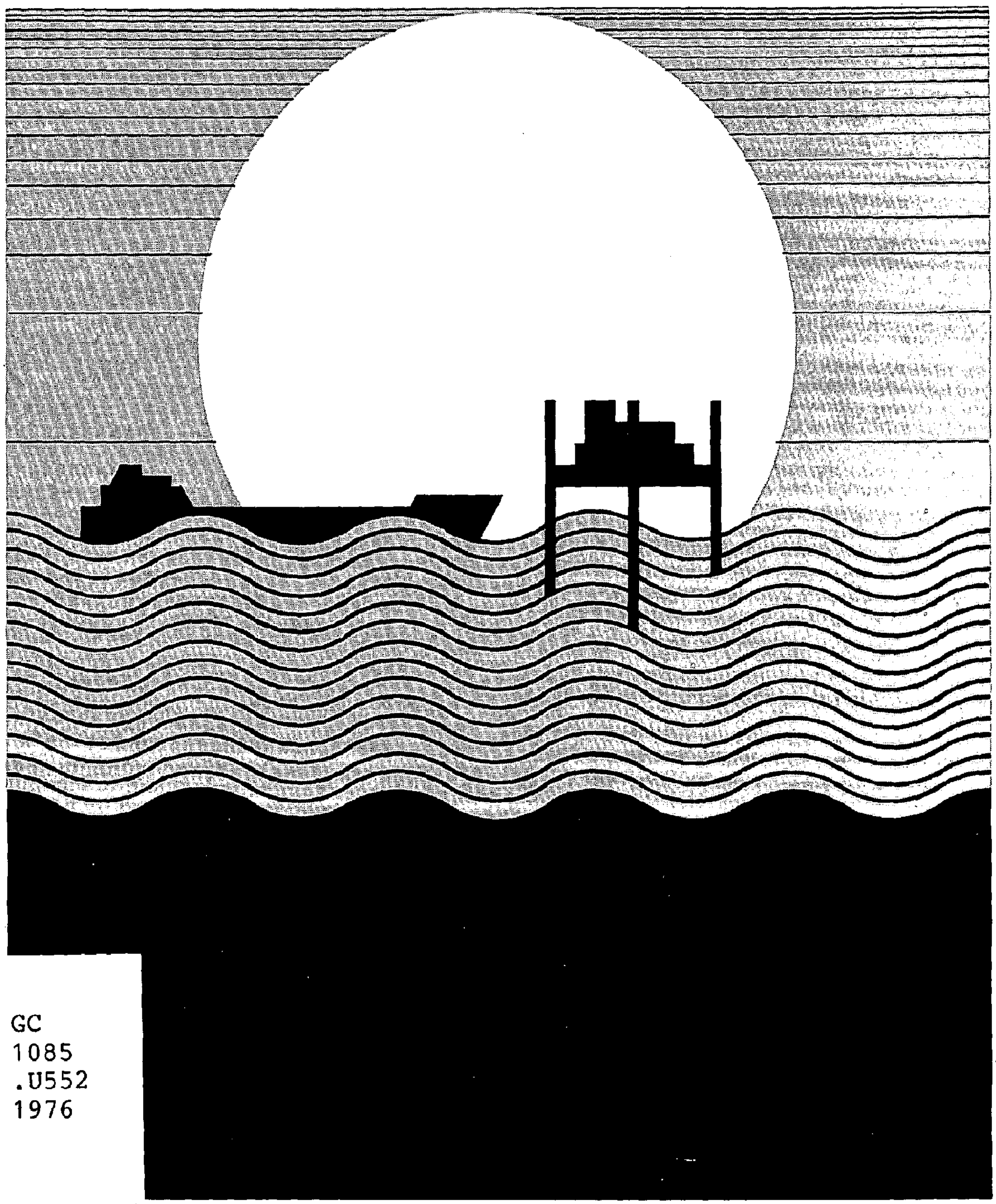
# The Environmental Quality Monitoring Report

## Prepared by the OCS Task Team

February 1976

**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**





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The Environmental Quality Monitoring Report was prepared by the NOAA Outer Continental Shelf Task Team. This Task Team was initiated under the guidance of the Associate Administrator for Environmental Monitoring and Prediction. The Task Team was requested to outline a generic plan for environmental quality monitoring on the OCS. In turn, the outline is to be used in developing broad guidelines for the design and conduct of monitoring programs that could assess the long-term effects of oil and gas resource extraction on the OCS.

This Report illustrates the multifaceted and complex elements which would compose monitoring programs. For instance, different locations will necessitate some specific and some general ecological considerations which in turn will modify the detailed perspectives. Thus, monitoring programs in various areas subject to different stresses may be very different and not necessarily modelled after this generic plan. Yet, the considerations and judgments contained herein should be considered in the design and conduct of any comprehensive Environmental Quality Monitoring and Assessment Program for the OCS.

Edward S. Epstein
Associate Administrator for
Environmental Monitoring and Prediction

# PREFACE

In light of the rapid development of the Bureau of Land Management's Outer Continental Shelf (OCS) Environmental Studies Program, NOAA's Baselines Task Force (Directors of certain Primary Organizational Elements (POEs)) designated a group, the OCS Task Team, under the guidance of the Associate Administrator for Environmental Monitoring and Prediction to outline a generic plan for environmental quality monitoring on the OCS. In their deliberations the Task Team has drawn heavily on the recent report of the NOAA Scientific and Technical Committee for Marine Environmental Assessment. 1/ Additional guidance in technical areas was sought from the activities of ongoing baseline and special studies and the NOAA report, Marine Pollution Monitoring: Strategies for a National Program.2/

The monitoring program is designed to inform users and be reactive to their needs. Users include State and Federal regulatory agencies, surveillance and monitoring teams, and resource inventory interests, such as coastal zone management programs in each State. Interaction with these groups will be necessary in evaluating environmental effects of exploring and exploiting resources of the Continental Shelf.

Monitoring: Strategies for a National Program.

Monitoring is used herein to denote predetermined, periodic observations obtained in a systematic and standardized manner and initiated after man begins some significant local activity. Studies prior to that time and especially while planning for the activity can be considered baseline or special studies research.

The basic strategy behind the monitoring program described herein begins with identifying critical species, habitats, and processes in the course of the baseline investigations. Concurrently, special research, hereafter called special studies, will yield further understanding of the effects of oil and associated contaminants on various species and increase our knowledge of the role of these species in the entire ecosystem. These studies will yield data in the location of OCS oil operations; on water mass circulation downcurrent from the potential pollutant sources; on living natural resources in jeopardy from possible oil contamination; and regarding the tolerance of these species to oil and associated trace metal concentrations.

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1/ Report of the Scientific and Technical Committee on Marine Environmental Assessment, Department of Commerce, NOAA, November 1974.

2/ Marine Pollution Monitoring: Strategies for a National Program, E. D. Goldberg, Department of Commerce, NOAA, October 1972.

From this information a calculation will be made of the acceptable limits of oil and trace metal release at these sources that will not endanger downcurrent populations.

To insure that these limits are not violated the monitoring will be designed to sample at such places as the source locations and in the areas of the potentially impacted populations. Pollutant sources requiring monitoring include oil rigs, pipelines, natural seeps, ships, refineries, and ports. If concentrations exceed the parameters, the appropriate regulatory agencies will be notified. On the other hand, if monitoring detects adverse effects at concentrations lower than the initially specified limits that were determined through laboratory studies, the acceptable limits will be revised downward.

The detailed monitoring plan for a given area will therefore flow from the baseline and special studies which will suggest and define the type, location, and frequency of samples and the specific analyses required to protect the surrounding environment.

The body of this report is written in a modified version of a format called Sequential Thematic Organization of Publications (STOP developed by Hughes Aircraft Company). STOP organizes subject matter into a series of relatively brief themes, each represented in a module of up to two facing pages introduced by a thesis sentence set in different type.

TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## EXECUTIVE SUMMARY

The introduction of pollutants into the marine environment, a result of man's activities, may have severe effects on the Outer Continental Shelf environment. In some areas these contaminants may be hazardous to health through ingestion of seafood products. Potential losses and restricted uses of certain living marine resources suggest economic hardship to portions of the fishing industry. Also, recreational areas may be lost as a result of contamination by high concentrations of pollutants.

The Outer Continental Shelf Task Team proposes a monitoring program combined with the necessary R&D and special studies to provide the data to properly assess and monitor the effects of man's activities on the environmental quality of the OCS. The program is proposed to follow two broad, continuous, and parallel streams of action. One will involve the integration and coordination of existing facilities and plans. The other will identify activities that require further development and planning.

Specifically, the OCS Task Team recommends the following:

1. Adoption of an observational system for the monitoring program including biological, chemical, geological, and physical oceanographic and meteorological elements.

Observational elements (Table 1) for the monitoring systems have been ranked according to a group of predetermined criteria. These criteria include relevance to an assessment program, feasibility of obtaining such data in a realistic time frame, utility in a leasing-regulatory program, and the affordability of obtaining such data.

2. Use available technology and facilities in the near-term (2-5 yr) to provide immediate information.

Research ships and their observational systems offer the most promise for obtaining immediate environmental information in the near-term time period. Associated technical personnel should be drawn largely from the preceding baseline effort. A portable system for performing sophisticated measurements in near-shore areas in times of accidental discharge of pollutants should be developed.

3. Develop remote, automated monitoring systems for use in the mid-term (5-10 yr) and future (10+ yr).

Midterm and future monitoring technology will not be available without a carefully conceived and directed R&D activity. An evolving technology is envisaged in the midterm and future, stressing increased reliance on buoys and remote data collection platforms. These systems offer a more cost-effective means of increasing areal coverage while decreasing reliance on the manned research ship. Through the increasing use of remote, unmanned platforms the total personnel commitment to the monitoring program in terms of both actual numbers and professional expertise, will be reduced with time.

4. Establish immediately a NOAA monitoring function.

The impending requirements for monitoring and the necessary R&D suggest the immediate establishment of this function. Eventually, management of a marine environmental assessment program should integrate the ongoing baseline effort with the proposed monitoring program.

5. Establish independent quality assurance procedures.

Central to the entire monitoring effort is a rigorous evaluation of the quality of collected data. The quality assurance program will include standard sampling protocols, laboratory quality control, standard reference materials, sensor and instrument calibration, and data management standards.

This report defines general requirements for environmental quality monitoring including strategies, certain general methodologies, management coordination within the program as well as with other programs, necessary research and development, and required resources. No attempt has been made to thoroughly specify observational and analytical techniques required to implement the program. This task can be accomplished effectively only after considering the results of the baseline studies. In addition, certain types of research, hereafter called special studies, will be required to determine effects, determine resulting processes, etc. The baseline studies, special studies, and monitoring program compose the total marine environmental assessment program.

For the purposes of this report, the areal bounds for monitoring extend from approximately mean high water on the coast, tidal waters of estuaries, across the Continental Shelf, and over the adjacent Continental slope where pollutant transport is likely.

Although it is recognized that secondary impacts of offshore operations on the coastal zone may be serious, they are not addressed directly in this document. There is already such recognition by the Coastal States and various Federal agencies of the precarious state of the coastline that we feel that most of the necessary studies are already underway or planned. Where such studies become baselines, they should be continued as monitoring.

## MONITORING OBJECTIVES

To minimize disturbance of the marine environment during development of OCS oil and gas resources, the Bureau of Land Management has initiated an OCS environmental studies program for affected OCS areas. By providing necessary ecological data and information, this program will be a framework for sound management decisions related to OCS minerals development.

The initial phases of the environmental studies program are to assemble present knowledge of the environment in OCS leasing areas and establish baseline descriptions. Subsequent special studies and continuing monitoring will augment the understanding of cause and effect relationships and detect changes in the environment, whether man induced or naturally occurring, to assure that contaminant levels do not exceed those determined to be acceptable.

An adequate monitoring program for OCS marine environmental assessment must achieve the following objectives:

1. Development of capability for assessing and predicting trends in environmental quality and the effects on ecosystems due to oil and gas exploration and development in OCS areas.

   Baseline programs of 2-5 years' duration are not likely to allow an assessment or prediction of long-term or low-level effects of pollutants on the marine ecosystem. Only through a time series longer than 2-5 years, i.e., through an ongoing monitoring effort and organism and ecosystems studies, can an understanding of the response of the marine ecosystem to man induced and natural changes be achieved. Program elements may be added, subtracted, or changed as understanding improves.

2. The capability for implementing measurement, assessment, and information systems at the time of an emergency.

   During the course of the development of the Outer Continental Shelf a capability must be available for dealing with emergencies. The information acquired in response to these events offers potential for evaluating the acute (and perhaps chronic) effects of pollutants on the marine environment.

3. The capability for monitoring at major spill areas to assess long-term impact.

The immediate effects of relatively high concentrations of petroleum hydrocarbons will be revealed by the emergency response system. In addition, rates of natural recovery and effects of remedial activities must be assessed. These long-term effects can be assessed only by specialized monitoring or special studies in the affected regions.

4. Provide information to regulatory programs.

Pollutant monitoring data will signal when acceptable levels of pollutants have been exceeded.

To accomplish these objectives, the task team has developed the environmental quality monitoring program described in the following sections. This program addresses not only required observational elements but also supporting platforms, quality assurance, research and development, and data management requirements. The suite of platforms utilized over the course of the monitoring program will shift eventually from the research ship as the initial, primary platform type to remote, unmanned data collection platforms. Personnel requirements are all too often overlooked or underemphasized in marine environmental assessment programs. The present program proposes early, rigorous attention to these essential components in order to insure the quality and continuity of the data.

The development and availability of improved observational methodologies through a well-conceived research and development program is pivotal to the present proposal. The ultimate system, requiring the fewest professionals possible and providing the broadest areal coverage, can be obtained only with new and improved observational and analytical tools.

# THE OBSERVATIONAL SYSTEM

## *Concepts and Criteria*

*The success of this monitoring program will be determined by the ability to focus one's finite resources on a well thought out observational program. Priorities have been established among certain marine environmental assessment elements according to a suite of predetermined criteria.*

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The generalized information requirements accompanying development of oil and gas reserves on the Outer Continental Shelf have been identified in the Report of the NOAA Scientific and Technical Committee for Marine Environmental Assessment. [3/] Taking those recommendations into account and considering ongoing baseline activities, observational elements (Table 1) for the monitoring program have been ranked according to the following criteria:

> Relevance: Are the information and data relevant to an assessment of environmental conditions and effects on ecosystems of the OCS? Is the information useful in determining the trajectories and fate of a given pollutant?
>
> Feasibility: What is the likelihood of obtaining meaningful data during development of the mineral resource? Will the data be useful in leasing and regulatory programs?
>
> Affordability: Is the information obtainable in a monitoring mode in a cost-effective manner? How meaningful are the observational elements in monitoring actual levels or a buildup of pollutants in the marine environment?

Concomitantly, a realistic 2-5 yr baseline assessment program alone would not:

- Provide a basic understanding of how natural environmental factors affect the marine ecosystem or distinguish man induced chronic effects with assurance.

- Provide a definitive understanding of chronic effects of pollutants on critical life processes or marine organisms or completely quantify the complex food webs through which contaminants may pass and the means by which some may be concentrated.

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3/ NOAA, op. cit.

