Time variations in the earth location of stations tracking GEDY-4, the satellite optimized for use in monitoring earth kinetics.

"The principal civil uses of these products, requiring improvement over the present status are:

(continuation of quote)

Use	Using Agencies	Product Used (1-6 from above)
Navigation or location on the earth's surface with accuracy ± 10 to 100 m	Geophysical prospecting firms, particularly the petroleum industry; oceanographic research agencies	1,2,3,4 (sometimes through navigation satellite)
Location of satellite camera positions and variations in elevation of the topography	Topographic mapping agencies	1,2,3,4,5 (sometimes through tracking photogrammetric satellites)
Variation in elevation of snow, ice, lakes, rivers	Water resources agencies and others concerned with hydrological forecasting	5
Satellite orbit determination and prediction	NASA; aerospace industry	1,3
Elevations of ocean surface	Oceanographic research agencies, federal and private	5
Analysis of orbits to determine satellite surface forces, drag, etc.	Space-research and meteorological agencies	1,2,3,
Location of satellite-borne instruments (nongeodetic) as a function of time	Space-research or applications agencies	1,2,3
Precise differences in position and time between distant stations on the earth	Time services; astronomy	3.4
Study of the earth's interior	Geophysical research agencies, federal and private	1,2
Study of crustal motions, variation in rotation of earth, etc.	Geophysical research agencies	6

"Geometric Satellite Geodesy - The fundamental objectives of a geodetic control system is to give the locations of selected control points, in sufficient number and quality, in a Cartesian (preferably mass-centered) coordinate system. The selection and the number of control points are based on the following needs:

"1. To unify the various geodetic datums and to connect islands, tracking stations, navigational beacons, and other isolated points of interest to such unified datums.

"2. To improve the internal quality of existing geodetic (triangulation or other) systems by establishing "super-control" points in sufficient number

"3. To control geodectically unsurveyed areas for future mapping activities

"4. To provide precise locations for scientific reference stations

"In this context, geometric satellite geodesy serves as the connecting link between dynamic satellite geodesy and cartography. The satellites, observing instrumentation, data-reduction procedures, and products, and uses of geometric satellite geodesy have been well developed, and no significant changes are recommended as a result of this study."

Cartography

Charts and maps are essential to any intelligent use of the seas and their resources. The earliest maps and charts were prepared for safer and speedier travel and transport on the seas. Charts are more useful in the coastal zones, where navigation can be related to geographical features by visual "fixes", rather than on the open seas, where navigation must be done by "fixes" on celestrial bodies.

Aside from their use for navigation in the coastal zones, maps and charts of the seas are basic requirements for the conduct of many other activities related to the seas. No measurement of the sea, the sea-floor, or the air above the sea has much value unless the location of the measurement can be noted on a map. The accuracy with which any measurement of the seas must be located on a map depends on a number of factors, including the purpose of the measurement. Base maps, on which data may be presented, are presently being prepared with appropriate precision and accuracy on scales varying froml:1,000,000 to 1:10,000. Satellites carrying geodetic sensors improved ground-based geodetic instruments, and high-level high-resolution photography enable the production of basic maps which meet almost all requirements of science and survey for precision and accuracy in the coastal zone (50).

The problems currently faced in preparation of thematic maps, where data are available, arise most often from inaccuracies in locating moving platforms from which measurements of the thematic parameters are made. The use of an all-weather satellite navigation system for ships and satellite interrogated buoys will improve this situation on the open seas. In the coastal zones there is need for more precise shore-based navigational systems.

PHYSICAL OCEANOGRAPHY [1]

The coastal zone is characterized by changes in water properties that are large in magnitude but occur over short time spans. In order to understand the area, many observations in limited time and space are necessary; yet critical observations may be difficult because of the dangers involved in operating ships in shoal waters.

Mixing Processes

There exists a most serious need for a better understanding of the circulation and the processes which control it on the continental shelf. This information is needed in order to predict the movements of fisheggs and larvae and other elements of the planktonic flora and fauna as well as the populations which feed on them. It is needed in order to predict the ability of the ocean to accept the waste materials, including heat, which man intentionally or unintentionally deposits in the sea either directly or indirectly.

Geologists and those involved in coastal engineering are concerned with sediment transport, delta formation of rivers, and wave and current forces acting in the nearshore zone. Forces that supply and remove material once delivered to the sea and that transport it about are not clearly understood. They are joined together in complex interactions between tidal currents, wind-driven currents, hydraulic river-flow, and wave transport. Furthermore, the mid-depth or bottom currents in the coastal zone are even less understood than the surface currents. Considerable interest has been generated in coastal zone oceanography by the biologist since it is in these zones that much of the upwelling of deeper nutrient-

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[1] Taken in part from consultant reports by A. C. Duxbury and D. F. Bumpus

.aden water is found that sparks the high productivity of the sea. Biologists are interested in discovering the rates at which nutrients are supplied to the photic zone from depth and the mechanisms that cause this supply. This same process of upwelling acts to furnish dense water to the more restricted and enclosed embayments along a coast and periodically to modify their flushing characteristics. This can be a boon to maintaining bottom water quality in embayments, but it can also be a detriment by flushing out valuable inhabitants of the bay in their planktonic stages.

The physical oceanographer is intested in the mechanics of those processes fundamental to phenomena in all other fields of marine study. He is after an understanding of the dynamics of the coastal zone and how it affects the mass properties of this region. Lack of a thorough knowledge of coastal region dynamics is no doubt the greatest stumbling block to a practice of good quantitative science in other marine disciplines.

An example of the complexity of the problem is shown by Duxbury, *et al.* (57, 58, 59), in studies of the Columbia River effluent region. The "climalotogical" mean conditions in this coastal zone and the reasons for changes in water properties seasonally had to be delineated. River hydrology; weather, including evaporation and precipitation; estuary and nearshore environments; physical characteristics of the ocean regime, including ambient water features and geostrophic currents; characteristics of the effluent in the ocean; major physical phenomena affecting dispersion of the effluent in the sea; and diffusion of river water in the sea are some of the initial parameters needed for this study. Once the qualitative behavior of the region on a large scale is understood, more detailed small-scale investigations of short-term variations in the coastal zone can be conducted. These investigations would involve such parameters as currents at the river mouths, local changes of salinity and nutrients, and tidal period oscillations of isohaline surfaces..