## Table 1 — Observational Elements

| | Primary | Secondary | Tertiary |
|---|---|---|---|
| Biology | • Benthos<br>• Macroalgae and Sea Grass<br>• Under Ice Biota<br>• Zooplankton and Ichthyoplankton<br>• Intertidal Coast | • Pelagic and Demersal Fish<br>• Phytoplankton and Microbes<br>• Birds & Mammals | None |
| Chemistry | • Petroleum Hydro-carbons<br>• Trace Elements<br>• Suspended Particulate Matter | • Nutrients | None |
| Geology | None | None | • Bathymetry<br>• Shallow/Deep Structure |
| Physical Ocean./ Meteorology | • Optical Properties<br>• Continuous meteorological data<br>• Aerial monitoring: Temperature, water mass, sea state and oil slicks<br>• Temperature and Salinity Profiles<br>• Sea Ice | • Tide measurements<br>• Currents & Circulation | None |
| Special Studies | • Biology of Bioassay Organisms<br>• Responses of Organisms to Contaminants<br>• Controlled Experiments in Ecosystems | None | None |

## THE OBSERVATIONAL SYSTEM/BIOLOGY

### *General Considerations*

*The biological monitoring program dictates that contaminant changes in tissues of organisms be assessed and that changes in population be determined.*

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The marine ecosystem and its constituent organims are a primary concern in any pollution monitoring program. Two aspects must be considered: (1) the presence and buildup of certain contaminants in key organisms 4/ and the environment, and (2) the effect of chronic and acute contaminant concentrations on population changes. The first aspect (although expensive and time consuming) relies on relatively straightforward analytical techniques; the second depends upon a detailed and accurate knowledge of what constitutes "normal" perturbations in population densities, distributions, and trophic relationships of key species and an understanding of the causes of the observed physiological and ecological responses. This knowledge does not exist in most cases and will not be supplied by baseline studies of 2-5 years' duration. Changes in densities, distributions, and relationships occur with overlapping cyclic frequencies of seasons, years, quarters of centuries, and longer. Superimposed upon these cyclic events are apparently stochastic events whose origin lies in the nondeterministic nature of many biological phenomena. These phenomena are sometimes affected by meteorological and climatological forcing, which also combines cyclic and stochastic phenomena and may be due to causes far outside the area under observation. To comprehend the causal relationships between chronic or acute concentrations of contaminants in the environment and observed changes in ecosystem or population characteristics will require extensive laboratory and field experimentation coordinated with measurements in the monitoring program.

The apparently insoluble question of what is "natural" and what is "unnatural" may tempt one to react without careful consideration and devise a hasty response. One strategy is to monitor what is believed to be key relationships and indicator species whose changes may signal impending problems. However, the record in this regard is not good. Knowledge usually has been insufficient to predict disaster; and early warning signs, even when observed, have been ignored. Indeed, most biological catastrophes have been near step functions, without a discernible gradual buildup. To test our predictive abilities it is essential

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4/ Goldberg, op. cit.

to conduct separate hindcasting exercies on unanticipated ecological accidents, using available models and data sets acquired prior to the accident.

Absolute priorities for monitoring various taxa and trophic levels cannot be assigned with assurance. On the basis of the objectives previously listed elements of the biological observational scheme were developed (Table 2).

**Table 2 — Biological Observational Elements**

| Primary | Secondary | Tertiary |
|---|---|---|
| • Pelagic and Demersal Fish | • Phytoplankton and Microbes | • None |
| • Benthos | • Birds & Mammals | |
| • Macro algae & Sea Grass | | |
| • Under Ice Biota | | |
| • Zooplankton and Ichthyoplankton | | |
| • Intertidal Coast | | |

## *Zooplankton and Ichthyoplankton*

*Among the plankton constituents to be measured, zooplankton and ichthyoplankton are ideal for a monitoring program due to sensitivity of the larvae to environmental changes and the close link between larval survival and population size.*

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Zooplankton and ichthyoplankton form a critical energetic link between phytoplankton and the larger animal species of the nekton and benthos. Besides providing a "rain" of organic material to the sea sediments, temporary plankters, including eggs, larvae and juveniles of benthic and nektonic forms afford constant replenishment and movement of individuals to many marine habitats.

Comparative historical data of at least several seasons' duration must be available in order to assess the effects of oil on the composition of plankton in any particular OCS area under development. The intrinsic variability of a zooplankton and ichthyoplankton community is determined by a large number of biotic and abiotic variables, some of which are breeding cycles, dormant periods, patchiness, diel migrations, temperature, and salinity.

### Sampling

Zooplankton and ichthyoplankton will be collected by plastic or aluminum bongo-style nets with calibrated flowmeters at least quarterly. Oblique tows to 200 m or the bottom, whichever is less, will be made across wind and for a distance of at least 1 km. An aliquot should be removed for species identification from the sample, and the remainder freeze dried.

### Analysis

At the organism/species level, preserved aliquots may be rough sorted for zooplankton. Ichthyoplankton should be identified at least to genus, and the most abundant to species. Zooplankton and ichthyoplankton population analysis should include:

- Biomass estimates by measurement of ash-free dry weight of freeze dried samples.

- Analysis of the contaminant body burden
- Secondary productivity estimates via the species level assessment.

## THE OBSERVATIONAL SYSTEM/BIOLOGY

### *Benthos*

*Benthic organisms are frequently sensitive indicators of environmental stress and are relatively easily sampled. Their populations are stable and readily locatable during repeated visits. Since many benthic organisms are filter and detritus feeders, they tend to accumulate and retain contaminants from the water. Benthic populations help support demersal fish, and therefore measurement of these populations is vital to understanding the changes in the fish stocks.*

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### Sampling

Assessment at the population level will include monitoring benthic infauna of sizes down to 5 mm and crustacean epifauna. The latter are particularly important ecosystem components in high latitudes and continental slopes. Rough sorting for smaller organisms and sorting out larger species, particularly shellfish, would precede preservation and storage. Species parameters to be monitored include composition, abundance, distribution, reproduction, mortality, and age class structure where appropriate.

Quarterly monitoring surveys can follow NOAA's Marine Resources Monitoring, Assessment, and Prediction [5/] (MARMAP) sampling design where appropriate. A nested sampling design should be considered in order to provide statistically useful data with respect to the nonrandomly aggregated faunal distributions, bottom topography, water depth, sediment type, currents, and well platform location. Benthic biomes are generally considered more stable than pelagic biomes in regard to biomass movement and turnover, and one would be tempted therefore to suggested very infrequent sampling. However, the concept of low-turnover applies primarily to the macrofauna such as large mollusks. The smaller fauna have high turnover rates, and their populations could respond rapidly to physical disturbances of the substrate or accumulation of petroleum residues. Moreover, many of the larger fauna are filter feeders and would be exposed to contaminants in the water. Finally, the setting of larval annelids and molluscs depends upon the presence of suitable substrate which is detected chemically. Hydrocarbon contamination could

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5/ MARMAP activities are underway in all OCS areas except the Gulf of Alaska, Chukchi, Bering, and Beaufort Seas. Some expansion of the present program will be necessary.

interfere with setting. The first indication of unsuccessful setting might not show up for several years until the smallest organisms, that normally would be caught commercially, did not appear. Therefore, the sampling design should include a technique for testing setting success, such as test panels or microscopic examination of selected sediment samples.

Benthic fauna populations are relatively immobile. "Control" areas that are similar to areas that may be affected by spills should be designated and inspected simultaneously with affected areas. The criteria for similarity should include quantity and quality of benthic biomass, sediment type, depth, influence by currents, etc. Control areas should be upstream of the potential pollutant sources. The most likely locations for control and test sites are on isobaths aligned with prevailing long-shore currents. The size of a site should not be less than 1 square km. Subsampling could be at specific, identifiable locations within each site.