Such studies point out that considerable variability exists in nearshore water properties at and near the sea surface because of the movement of dissimilar water types under tidal, hydraulic, and local wind-driven forces. Short-term local changes are dramatic and of a magnitude comparable to the longer-term seasonal changes, but not of the same size scale. This means that normal data-collecting procedure that yield a single data point at each geographic location with a time separation between each point should not be used to produce distribution fields that are treated as synoptic. The region is too active and too variable. In fact field studies have shown that a vessel cannot cover this coastal zone taking data at a rapid enough pace to yield a sensible synoptic picture of the region. Other methods must be employed.

Needs - At present, major needs for understanding the physical regime are easy to catalog: 1) Surface wind velocity measurements over the region that can be averaged over varying time increments to determine surface wind stress components; 2) Surface temperature distribution and their changes with time so that changes predicted by numerical models may be checked; 3) Measurements of surface currents over a large area that are monitored over time, so that the time response of currents to changing wind stress can be judged; 4) Incoming radiation, effective back radiation, and evaporation measurements to establish heat budgets and determine the contribution of advection, radiation, and evaporation to the observed local changes in temperature; 5) Changes in salinity which are necessary for determining mass field changes.

If this data were synoptic and repeated in time, it would be possible to determine the surface current field with its divergences and convergences, estimates of upwelling from continuity, transport of various chemical parameters, and their changes in time. In some instances, tidal contribution to the flow may be detectable, and the zone of influence of hydraulic flow from rivers may be delineated. Conventional techniques using ships or buoy-mounted meters for these measurements are not feasible because of the doverage required. Conventional measurements are useful, however, in that they can be made at a few locations as ground-truth measurements to provide continuity in measurements between the discrete measurements made by a remote sensor array.

Spatial and temporal requirements - The frequency of measurement and the detail of spatial distribution required to study the coastal zone under consideration depend on what is desired. Semi-monthly intervals and resolution such that average values over areas 1/2 mile square are sufficient to determine the "Climatological" mean patterns. If changes having periods of a tide cycle are desired, a time increment of 90 minutes between successive sampling with average values over about 1/8 mile square is required.

A practical scale of investigations exists between these two extremes and represents the typical time scale over which wind patterns may change sufficiently to alter the local wind-driven circulation. At this scale, daily or bidaily observations are required, with a resolution of surface averages over 1/4 mile square. Measurements would have to be continuous for a period of time and would not be dependent on time of day.

Analytical requirements - For use in calculating the dynamics of coastal waters, temperature and salinity measurements will probably suffice at an accuracy of $\pm 0.01^{o}C$ and $\pm$ 0.01 $^{o}/oo$, respectively, over the range of $-2^{o}C$ to $32^{o}C$ and 0 to 40 $^{o}/oo$. Current velocities may range up to 6 meters/sec in coastal areas; however it is desirable that they be measured at speeds down to a few tenths of a cm/sec (59). All 3 parameters can now be measured continuously by in situ sensors suspended from ships or attached to buoys. These can be used to provide useful ground-truth data for evaluating remote sensors.

Remote sensing - Since the more rapid the coverage, the more synoptic the data, remote sensing techniques hold some promise for studying the physical changes in the coastal zone environment. Although present remote techniques are limited in that they primarily monitor surface conditions only,they can be useful in obtaining patterns of gross changes not otherwise available.

Of those measurements most needed in physical oceanography, temperature appears to be the easiest to sense remotely. Instrumentation for remotely sensing surface temperatures is available and in use. Remote sensing of salinity has not been accomplished but is of urgent need. As for as is known, surface wind measurements have not been made remotely. However there is a possibility of using a scatterometer of some type that senses changes in roughness of the sea surface and orientation of the waves,to infer qualitatively the local surface wind. This type of measurement may be more satisfactory than the present method of determining surface wind fields from pressure isobars that are based more on artistic license than on data in the region considered.

Estimates of the incoming and outgoing radiation balance can be measured relatively simply from a remote sensor array, provided cloud cover can be compensated for. Currents at the sea surface have not been measured from a remote position. Physical phenomena such as thermal fronts associated with velocity shear boundaries can be used to delimit the edge of a current, but they do not yield the magnitude or direction of flow. It should be possible tofloat inexpensive targets in a pattern that would be sensed for position on successive passes of a remote sensor. Stepwise tracking of individual targets through space using the original pattern as an aid would allow displacement of a target per time between observations to be used to develop the current field.

Useful ground/satellite experiments - An example of a useful ground experiment in conjunction with a space satellite (Nimbus) is one attempted at Woods Hole which failed for several reasons but which should be repeated. The Nimbus Satellite has the Interogation Recording Location Subsystem (IRLS) capability. The plan was to successively field three drogued IRLS buoys at the locus of the haddock spawning in Georges Bank at 2-3 week intervals, to track them over a period of several months, and to sample the haddock egg and larval population in the vicinity of the drifting buoys from time to time to gain insight into the movement and dispersion of said juvenile population. Similarly, any satellite having interogation capabilities could be used to monitor "talking" drift buoys as a means of studying coastal current patterns.

Another experiment by which the tidal and secular horizontal motions over broad areas of the continental shelf might be defined is possible. During each of the seasons, suites of self-recording current meters would be moored in sections across the continental shelf (3 current meters to a station, 3-5 stations to a section) for periods of a week on a quarterly basis. The sections might be at roughly 100 mile intervals except where the topography, estuarine effluent, ocean current intrusion and local investigator's research requirements suggest. These measurements would be supported by wind measurements at each end of the section and by thermographs paired with the current meters. Temperature-salinity sections would be made when each section is laid and again as it is recovered so that the water being advected can be identified. While it is recognized that current records of one lunar period (29 days) is the ultimate choice, an intolerable loss of equipment and data is anticipated at the present time with this method in tidal waters, whereas 100% recovery of equipment and data can be anticipated if current meters are moored for a week at a time. Maximum success can be gained using submerged buoys and sonic releases. The wind measurements at the outer end of the sections would have to be obtained from surface buoys.

Results of this experiment would then be compared with temperature and imagery data obtained by ERTS-A & B obtained at the same time and place. This would provide a means of evaluating the suitability of satellites for studying the currents and mixing processes of coastal waters.

Air-Sea Interactions

In addition to their use in water mixing problems, remotely sensed temperature and sea state are also applicable to the study of heat and moisture flux across the air-sea interface in coastal regions. However these studies along with those related to sea-ice conditions are of equal importance to the open ocean invironment and have been extensively reported on elsewhere (60). Those related to meteorological problems follow.

Coastal Zone Meteorology (COZMET) [2]

Meteorology is divided into many sub-disciplines. These divisions may be on a sensor basis - i.e. radar and satellite meteorology -, on a latitudinal bais - i.e. tropical and polar meteorology -, on a vertical basis - i.e. continental and marine meteorology -, etc. Unfortunately, Coastal Zone Meteorology(COZMET) does not exist per se as a sub-discipline. Unfortunately, because many of the large population centers of the world are close enough to coasts to have their atmospheric environment and their effect on the environment (in terms of pollution and ecological balances) significantly affected by the proximity of the ocean.

One would expect that the advances that are being and will be made in the many sub-disciplines of meteorology will also improve our knowledge of COZMET. Such expectations have a basis, but the current priorities of the national meteorological community - preoccupations both in talent and resources with long-term prediction - precludes the rapid generation of basic knowledge in COZMET. This preoccupation has been expressly stated in one sub-discipline of meteorology that offers a tremendous potential for the yet to emerge COZMET. This preoccupation has been expressly stated in one sub-discipline of meteorology that offers

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2 Taken in part from Rene V. Cormier consultant's report.

a tremendous potential for the yet to emergy COZMET meteorologist - that sub-discipline is satellite meteorology. Quoting, "Emphasis will be placed upon the requirement to acquire data on a global basis for large scale weather analysis and forecasting..." (61).

Thus, those with coastal zone interests should not wait for the meteorological satellite community to acquiesce to their needs, but should make maximum use of the opportunity afforded by the ERTS system. This system can not only improve understanding of COZMET, but also of other coastal zone processes - oceanographic, biological, chemical, and geological - which are intimately linked to and dependent on the meteorology of a coastal region.

Satellites offer a tremendous and hitherto unused potential toward the understanding of coastal zone processes because their measurements are not limited to expensive and often-times unrepresentative point observations but can provide a continuous sample of measurements from an area with differing degrees of spectral, spatial and temporal resolution.

The ERTS A has the potential to make the measurements with the spatial resolution necessary for the development of better knowledge of the complex mesoscale meteorological processes found in coastal zones processes which for example are responsible for the distribution or inhibition thereof of atmospheric pollutants.

Needs and Problems in COZMET - The major problems of COZMET are tied to our lack of understanding of not only air-sea and air-land exchange processes but also to the drastic changes that take place in these processes at the coastal boundary where an abrupt discontinuity exists in terms of both the thermal and roughness properties of the interface, and occasionally in terms of rapid changes in surface elevation as well. To this are added the complexties caused by the diurnal and seasonal cycles of solar insolation. Diurnally, because of the respective small and large thermal inertias of land and water, large and rapid drops of land temperatures occur, whereas ocean temperatures remain relatively constant. Seasonally, coastal zone air masses are warmer than land air masses in winter and cooler in summer; also, land surfaces may seasonally change their roughness properties.

These complex temporal changes in thermal and/or roughness properties in conjunction with spatial changes in coastal zone elevations and potential advertent and inadvertent, man-made land-use changes, can cause unique wind, temperature, and possibly precipitation distribution patterns in coastal zones (62). Patterns which differ markedly from those found inland or in purely maritime environments.

One needs only to be familiar with the winter climate discontinuity that exists between inland Williamsburg and coastal Norfolk, Virginia, 30 miles away, to grasp the points above.

The above discussion has linked the "problems" of COZMET to the lack of understanding of basic processes, but so far has skirted the central issue - specifically, what are the basic problems and needs of COZMET.

> The basic problem is the current inability to predict the complex wind, temperature and (possibly) precipitation patterns that are unique to coastal zones.

The solution to this problem will require a two-pronged attack; one of which can be materially assisted by the ERTS system. This one attack will be the acquisition of more data on the spatial and temporal distribution of parameters such as air and sea surface temperatures, albedos of different terrains under different conditions of vegetation, ocean currents, and cloudiness. The other attack will be the use of such data by researchers as inputs necessary for the development and verification of numerical (computer) environmental prediction models designed for both arbitrary and particular coastal zones. The development of such models which are based on the integration of both the meteorological and oceanographic thermohydrodynamic equations, is presently being held back by the lack of such data. One cannot hope that the ERTS system will supply all of the required data, however such a system could economically provide some of the required data inputs.

The above two-pronged attack is an ambitious undertaking and will require many years of data gathering and basic and applied research. The question that needs to be asked is which specific problem of COZMET, if any, is most amenable to solution, and in this climate of fiscal austerity, comes within the context of established national priorities.

One established "fact of life" of COZMET, the qualitatively well-known sea and land breeze coastal wind circulation system, fits the above criteria. We possess some degree of understanding of this phenomenon, it is most amenable to modelling, and is extremely important for the dispersion of pollutants in coastal regions (63).

The ERTS system can provide measurements which will lead to a better understanding and improved prediction capability for this wind system. Such understanding could through selective aldedo changes of land surfaces lead to the eventual modification and control of the phenomenon and its attendant rainfall.

Measurements required to satisfy needs - Satellites can through passive radiometer sensing measure a number of meteorological and oceanographic parameters (64, 65), some of which could lead not only to a better understanding of sea/land breezes but also to other COZMET processes as well.

For the study of the sea/land breeze, the ERTS system would desirably provide measurements of the following parameters with horizontal resolutions of the order of 1000 feet or less (resolutions which are not in being or planned for the National Meteorological Satellite System):

1. Albedo (percent of reflected sunlight in the visible spectrum) of coastal terrain under different vegetation conditions (different seasons with emphasis on summer), during dry and following rainy periods, and under differing solar elevation angles (different times of day). Measurements should be made along coasts with different types of terrain and vegetation and terrain elevations.