Analysis

Population level analyses will require an effort equivalent to annual MARMAP cruises. Setting success analyses could be regarded as special studies or, if sediment analyses were used, they could be conducted on cruises that occurred at the proper times.

Selected specimens from the population level assessment, representing age classes or size, geographic distribution, rough-sorted taxonomic categories, and species, will be obtained for estimates of diseased organisms, breeding condition, and body burden of contaminants.

Organism level assessment requirements are identical to those for fish (described in a later section).

## *Macroalgae and Sea Grasses*

*Besides supporting immense populations of ducks and geese, sea grass and macroalgae beds stablilize coastal sediments and shorelines, provide habitat and food for estuarine species including migrating anadromous fish, and are a major part of the coastal detritus ecosystem. Sea grass and macroalgae appear particularly susceptible to chronic petroleum pollution. Consideration of these forms is of first-order importance in the OCS monitoring program.*

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Macroscopic algae (seaweeds) are of special importance in cold coastal waters. On the west coast of North America they form extensive beds of vegetation attached to the bottom. These beds damp wave action, decreasing beach erosion and long-shore transport, and support marine detritus ecosystem. Sea grasses, including Zostera, Thalassia, and Posidonia, are distributed worldwide in shallow marine waters. The effect of oil spills and consequent remedial actions have been studied on intertidal forms, but much less effort has been expended upon their subtidal attached counterparts.

### Sampling

The assessment would be at the population and organism level. These communities are complex, however, and require sampling of a variety of biotic components, not just the algae or the grasses themselves. In fact, it is important that control and test sites be established and that they be used for special studies within the monitoring program. Species parameters to be sampled annually include composition, abundance, distribution, reproduction, mortality, productivity, and pathology.

### Analysis

Both types of biomes, macroalgae and sea grass, can be reached by small boats, and field work may involve wading or scuba. Logisitic support should be relatively simple and inexpensive.

Selected specimens, representing trophic levels and geographic distribution, would be obtained for organism level estimates of diseased organisms and body burden of contaminants.

Changes in areal extent of algae and grasses can be observed by satellite or high flight, using multispectral imagery. Since change should be slow, there should be little problem in choosing suitable frames. Some computer processing will probably be necessary to enhance the plant features. Satellite imagery may also be used to determine the extent to which algae and grass beds are threatened by oil spills.

Selected sampling sites should be identified and examined annually. Sampling designs and special studies for seagrasses should be modeled after and tied closely to the Seagrass Ecosystem Program supported by the National Science Foundation. Sampling designs and special studies for macroalgae should be based on the kelp bed studies undertaken by California Institute of Technology.

## *Under-Ice Biota*

*Several regions potentially affected by OCS oil and gas exploration and development lie within or close to the Arctic Circle. Extensive ice sheets of long annual duration cover many of these regions, particularly in the Bering, Beaufort, and Chukchi Seas. Seasonal ice cover provides nutrients, organic matter, and substrate to browser and grazer invertebrates under ice, in ice fronts, and in leads.*

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The under-ice biota are important in providing organic matter to the water column and benthos, particularly during break-up and recession of the ice cover. Oil and gas development in arctic areas will very likely have significant effect on this high-latitude biome.

### Sampling

The assessment of under-ice forms would be at the population and organism level.

The population level assessment would consist of seasonal collections at a minimum of 10 sites representing ice fronts and leads and polynas where the ice thickness is over 1 metre and at randomly selected sites of ice less than 1 metre thick. Particular attention would be given to invertebrates living on the underside of ice and on the sea floor directly beneath each sampling site.

Sampling under sea ice is not very advanced technically. Benthic sampling has been done through holes but has been limited to small dredge collections. Few attempts have been made to use a moving ice floe or sheet as a vessel for dragging anchor dredges. Collections on the underside of ice by scuba involve personal risk due to low temperature, ice movement, and route-finding problems. It is hoped that the NSF program for Processes and Resources of the Bering Sea Shelf (PROBES) will provide methodological advances useful in monitoring. A proposed strategy for sampling is mentioned above, but a statistically valid and technically feasible approach must be developed to ascertain trends or changes. Determining an adequate sample size may be the first problem.

The PROBES program may provide the basic monitoring data in the Bering Sea, and the approach and methodology perhaps could be extended to the Beaufort Sea, Chukchi Sea, and northeastern Gulf of Alaska.

Analysis

Under-ice fauna are mainly derived from the benthic fauna. Taxonomic problems will likely be similar for both in a given area. Statistical analysis of distribution and abundance data of under-ice fauna will be much more difficult because of the sampling problems. Also there may be problems in obtaining adequate samples for the organism-level assessment.

Parameters to be monitored include species abundance, distribution, composition, pathology, reproductive biology, and size-frequency distributions.

Selected specimens from the population level assessment would be obtained for organism level estimates of diseased organisms and body burden of contaminants.

## THE OBSERVATIONAL SYSTEM/BIOLOGY

### Pelagic and Demersal Fish

*Many fish are at the top of their food webs and tend to concentrate various contaminants in their flesh, especially since the individuals are relatively long lived. Species farther down food chains often are oily and therefore concentrate contaminants to a significant degree, even though they are relatively short lived. Priority should be placed on monitoring pelagic and demersal fish tissues and populations.*

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Sampling of fish populations is well established. Contaminants in fish tissue will indicate conditions requiring attention and are themselves of serious concern.

Besides acting as early warnings of impending or actual problems, changes in the populations of commercial fish species are of considerable economic interest. The combination of fishing pressure and environmental stress could lead to serious declines in valuable marine resources. A decline in the stock of a desirable commercial species may be accompanied by an increase in a much less desirable species.

#### Sampling

The procedures followed in the MARMAP stock assessment surveys are adequate for estimating gross changes in fish populations over long periods and can also supply specimens for contaminant analysis.

The poulation-level assessment sampling will follow current MARMAP Survey II and III protocols and can be conducted via scheduled MARMAP cruises. Parameters to be measured include species composition, abundance and distribution, reproductive biology, fishing and natural mortality, and age class structure.

Quarterly surveys can follow the MARMAP sampling design. An alternative to regularly spaced stations located on straight cruise tracks should be considered. In this respect a nested sampling design will provide statistically useful data on the nonrandomly aggregated distributions of fish, bottom topography, currents, and well platforms.

#### Analysis

Assessments will be at the poulation and organism levels.

Population-level assessment analyses would require an effort equivalent to quarterly MARMAP cruises. Also, population parameters for abundant (or indicator) noncommercial species should be monitored.

Selected specimens from the population-level assessment representing certain age classes and geographic distributions will be obtained to estimate diseased organisms, stomach contents, condition of gonads, tainting, and body burden of contaminants.

Organism-level analyses will require freezing of selected organisms and organs at sea with subsequent histopathological analyses. Each quarterly survey could yield 1,000 specimens for later subsampling.

## *Phytoplankton and Microbes*

*Algae are at the base of all food pyramids. If there are significant changes in either annual primary productivity or species composition, entire food webs may be disrupted.*

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### Phytoplankton

Phytoplankton, including micro-organisms, will be assessed at the population and organism level. Because these organisms are very abundant and very small, identification and "counting" are time consuming and frequently difficult. Moreover, almost the entire range of plant divisions and animal phyla are represented. Emphasis therefore must be placed on the population level.

Three types of observations will be undertaken: areal measurement of surface chlorophyll by satellite, aircraft, and ships together with appropriate environmental data; seasonal surveys for species assessment; and measurements of physiological parameters at a few stations where the largest populations are normally encountered. Interpretation of even limited point-sampling will be aided appreciably by use of satellite imagery to delimit water mass boundaries.

### Microbes

Levels of petroleum hydrocarbons have been reached in some bays and harbors which can diminish populations of hetertrophic (decomposer) bacteria while increasing those that can metobolize petroleum. A decrease in decomposers could severely affect detritus and remineralization of nutrients.

### Samping and Analysis

Phytoplankton. Chlorophyll concentrations are commonly considered an indicator of phytoplankton biomass. At the population level, biomass abundance and distribution can be measured in three modes whose characteristics and methods of measurement are described below:

- o Broad areal coverage, synoptic, low resolution, low precision, low accuracy, e.g., satellite and aircraft techniques.

- o Reduced areal coverage, semisynoptic, high resolution, high precision, low accuracy, e.g., shipboard fluorescence methods. Fluorescence, calibrated by spectrophotometric measurements, can be measured underway continuously, at one depth, or discretely from pumped or collected samples.

- Poor areal coverage, nonsynoptic, medium resolution, high precision, high accuracy, e.g., pumped, or discretely collected samples examined spectrophotometrically. This technique should be routinely used only for calibration.

Productivity is loosely related to standing stock of organisms. Productivity can be very high even with low standing stocks and very low with high standing stocks. As an alternative to numerous complicated and time-consuming productivity measurements integrated over time, area, and depth, we urge that physiological parameters such as the "assimilation ratio" (gC/g Chl *a*/hour at light saturation) be employed to determine the "health of population."

Species distribution, abundance, and diversity parameters may be calculated from the population data file. Samples should be taken on quarterly, seasonal cruises at a minimum of 25 locations, at 15 metres, representing estuarine, shelf, and slope water (identified by salinity). A subsample should be processed by particle counter while fresh, and another subsample preserved and examined microscopically. Particle counting will estimate microflagellate population, and microscopic counting will provide species data on net-plankton.

*Microbes*. Waterborne microorganisms should be collected in clean, sterile containers. Sediments and water column samples should be filtered to remove particles larger than one micrometre for subsequent analyses for ATP activity.

At the organism and species levels, sediment and water samples should be analyzed for growth of organisms on various substrates. These techniques will allow an estimate of changes in population of decomposer organisms that utilize specific substrates.

## *Birds and Mammals*

*Spills of crude oil affect higher marine vertebrates in readily identifiable ways, and these populations are usually the first to be inspected for damage. Although potentially severely affected by oil birds and mammals are not good early indicators of petroleum pollution and are therefore assigned a secondary priority for the monitoring scheme.*

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Populations of large vertebrates are generally of high trophic level and represent relatively few species in easily defined niches. Population information can be derived from organism level assessments. Parameters to be assessed include extent of colonies, breeding areas, feeding grounds, and distribution and migration routes. Organism-level parameters to be measured include body burden of contaminants, breeding success, morbidity and mortality.

Studies of California sea mammals have suggested extensive synergistic effects between pollution levels and virological symptomology. Furthermore, serological analyses reveal common immune reactions among Alaskan and Californian pinnipeds and land mammals. The importance of pathological monitoring is thus beginning to be appreciated.

If baseline data do not describe the seasonal surface ocean currents between the lease areas, pupping and hauling-out areas, a special study will be needed. Such data would be critical in determining the type of emergency procedures required in the event of spills.

### Sampling and Analysis

Bird populations are estimated most easily during breeding periods. Aerial photographic surveys should be used for "counting" with ground-level estimate of breeding success. Selected samples of adults and young should be taken for contaminant analysis and pathology.

Marine mammal populations except for sea otter may be assessed by a combination of high and low altitude aerial photography. Sea otters probably must be estimated by shipboard observers. Samples and beached animals should be taken for contaminant analysis, pathology and blood samples. Techniques developed for the Arctic Ice Dynamics Joint Experiment (AIDJEX) may be utilized for aerial surveillance.

Birds and mammals are particularly vulnerable to oil spills. Except in ice, mammals are probably able to avoid oil or clean themselves. A spill in ice or near a rookery should instigate immediate surveillance to determine the extent of the spill and the effect on young and female mammals.

## *Intertidal Coast*

*The types of intertidal coastline likely to be affected by oil spills, nearshore chronic leaks, and other pollutants from oil and gas activity are rocky intertidal, sandy beaches, mud flats, salt marshes, and shallow estuaries.*

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Assessment appropriate for shallow estuaries has been considered under "Macroalgae and Seagrasses". Rocky intertidal areas appear to recover rapidly from spills, although associated organisms such as seals and sea lions may be particularly vulnerable. Sand beaches and mud flats tend to accumulate tarry residues which may persist for years after burial. Salt marshes are particularly susceptible, since the dense plant growth can trap oil and most of the perennials can withstand only moderate pollution.

### Sampling and Analysis

Each type of coastline requires very different sampling procedures. After detailed mapping to determine the distribution of geomorphological types, areas should be selected for seasonal, detailed sampling. In addition, general changes in salt marsh vegetation can be determined by aerial photography. Remote and on-site sampling should be conducted quarterly.

### Rocky Intertidal

Sampling on horizontal and vertical rocky intertidal coasts can be accomplished only by frequent visits to selected sites and detailed analysis of transects and randomly selected quadrats. False-color photography may be used to determine overall changes in plant animal distribution at the population level. Species diversity, abundance, and distribution should be determined at the organism level. Samples of abundant taxa of plants and animals should be freeze dried and analyzed for pollutant content.

### Sandy Beaches

Visual inspection for tar balls and cores at dug pits for buried tar deposits should be employed for contamination analysis. Integrated core samples from the intertidal should be eluted with solvents for hydrocarbon content. Sandy beaches generally have low animal populations, but intertidal areas provide food for sandpipers and other small birds.

Mud Flats

Mud flats should be sampled for surface contamination by small boat or wading. False-color aerial photography can determine gross changes in plant distributions and abundance (primarily algae and some vascular aquatic plants). Small volumes of sediment should be fine screened for invertebrates to determine species diversity. If the biological material is adequate, portions should be freeze dried for hydrocarbon analysis.

Salt Marshes

False-color aerial and low or ground-level photography will reveal gross changes in vegetation patterns. Standard transects should be sampled for vegetation and associated invertebrates. Subsamples should be freeze dried for hydrocarbon analysis. Samples of substrate biota in vegetated areas and drainage channels should be obtained for hydrocarbon analysis.

## THE OBSERVATIONAL SYSTEM/CHEMISTRY

### *Petroleum Hydrocarbons*

*Natural and petroleum-derived hydrocarbons contained in or associated with representative organisms, the water column and suspended and bottom sediments claim high priority in any monitoring scheme because of their toxicity and potential impact on the marine ecosystem. Certain indicative petroleum components should be used as "tracers" for other petroleum components. Oil slicks and tar balls should be analyzed.*

---

In view of the large number of samples and associated cost likely to be encountered in a monitoring program (Fig. 1), key components of petroleum hydrocarbons should be selected as indicators of possible environmental impact. In the Gulf of Mexico, low boiling point hydrocarbon components ($C_1$-$C_4$) were shown to be sensitive tracers of spilled petroleum hydrocarbons and natural seeps. A light hydrocarbon monitoring program will indicate spilled oil and be a potential tracer of the highly toxic soluble aromatic compounds.

### Sampling

An in situ pumping system or "towed fish" deployed from midship or forward boom would minimize ship contamination in a sampling system for petroleum hydrocarbons. Broad-scale areal surveillance of surface oil effects will employ many sensing techniques in the near term as well as in future phases of the monitoring program.

A minimum sampling frequency would be biannual, but a greater frequency may be required under conditions of high dispersion rates. Spatial sampling, vertical and horizontal, should be sufficiently dense to elucidate highly impacted areas and to monitor the dispersion rates of the pollutant with time.