2. Sea Surface Temperatures using IR sensing in the atmosphric window centered about 10 microns. Measurements need be made once a day preferably at the time of minimum cloudiness to reduce the potential cloud contamination of such measurements; although this will be much less of a problem with the ERTS system (than with the National Meteorological System) because of its high spatial resolution. Such measurements should be made for extended periods during each season with emphasis on summer, and also following periods of unusual meteorological conditions.

3. Land Surface Temperatures also using IR sensing in the 10 micron window. These need be made more often than once a day, with a minimum of two measurements per day - one at mid-day and the other at midnight. Should be made for extended periods of time during each season with emphasis on summer, and during dry and following wet spells. Coasts with differing soils/rocks/terrain/vegetation/forest canopies/ and elevations should be sampled.

4. Cloud Cover using high resolution imagery in the visible spectrum (reflected sunlight, moonlight or starlight), and high resolution IR sensing in the 10 micron window. These two measurements should enable the determination of both the horizontal distribution and height of clouds within the coastal zone. Continuous observations of these parameters would be preferable; but as a minimum, 4 observations per day with some emphasis for the daylight hours is required. Should be made for extended periods of time each season with emphasis on summer.

5. Heat Fluxes. Consideration should be given to measuring land and sea surface temperatures using a "window" wave length longer than in the IR, such as in the microwave. Radiation at this wavelength emanates from a somewhat lower level in the soil or water, possessing a somewhat different temperature measurements in conjunction with the IR determined temperature, might be conceivably used to determine sensible heat fluxes over land and ocean. The feasibility of this concept has however to my knowledge not yet been demonstrated. A microwave window measurement would also be of value to determine surface temperatures in the presence of clouds.

Ground truth Experiments - All five parameters mentioned above will require "ground truth calibrations" before satellite determinations of them can be reliably used for COZMET diagnoses or prognoses. Ground truth experiments can be conducted for the first four of the parameters - albedo, sea surface temperature, land surface temperature, and cloud cover - using data from ERTS A (or ERTS E/F, if these satellites carry sensors similar to ERTS A.) The fifth parameter - heat fluxes - would require microwave radiometry on ERTS E/F.

The following numbered paragraphs will briefly describe possible ground truth experiments for each of these parameters.

1. Albedo: Aircraft measurements of this property using sensors identical to those flown on the satellites should be made at varying altitudes and solar elevation angles and compared with simultaneous ERTS measurements. Differences in these measurements, if any, could then be related to altitude and/or solar elevation angle in order to establish "calibration curves". It would also be desirable to relate the albedo of a forest canopy as measured by ERTS to the short-wave radiation blance within the canopy itself.

2. Sea Surface Temperature: The determination of sea surface temperature from IR radiometry is dependent upon knowledge of the emissivity of the ocean surface and the amount of water vapor and carbon dioxide between the water surface and the sensor. Although it is widely assumed that water has an emissivity of 1.0 in the infrared, it has been pointed out (69) that (based on laboratory measurements) this assumption may be grossly in error, especially for measurements made at oblique angles to the water surface. The emissivity of water may also be affected by the presnce of surface oil films, salinity, and roughness (67). For these reasons, ground truth measurements for sea surface temperature should consist of measuring, 1) the vertical distribution of water vapor and carbon dioxide over a test area, 2) the amount of surface oil present, 3) salinity of surface waters, 4) sea state with a photographic record thereof, and 5) skin temperatures using near surface radiometer measurements. These measurements should be related to the simultaneous 10 micron measurement made by the ERTS system at differing angles to the ocean surface.

3. Land Surface Temperatures. Like water surfaces, the IR emissivity of certain land surfaces may be less than 1.0 and may depend on a number of factors. Over non-forested vegetated country, the emissivity will be related to the crystallographic structure of the surface soil or rocks; and within forested areas, the "effective emissivity" (if capable of definition), is complex and poorly understood. Thus unique ground truth measurements need to be made with regards to land surface temperatures. In non-forested areas, the temperature of the top millimeters of different soils need to be measured and correlated with ERTS determined temperatures (corrected for atmospheric water vapor and carbon dioxide absorption and cloud contamination). These correlations should be made with satellite measurements taken at different angles to the soil surface. Over forested areas, the "surface" temperatures determined by ERTS should be related to measured actual values of surface temperature made within the forest canopy.

4. Cloud Cover. The horizontal (high spatial) and vertical distribution of clouds as measured by ERTS need to be correlated with simultaneous ground-based and aircraft measurements of the same clouds.

5. Heat Fluxes: The feasibility of the determination of heat fluxes using satellite joint sensing in IR and microwave regions as previously outlined has not been proven. Thus, the first ground truth experiments that needs to be conducted is the correlation of satellite determined heat fluxes measured over oceans and homogeneous non-vegetated land areas with conventional heat flux measurements concurrently made over these areas. Assuming that such ground truth measurements prove the feasibility of this technique, other ground truth experiments could be planned relating satellite measurements taken over more complex non-homogeneous land surfaces to heat flux measurement determined *in situ*.

International Decade of Ocean Exploration

The International Decade of Ocean Exploration (IDOE) for the 1970s was proposed by the President of the United States in March 1968. The National Council on Marine Resources and Engineering Development invited the National Academy of Sciences and the National Academy of Engineering to study the goals and overall implications of such a program. The product of subsequent meetings and workshops was the report, "An Oceanic Quest" (5). Included in its overall recommendation concerning the scope of the IDOE was the suggestion that such programs funded by the United States Government should be coordinated through an interagency group.

The management of the International Decade of Ocean Exploration (IDOE) has since been assigned to the National Science Foundation. This agency has published the long range goals of the IDOE in its notice #29 in July 1970. These major goals are:

1. to increase opportunities for international sharing of responsibilities and costs for ocean exploration and to assure more equitable use of limited resources.

2. to begin long-range efforts to protect the marine environment by accelerating scientific observation of the natural state of the ocean and its interactions with the continental margins.

3. to develop and improve an ocean forecasting and monitoring system, to facilitate prediction of oceanographic and atmospheric conditions, and to reduce hazards to life and property and permit more effective use of marine resources;

4. to expand seabed assessment activities, to provide scientific information needed to permit better management of ocean mineral exporation and utilization.

5. to improve worldwide oceanographic data exchange.

The present policy regarding the initiation of the IDOE program by the NSF is the solicitation of proposals from institutions or organizations to encompass topics of broad national or international significance applicable to the above goals. As of August 1970 no funds had yet been appropriated to the IDOE program. However the IDOE administrative office has indicated an anticipated $15 million in funding for the fiscal year beginning July 1970. This amount of money would allow only a limited number of contracts to be awarded in view of the scope desired in this program. The proposals for the first series of awards are to be received by October 1, 1970. They are then to be reviewed and assigned priorities for funding in 1971. NSF has indicated an emphasis will be placed on three major themes for the 1971 awards. In each of these, the rapid availability and accessibility of data and intercalibration of instruments will be stressed:

1. Environmental quality. Studies to provide comprehensive "baselines" of the chemical and biological characteristics of the entire ocean with particular application to pollution monitoring and control;
2. Environmental forecasting. Studies with emphasis on modeling and oceanic variability, air-sea interaction, upwelling and the flow of energy, nutrients, and other substances through the food web.
3. Seabed assessment. Studies with emphasis on the topography, structure, and dynamic properties of the continental margin and deep ocean floor including the general character and stratigraphy of ocean sediments.

It is apparent that ERTS A & B and future earth resource oriented satellites could in varying degrees be directly applicable to each of the above listed priority areas that IDOE has established. Environmental forecasting would appear to be the most promising area of direct application of present satellites sensory equipment for the study of air-sea interaction, sea state, and application to weather patterns and predictions of broad scope. The relationship of ERTS in sea bed assessment would be limited to the more shallow regions of the coastal zone regions, excluding completely any studies of the deep ocean floor. There are several possibilities in the application of ERTS to environmental quality investigations that are discussed in this report under fisheries.

The global mapping of productive areas of the world oceans and coastal regions, indicating patterns of concentration, seasonal fluctuation, and overall productivity would be both feasible and of significant value. There would be apparently little useful application of the ERTS program in the monitoring of pollution in marine waters or the fundamental analysis of water for chemical or biotic composition. This still requires an extensive effort from ships of opportunity that would be available for extensive sampling of the world seas.

To date, the NSF-IDOE administrative office had indicated that no overtures have been made by NASA officials to encourage the application of the ERTS program to the IDOE. On 26 August 1970 Mr. John R. Twiss, Special Assistant to the Director for the IDOE, indicated that there were no committees functioning between IDOE and the Global Atmospheric Rsearch Program (GARP), nor was there any communication from the various world organizations of the United Nations about satellite usage in IDOE. He indicated the only way satellites would be brought into the IDOE program, as it presently stands, would be through the acceptance of proposals that specifically indicated the use of ERTS or other satellite systems. NSF has also indicated a preference to proposals of such broad scope that they transcend national boundaries and represent joint efforts from representatives of the international community. There is also an emphasis placed on the benefits that may be derived from the results of IDOE programs to the international community and especially to developing countries in the use of oceanic resources. It is difficult to ascertain at this time if these limitations will be a factor in the development of ERTS related proposals submitted and those approved that would be of international significance to demand a high priority. It is also apparent that the present status of the IDOE is in a formulative stage of establishing the direction and management of long term programs. This philosophy may change in the current decade regarding management, funding, and areas of recommended emphasis.. No doubt there would have been numerous advantages in having the IDOE program located under the National Oceanic and Atmospheric Administration (NOAA). More closely coordinated efforts would possibly be accomplished in this organization concerning problems of broad national and international scope. This is especially true regarding the multiple ocean-oriented interests of the participating agencies in NOAA: The Environmental Science Services Administration (ESSA), the Bureau of Commerical Fisheries, the National Data Buoy Development Program, National Oceanographic Data Center and the National Oceanographic Instrumentation Center.

RECOMMENDATIONS

1. A review of the major problems in coastal zone oceanography indicates a common need for more physical data of the water system. This represents the major priority of the coastal zone community. Information is needed on water circulation, current patterns, and the temporal variations associated with these phenomena. Local and synoptic regional temperature and salinity data, plus the interactions of coastal water to the shoreline and shelf area, have application to biological, chemical, and geological coastal studies.

2. It is also recognized that many of the problems associated with fisheries biology, chemical analysis, and pollution, require extensive in situ sampling not applicable to remote sensing. However, each of these areas require supportive information from the physical parameters. It is in the area of Physical Oceanography that the ERTS sensory capabilities appear to be most applicable in the coastal zone.

3. A report developed by a special working committee of the Intergovernmental Oceanic Commission (UNESCO) supports a more concerned effort in the physical aspects of oceanography.

This was an ad-hoc non-governmental international ocean engineering working group that met at the Sixth Session of the IOC in 1969. Their recommendations contain a number of ideas which emphasize the present discussion. They wished to point out the need by engineers for large amounts of reliable data from scientific research in oceanography. Their suggestions were made in four areas of interest. The following sections A, B, C, and D, have been taken, in part, or totally from this report (22).

A. Surface waves. It was suggested that high priority be given to:

"1. Collection of more measured wave data, especially in the spectral form, with more coverage of coastal areas;

"2. Development of better contact between the supply and demand for wave data, especially with regard to information for distant or special areas;

"3. Comparative evaluation of visual, measured and forecast wave data."

B. Wastes and Pollution. In addition and complementary to the effort on long-term larger scale processes recommended by the IOC working group, the engineers suggest research and exploration on short-term smaller scale processes which would include:

"1. Continuous monitoring of appropriate parameters to determine for wastes management systems and their environment:

(a) the functional effectiveness of the existing designs,
(b) a basis for future design,
(c) base line information to determine the long-term and short-term ecology of the local environment, its interrelationship with wastes systems as well as the long-term large scale global oceanic processes.

"2. This monitoring should be primarily in the coastal zone regions of multination concern."