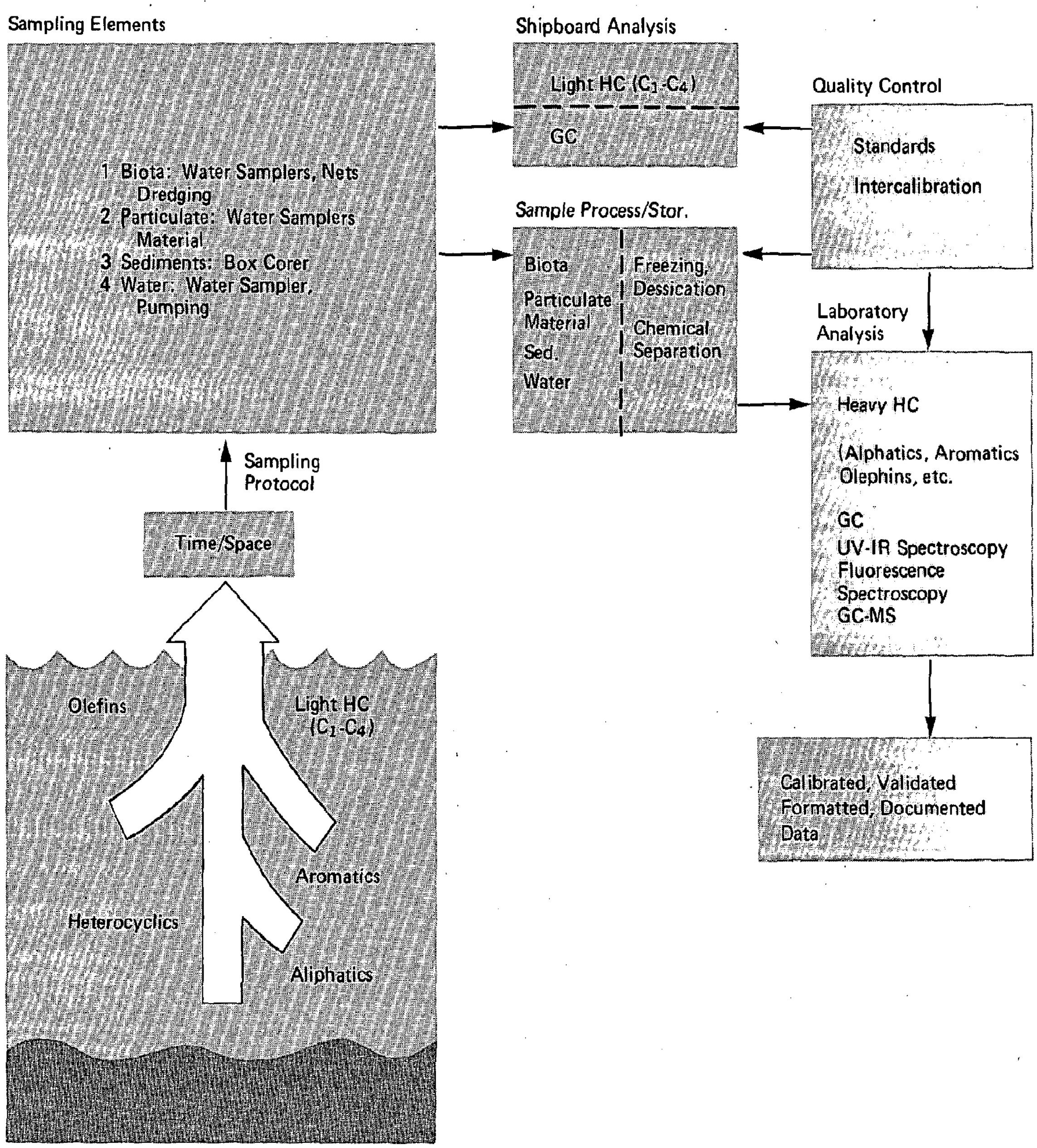
### Analysis

The requirements of a hydrocarbon monitoring program are, first, to evaluate increases in the concentration of toxic hydrocarbons over ambient levels and then to correlate the observations with significant seasonal changes in biological communities. An exception is the distribution of dissolved light hydrocarbons, which are sensitive environmental indicators of more toxic fractions.

Sublethal concentrations in biological communities can be evaluated with gas and column chromatography supplemented by UV, IR, and mass spectroscopy. Gas chromatographic/mass spectrometric systems are valuable for individual compound identification, particularly aromatics, and are very useful in studying diagenetic and weathering processes of oil pollutants.

The major obstacles to analyzing hydrocarbons (aliphatics, olefins, and aromatics) are their low natural levels and a myriad of contamination problems. These problems are not encountered, however, in the analysis of the low boiling fraction, $C_1$-$C_4$, as their ambient concentration levels are relatively high.

**Figure 1 – Hydrocarbon Analytical Program**



## *Trace Elements*

*Trace elements introduced via oil and gas activities may be assimilated directly from the water, through ingestion of prey, and through consumption of particulate matter by detrital feeders. Trace elements may become more soluble from complexation with petroleum-derived hydrocarbons and thus more toxic to marine orgnisms. Trace metals are a likely result of drilling, and sediments are their most likely sink.*

---

Trace elements may be removed by adsorption processes on suspended particulate matter and by scavenging mechanisms involving hydrated iron oxides. Evaluation of natural sources, sinks, and transport pathways (including riverine transport) for trace elements (Fig. 2) should be improved during the monitoring phase.

### Sampling

Care must be exercised to minimize contamination arising from various shipboard operations during sample acquisition, processing, and storage. (Elements of interest for OCS oil and gas activities are mercury, lead, cadmium, zinc, nickel, copper, chromium, all of which are significantly toxic to living systems).

Acceptable procedures for sampling trace elements include the use of discrete water samplers (water, suspended sediments, planktonic organisms), nets (plankton, macro fauna and flora), and box cores (surficial sediments). In situ pumping systems are recommended, provided problems in sample contamination are resolved.

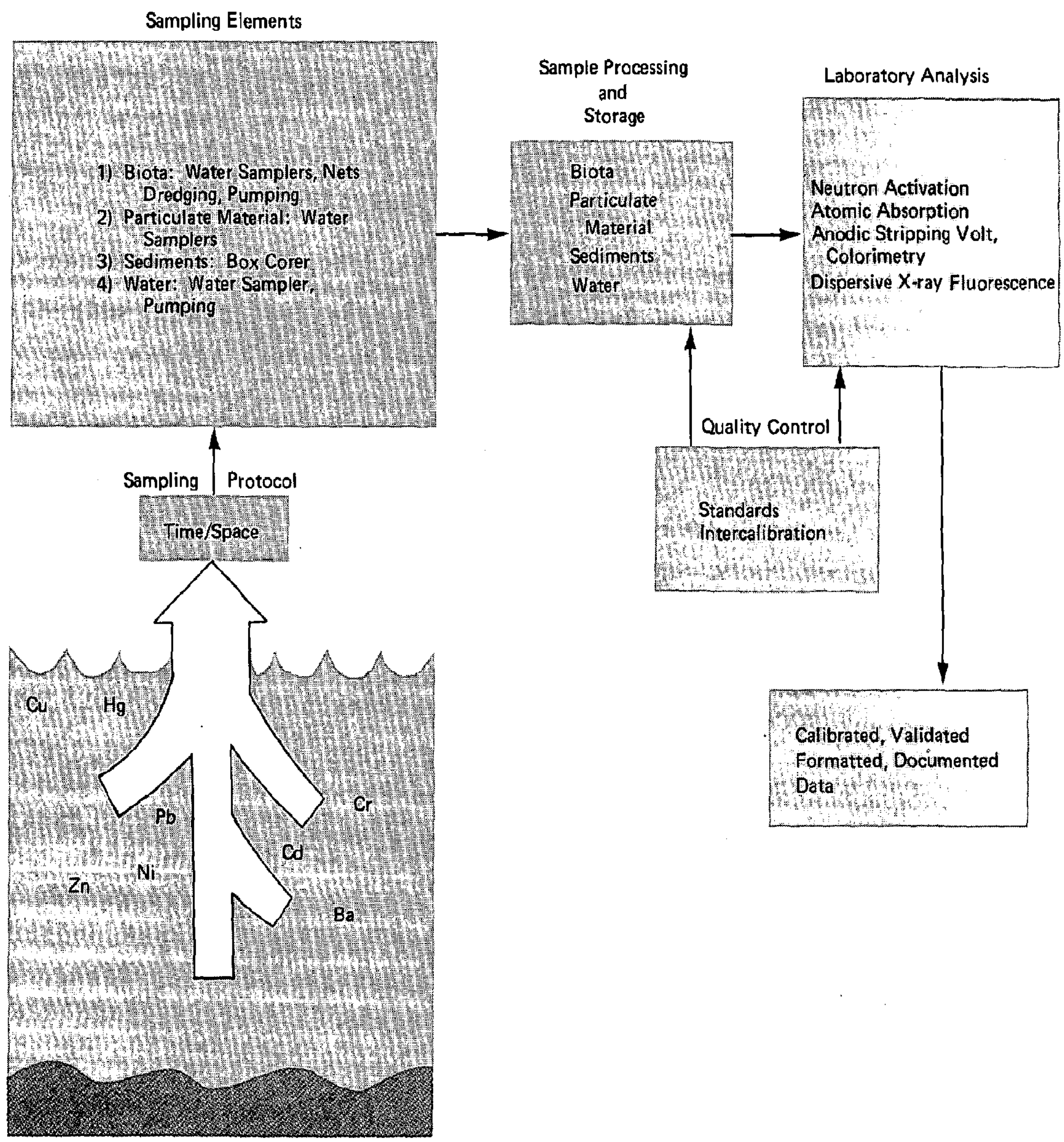
### Analysis

Procedures chosen for trace element analysis should be capable of detecting sublethal concentrations in respresentative organisms. Present instrumentation has reliably detected toxic elements in apparently healthy biological communities suggesting that the sensitivity of these present techniques is adequate.

Instrumental techniques commonly employed for trace metal analysis are neutron activation analysis, atomic adsorption spectroscopy, visual spectrophotometry, and anodic stripping voltametry. Neutron activation is widely used in the analysis of mercury, cadmium, copper, zinc, and has the advantage of being nondestructive. Atomic adsorption spectroscopy and colorimetry are also used routinely for lead and nickel. Anodic stripping voltametry is particularly useful in the study of copper, zinc, and cadmium speciation. Dispersive X-ray fluorescence may also be applicable to the analysis of some trace metals, particularly in suspended particulate matter (see "Suspended Particulate Matter"). The applicability of the last method to sediments, air particulates, water, and biological substrate awaits additional development.

Trace element analysis aboard ships at this time is not practical because of extensive sample processing time and equipment. Thus, these analyses should be ashore under controlled laboratory conditions until acceptable methodology for at-sea operation becomes available.

Figure 2 — Trace Element Program



## *Suspended Particulate Matter*

*An analysis of suspended particulate matter using horizontal and vertical mass and grain size distributions, mineralogy, major and trace element composition, and adsorbed hydrocarbons will be included in the monitoring program.*

---

Knowledge about changes from the initial baseline chemical composition of suspended particulate matter is necessary to assess man's impact on the environment. The suspended particulate matter observational element is designed to provide this information (Fig. 3). Trace metals and petroleum hydrocarbons which are released during drilling and transport are adsorbed onto surfaces of suspended particles and transported to the sea floor as particles settle. Contaminated particles may be assimilated by filter and detrital feeders, and the toxic pollutants may be magnified at the higher trophic levels. Furthermore, in near-shore regions severe storms might cause contaminated sediments to be resuspended. This would present the opportunity for toxic pollutants to be rereleased into the water column.

### Sampling

Several options exist for sampling suspended particulate matter during a monitoring program. Each option has a unique set of advantages and disadvantages. The most important prerequisite should always be the collection of contamination-free samples. The most common option uses samples taken from a ship at a preselected grid of stations. Sampling devices would be standard PVC Niskin bottles or a submersible pumping system.

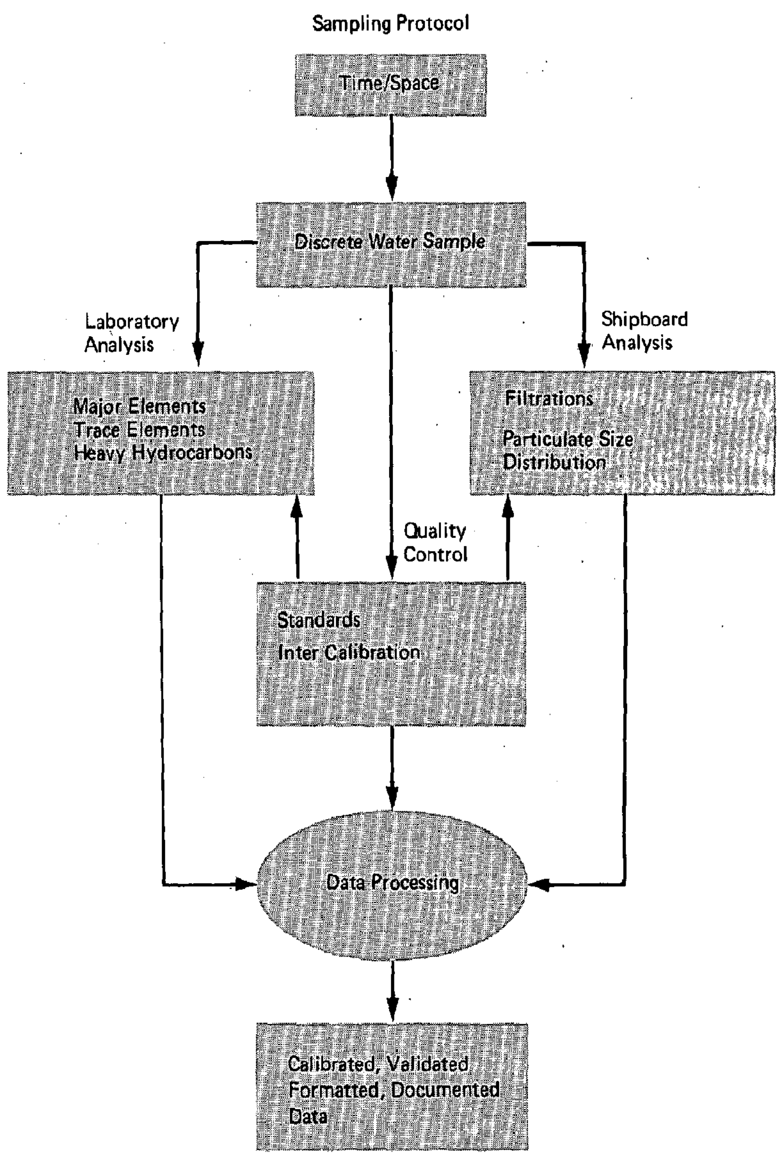
Other sampling options included fixed platforms, such as drilling platforms and buoys. These options provide the opportunity for long-term studies of temporal variations, but lack the flexibility of location needed for synoptic work. A combination of regular shipboard cruises and frequent sampling from fixed platforms would be best for a comprehensive monitoring program.

Within representative areas, the sampling should be of sufficient frequency and detail to determine natural variations due to fluctuations in input from rivers, glaciers, and atmospheric sources and differentiate them from anthropogenic sources.