"Appropriate parameters include indicators of natural local upwelling, local surface currents, local temperature and density distribution, biological processes and their spatial and temporal variability. Details of mixing processes and other mechanical processes (such as "slicks") are of importance. The parameters primarily in the local area and secondarily in the global ocean, also include indicators of physical, chemical, and biological processes and effects which are either created or modified by the existence of the wastes systems.

"Coordination is necessary to ensure that all of the data obtained in the monitoring effort is mutually compatible."

C. Sea and Shore Inreraction.

"The interaction between the sea and land occurs in many instances where some portion of the land consists of movable material. This interaction is governed by the motion of the water of the sea and the characteristics of the movable material as suspended and or bed load.

"To predict this movement, the five following phenomena are of importance:

"1. Waves.

"2. Currents generated by:

a. Tides
b. Storm surges and tsunamis
c. Net transport of water due to waves, resulting in longshore and rip currents
d. Wind stresses.

"The movement of material takes place under a combined influence of waves and currents. This important phenomenon is a process not well understood. Detailed knowledge of this phenomenon is required in order to be able to predict transports in magnitude and direction varying with the time, especially in the vicinity of shipping channels which have to be dredged and maintained. In this case an overall knowledge of the resultant littoral drift which is obtained from a study of case histories of changes of the coastline is not sufficient.

"In this respect the development of the coastal profile which has a very important influence on possible erosion or accretion of the coast has to be studied. Also the development, maintenance and nourishment of artifical beaches, partly to protect coasts, partly to serve recreation resources has to be mentioned here.

"Changes in relative levels between sea and land which are of equal importance are those that result from tectonic movement associated with earthquakes, isostatic changes, and extraction of oil and gas. These phenomena have agreat bearing with respect to engineering projects.

"It is suggested that studies of the above mentioned phenomena, as typical examples of the need of engineers, areincorporated in the program of the proposed decade.

"It should be stressed that it is scientifically impossible to distinguish sharply between "coastal engineering" and "near-shore oceanography", since the underlying hydrodynamic principles are the same."

D. Sea Bed Conditions

"There is a growing interest in the utilization of the sea bed. In the near future for technological reasons the interest will have to concentrate on less deep water, i.e. the emphasis with respect to sea bed conditions will be on the physiographic continental shelf.

"Because of the ever explanding need of all countries for raw material, such as sand, and the need for data required for economical designs, sea bed investigations should be stimulated to facilitate future utilization in this area.

"Some important uses of or operations on the sea bed are:

"1. Mineral resources (sand, gravel, phosphorites, etc.).
"2. Pipe laying, dredging and trenching operations.
"3. Design and construction of foundations of offshore structures.

"In order to obtain adequate information regarding the above items, the following will be required:

"1. Sounding and scanning the sea bottom in continuous profile to obtain sufficient details of the sea bottom topography; for instance, for pipe layout and installation.

"2. Strata-profiling to give information of stratigraphic variations.

"3. Drilling and sampling at properly spaced grid points with the determination (in situ or laboratory) of important soil/rock properties such as:

"(a) quantitative mineral content
(b) grain size distribution
(c) density
(d) plasticity and liquid limits as used in soil mechanics
(e) shear and breaking strengths, as used in soil mechanics
(f) thixotropy, for use in the design of foundations, including anchors, subject to repetitive loading

"4 Recording of sea bed motions resulting from earthquakes."

4. Ground truth experiments are necessary to calibrate satellite sensors and to correlate their data with actual conditions at the appropriate points near the earth's surface. All of the measurements desired by coastal zone researchers cannot be made from satellite-borne sensors. A few suggestions have been made in the preceeding sections of this report about some of the measurements which could be made near the earth's surface and from orbital altitudes. These suggestions are made with the goal of obtaining data to aid in the solution of our most pressing problems of the coastal zone.

5. In December 1968 the General Assembly of the United Nations adopted resolution 2467 which included the initial statements of the Inter-governmental Oceanographic Commission (IOC) to outline its program. Emphasis was placed on coordinated national and international long term studies of world-wide exploration of the oceans and their resources, specifically mentioning the International Decade of Ocean Exploration as an important part of this effort. the IOC report (23) discusses the scientific content of such a program, with detail comments on problems of ocean-atmosphere interaction, ocean circulation variability and tsunamis, with additional comments on living resources pollution, and an inte-

grated global ocean station system. Numerous study areas and projects are outlined in this presentation.

The most promising aspect of the IOC report that relates to the ERTS program concerns obtaining synoptic oceanographic and meteorological observations, e.g. in World Weather Watch, Global Atmospheric Research Program, and Integrated Global Ocean Station System. National application of ERTS sensory data is also feasible for investigators involved in various regional studies, such as with the International Commission for the North-West Atlantic Fisheries (ICNAF) and in planned investigations of the Caribbean Sea, Antarctic waters, the Mediterranean, etc. Greater application of the ERTS program to the oceanographic needs of national and international scope could be attained by involvement in certain aspects in many of these programs.

6. One of the most comprehensive reports (6) regarding global oceanic research was prepared at Ponza in 1969 by the Advisory Committee on Marine Research of the Food and Agricultural Organization (ACMRR), the Scientific Committee on Oceanic Research (SCOR), and the World Meteorlogical Organization (WMO). This group identified conspicuous problems of interdisciplinary and international scope, concentrating on four major groups:

1. Ocean circulation and ocean-atmosphere interactions
2. Marine biological production
3. Marine pollution
4. Dynamics of the ocean floor

Each of these groups is discussed in detail with specific tasks suggested. Reference to this "Ponza" report has been made several times in this paper. It is the opinion of this committee that the Ponza Report and the IOC outline (23) offer the most complete overviews of the present and future needs of the global oceanographic community. These reports should be considered in more detail by NASA representatives for a more comprehensive review of international presentation. The reports formulated by the Commission on Marine Science Engineering, and

Resources (1, 2, 3, 4) provide an excellent coverage of the basic tenets of a national effort in marine science.

7. It is recommended that communications be established between NASA and the NSF Director of the International Decade of Oceanographic Exploration to discuss cooperative efforts between the two agencies concerning ERTS and IDOE. There would be obvious problems in such an effort regarding the selection of proposals of mutual applicability and priority rank between the two agencies. Guidelines on funding, administrative details, and the degree of emphasis on national and international efforts may also be areas of mutual concern and possible conflict. However, there would be numerous areas of global and national significance, within the confines of the IDOE program, where ERTS would provide a valuable contribution.

Once the role of ERTS can be established in the IDOE program, NASA should alert the scientific community of the goals of IDOE and the possibility of ERTS related proposals. To whom, and in what sequence, these proposals would be submitted and evaluated would have to be resolved at an early date.

8. Another major problem transends the boundaries of the different disciplines represented in this report. Although each scientific community is enmeshed in its own particular endeavors, a basic need exists for the entire program of coastal zone research. A system for coastal zone management is imperative. A management program is essential for the coordination of numerous programs and interests. These include: economic and urban development, conservation, recreation, pollution, commercial fishing and shipping, dredging, offshore oil and mineral production, and shoreline development. A review of these different topics in regard to management recommendations and needs have been prepared by the Commission on Marine Science, Engineering and Resources (1) and the National Estuary Study (17)

" We are fortunate that man, in his haste to explore the universe, has taken time to look back at the planet which has succoured him for so many centuries." (66).

(Langley Task Order)

APPENDIX

EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS) E&F:
A CONCEPTUAL STUDY AND REQUIREMENTS DEFINITION
FOR AN OCEANOGRAPHIC SATELLITE

1.C Introduction

The ERTS E&F electronic data-return satellites, which are intended to follow ERTS A&B will give first priority to the needs of the oceanographic community and, within this constraint, satisfy other Earth observations objectives. NASA's Langley Research Center has been requested by the Agency to conduct early investigations of the oceanographic needs and experimental objectives and requirements. In responding to the request, the Center has opted to ask members of the oceanographic community to participate in the study effort.

2.0 General Guidelines and Constraints

2.1 Specific Oceanographic Considerations

Foreseeable differences in the scope and requirements of oceanographic research objectives have prompted a categorization of these objectives into two broad classes - those associated with open ocean or global coverage and those related to coastal zone investigations. The effort required in this study will emphasize the needs of coastal zone oceanography. This will include, mainly, investigations of the events to the edge of continental shelves, extended where desirable to include important coastally-influenced phenomena, and inland to the points of tidal influence (in bays, estuaries, and rivers).

2.2 A Guideline of National Priorities

The needs of the oceanographic community in coastal zone oceanography are many, and vary according to particular branches of study or applications. Because of this diversification, difficulties may naturally arise in establishing, within the Community, the relative importance of the various needs. It becomes necessary and desirable therefore in considering space-oriented experiments, to maintain national needs and national priorities as the primary guideline in assigning experimental priorities. Accordingly, the following oceanographic priorities will serve as that guideline for this study:

1. Pollution
2. Fisheries ("Food from the Sea" Program)
3. Hazards to shipping and coastlines
4. Coastal geography and cartography
5. Scientific and cultural research not related to the above categories.

The focus on national priorities is established to guarantee that the experimental objectives of coastal zone oceanography defined in this study will be problem-oriented, cohesive, and relevant.

3.0 Objectives

The broad objectives of this study are:

(1) To relate the experimental needs of the oceanographic community to national needs and national priorities

(2) To define the breadth of experimentation in coastal zone oceanography which may require the use of a space platform.

(3) To help establish experimental priorities which will help NASA in the selection and grouping of experiments for ERTS E&F.

4.0 Tasks

1. Establish the needs of the oceanographic community in the coastal zones. Each need shall be identified with one or more of the "priorities".

2. Identify and justify experimental objectives or phenomena to be observed to satisfy the needs established in (1).

3. Establish the "ground truth" experimental requirements (surface, subsurface, or land-based) to satisfy the objectives or observations of (2). These should include specific measurements, frequency of measurements, spectral resolutions if applicable, time of day, season, geographic resolution, etc.

4. Describe and establish the requirements for a useful "ground" experiment in coastal zone oceanography that might be conducted in conjunction with the ERTS A space experiment. Specify requirements for space data and number of remote "ground" stations. (A brief description of

the ERTS A payload is attached.)

5. How might ERTS A&B and ERTS E&F best be coordinated through the International Oceanographic Decade?

5.0 Study Period

The study is envisioned as a 2000 man-hour effort. A final report will be required by September 15, 1970.

A STUDY OF THE UTILIZATION OF THE EARTH RESOURCES TECHNOLOGY SATELLITES IN THE COASTAL ZONE OCEANOGRAPHIC INVESTIGATIONS

I. INTRODUCTION

The planned launch of the first Earth Resources Technology Satellites invites conjecture as to their application to the oceanographic community. The payload of ERTS A. scheduled for launch in 1972, is designed for land resources. Previous measurements of electromagnetic radiations and reflections and other physical parameters of the sea surface from both air and space craft have already established the broad avenues of possible utilization of remote sensing devices. The need for the further development of more sophisticated instrumentation seems justified in future space platforms. The use of remote sensory devices is especially applicable in problems of coastal zone ocenography. Synoptic sensing from orbital units may offer solutions to problems in a global and regional scale not normally attainable using present ground based techniques because of space and time limitations. Before maximum benefits can be obtained from the data collected by space craft sensors, an appraisal of current and projected oceanographic problems is necessary.

A committee from the School of Sciences at Old Dominion University submits this proposal to determine and investigate the major problems, or needs, of the research community concerning oceanographic coastal zones. Emphasis would be placed on the entire coastal area under the influence of the oceans, which would extend from the continental coastline to the margin of the continental shelf. This area would include estuaries, salt marshes, bogs, or other shore areas that would have a definite relationship to the coastal oceanographic environment. An additional goal of this committee would be to make recommendations concerning the application of the Earth Resources Satellite sensory data to the solution of the specific problems that concern coastal zone oceanography. The methods for accomplishing these ends are subsequently outlined below.

II. PLANNED APPROACH

1. A multidisciplinary study committee would be organized of individuals who have a particular expertise in oceanography or subject areas of oceanographic significance. This committee will be augmented by the participation of consultants, for short time periods, who may contribute to the input of specific tasks that are established by the committee. The committee would function during a three month period that would begin on June 1, 1970.

2. Committee participation will initially enter a phase of investigating problems of coastal zone oceanography pertinent to specific disciplines. This action will develop from sub-groups of the original committee and will entail both library research and study. Specific problems and needs will be identified in each discipline. Emphasis will be placed on problems of practical application, e.g. pollution, food production, transportation, hazards, shore line alterations, etc.

3. The second phase of involvement will consist of a period of interdisciplinary exchange and interaction between different sub-groups and the entire committee. From this discourse will develop a refined list of specific discipline and inter-discipline problems for each sub-group.

4. The entire committee will then evaluate the recommendations from each sub-group. The significance of these specific problems will be evaluated in regard to the scope of the project and a list of prime problem areas will be established and priorities assigned.

5. Each problem area will then be assessed in regard to the type, amount, and frequency of "ground truth" data required from coastal, or water based sources, to provide significant information.

6. The relationship of suitable "ground truth" investigations and data obtained from ERTS to each problem area will be assessed. Specific requirements for both "ground" and space flight data would be established.

7. The committee will confer with national and international agencies concerned

with the development of the International Oceanographic Decade to establish the best means of coordinating ERTS A&B, and ERTS E&F with the IOD program.

III. EXPECTED RESULTS

The committee report will include an evaluation of the major practical problems concerned with applied coastal zone oceanography. A priority list will be established that will indicate the more critical areas (problems) of concern in coastal oceanography and those that deserve immediate attention for assay and study. Recommendations will be made regarding specific experimental tasks that offer solutions to these problems and will utilize the coordinated effort of ground truth experiments and data from the Earth Resources Technology Satellites. The final report is expected to be completed by September 15, 1970, but not less than three months after the effective date of the task order.

IV. COMMITTEE PERSONNEL

The Study Committee mentioned in this proposal refers to 11 members of the faculty of Old Dominion University, selected to assure broad interdisciplinary coverage in coastal zone oceanography. The time that each member of this committee will contribute will vary in regard to individual prior commitments for other work during the study period.

A four man committee has been formed for planning and coordination. This committee is composed of:

Dr. William J. Hanna, Department of Geophysical Science
Dr. Harold G. Marshall, Department of Biology (Principal Investigator)
Dr. Melvin A. Pittman, Dean, School of Science (Co-investigator)
Dr. J. Frank Slowey, Institute of Oceanography

In addition to the above names, the Study Committee includes the following:

Dr. Ray S. Birdsong, Dept. of Biology
Dr. Thomas A. Gosink, Dept. of Chemistry
Dr. Gerald F. Levy, Dept. of Biology
Dr. Donald J. P. Swift, Institute of Oceanography
Dr. George S. Ofelt, Dept. of Physics
Dr. Gerald L. Shideler, Dept of Geophysical Sciences
Dr. Randall S. Spencer, Dept. of Geophysical Sciences

In addition to the Study Committee listed above, consultants will be utilized during the study period to provide additional input and expertise regarding the overall scope of the project.

(Letter and Questionnaire forwarded to Marine Geologist)

Letter: "A group of faculty from our School of Sciences is preparing a conceptual report on the most urgent requirements for research into the problems of coastal-zone oceanography. We are concerned with the relative importance of problems in all of the disciplines relating to estuaries, shore lines, and continental shelves on a global basis.

"We request your assistance with this report. In order to broaden the outlook of our report, we would be grateful to have from you a list of a few of the most urgent research needs of coastal-zone oceanography. To assist you in giving us your opinions, we enclose a check-off sheet. Please do not let your suggestions be limited by our list of problems and needs.

Additional sheets are enclosed for the use of any of your colleagues who would favor us with their opinion"

Questionnaire:

"OLD DOMINION UNIVERSITY
Coastal-Zone Oceanography
Research Needs Study

"A. Urgent Problems (Please rank in order of importance)

____ Petroleum resources under shelves
____ Metal ore resources on shelves
____ Mineral aggregate resources of shelves
____ Channel silting
____ Beach erosion
____ Shore-line changes by storms
____ Shell-fish resources
____ Estuary pollution
____
____

"B. Data deficiences (Please rank in order of need)

____ Shelf currents
____ Bottom topography
____ Temperature profiles
____ Chemical profiles
____ Species distribution
____ Suspended sediment loads
____
____
____

"C. Instrument Needs. (Please rank in order of need)

____ Current meters
____ Sensitive magnetometers
____
____

OLD DOMINION UNIVERSITY
Coastal-Zone Oceanography
Biological Research Needs

Your area of research ______________________________

Please rank these major study areas in the order which you feel they should be given priority:

_______ coastal geography and cartography
_______ fisheries
_______ hazards to shipping and coastline
_______ pollution
_______ other (specify) ______________________

The following example is given as a guide. Please list the problems in order of importance. Note reference is given to both regional and global problems.

Example - Problem: (Regional or Global) Estuarine pollution
Geographical area of greatest concern: Chesapeake Bay
Data deficiencies: Detection of specific pollutants.
Instrument needs: Long term monitoring of pollutants and currents.

....

.. Problem: (Regional or Global) ______________________________
Geographical area of greatest concern: ______________________________
Data deficiencies:

Instrument needs:

Comments:

....

2. Problem: (Regional or Global) ______________________________
Geographical area of greatest concern ______________________________
Data deficiences:

Instrument needs:

Comments:

....

3. Problem: (Regional or Global) ______________________________
Geographical area of greatest concern ______________________________
Data deficiences:

Instrument needs:

Comments

....

Name ______________________________
(Optional)

June 26, 1970

Dear Colleague:

An interdisciplinary committee from our School of Sciences has been asked to prepare a report defining the most pressing problems in coastal-zone oceanography. We are concerned with the relative importance of problems in all of the disciplines relating to estuaries, shorelines and continental shelves. The scope of this study is world wide.

In order to broaden the outlook of our report we would greatly appreciate your suggestions. To assist you we have enclosed a form. Please do not let our examples limit your suggestions. Please pass along the additional sheets to any of your colleagues who may be interested in contributing their opinion.

Due to the time limitations upon us, we would be grateful for the prompt return of your commemts.

Sincerely,

Harold G. Marshall Ph.D.
Department of Biology
Old Dominion University
Norfolk, Virginia 23508

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