## Analysis

The analytical portion of the monitoring program for suspended particulate matter will include suspended load, grain size distribution, mineralogy, major and trace elemental composition, and adsorbed hydrocarbons. Because flocculation and sedimentation will occur during transport of samples to the laboratory, it will be necessary that filtration and grain size determinations be performed in the field. All other sample handling and analysis should be in one central analytical laboratory or a regional laboratory. Because large numbers of samples are anticipated, automated analytical procedures are preferred over manual techniques which are subject to human error.

Figure 3 — Particulate Matter Analysis



## *Nutrients*

*Nutrient ($NO_3$, $NO_2$, $NH_4$, $PO_4$, Si, urea, and amino acids) and oxygen concentrations, distribution, and ratios provide valuable support information for primary productivity observations, and water quality standards and secondarily, water mass tracing. Under certain limiting conditions, nutrients may behave as conservative tracers and thus may be useful in tagging water masses not readily distinguishable by the prevailing salinity and temperature field.*

---

The concentration and distribution of dissolved nutrients and oxygen should be determined in support of primary productivity measurements. Little or no direct environmental impact on nutrient constituents is expected to arise from oil and gas production on the OCS. Some local eutrophication may result from exploration and drilling, particularly in sheltered waters of sluggish circulation, but this effect is considered minimal and not necessarily undesirable.

Nutrients are best measured routinely and without delay aboard ship, by either discrete water bottle sampling or a continuous pumping system. Both systems are state-of-the-art and can readily be coupled to an autoanalyzer. In view of the large number of analyses that may be required, the autoanalyzer should be coupled to the central data system. The minimum requirement is a display for real time analysis complemented by analog-digital conversion and storage of digital results on magnetic tape or disc. This complete system is available at several levels of sophistication. Electrochemical sensors and remote sensing cannot yet detect ambient concentration levels of nutrients. The execution of the sampling protocol should be dictated by the requirements of the primary productivity program, i.e., when physiological parameters are determined.

## THE OBSERVATIONAL SYSTEM/SEA ICE

### Sea Ice

*In Arctic OCS areas, sea ice must be monitored for extent and movement because it determines the distribution of birds, mammals, and under-ice biota, significantly affects transport processes and oil recovery, and is hazardous to offshore structures.*

---

Baseline studies will provide the basic techniques and groundtruth data to enable interpretation of satellite data on a routine basis. Extent, thickness distribution, ridges, leads, and polynas of the ice will be determined from data acquired by aircraft, NOAA operational satellites, and NASA experimental satellites. Interpretation of the visible, infrared, and microwave data which will be available from these platforms should provide an adequate picture of sea ice characteristics. Samples of sea ice and tabular ice will be obtained on a regular basis for analysis of contaminants. Monitoring of sea ice will be routine, following the conclusion of the baseline studies.

The reasons for monitoring sea ice are based on its being the most dominant year-round feature of the environment north of the Bering Strait. Firstly, the distribution, nature and extent of sea ice determine the presence and distribution of birds, mammals and under-ice biota. Secondly, transport processes, including those moving spilled oil are substantially affected by sea ice. On the surface, the spread of oil may be hindered by sea ice. Oil may be trapped in leads or polynas or spread by the pumping action of leads opening and closing in the pack ice.

Also, the recovery of oil (from a bottom well blowout) from under the ice requires information on the thickness, roughness, presence of ice keels, and ice in the vicinity of the blowout and data on the currents under the ice.

Finally, ice is a threat to all offshore structures, whether they are ships, platforms, bottom-mounted well heads, pipelines, or anything else. Swiftly moving pack ice threatens surface structures, and ice keels scouring the sediments of the ocean bottom may interfere with bottom-mounted equipment.

### Sampling

Daily satellite coverage of the ice-covered waters along the Beaufort, Chukchi, and Northern Bering Sea coasts is required. The NOAA operational satellites and NASA experimental Nimbus satellites provide broad aerial coverage and synoptic imagery in the visible, infrared, and microwave bands that is normally adequate. If spills or other catastrophes occur, high-resolution imagery of the affected areas will have to be provided by aircraft.

## THE OBSERVATIONAL SYSTEM/GEOLOGY

*Geological monitoring requirements, except for contaminants, are of tertiary significance in an OCS environmental quality program because present geological baseline information being collected is adequate and expected changes in geological parameters are slow.*

---

Surficial and suspended sediment properties relating to contaminant content and transport are addressed under "Chemistry". (Geological monitoring otherwise is described in Fig. 4).

### Bathymetry

Bathymetry can be monitored for change on a periodic basis, usually related to infrequent natural or manmade catastrophic events, such as large storms, earthquakes, or platform accidents. In any case, monitoring would be limited only to careful resurveys of areas of particular interest.

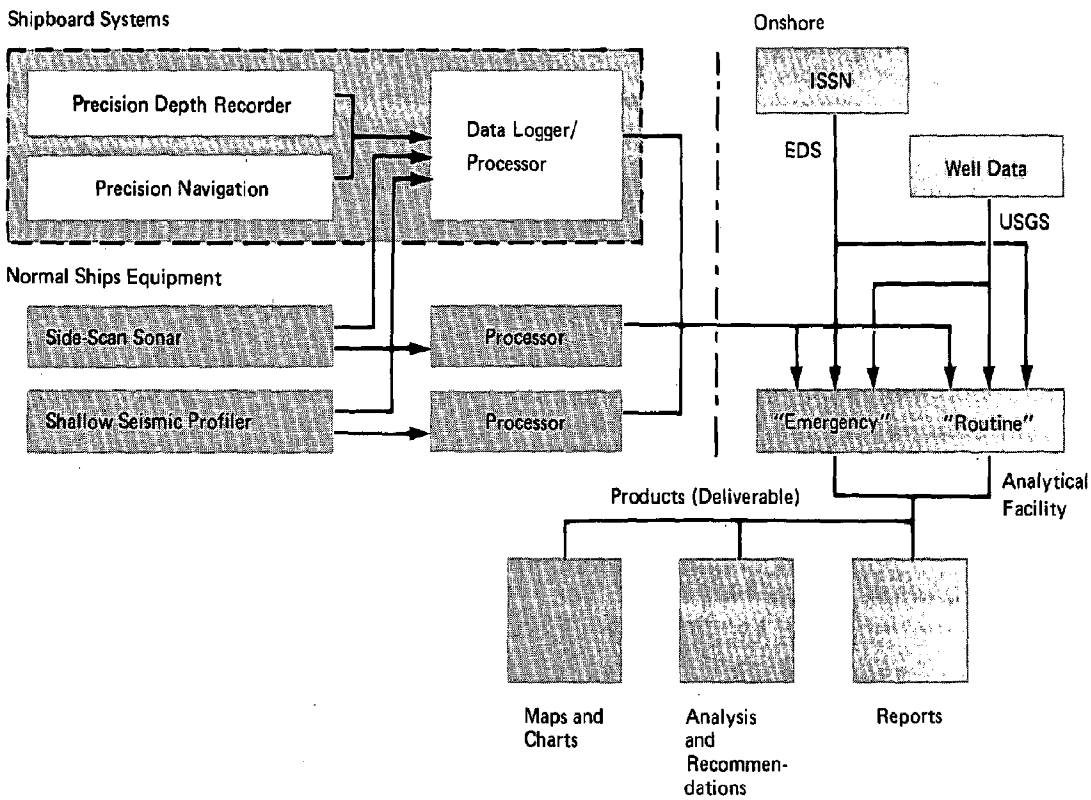
Bathymetry requires some sophisticated but proven equipment for accurate navigation and precision depth location. This equipment is standard on most bathymetric survey ships, which also have some online data processing capability. The only additional items that might be required for bathymetric measurement are side-scan sonar and shallow seismic reflection profiling gear.

### Shallow and Deep Structure

Changes in the geological structure are both shallow and deep. Shallow structural changes will have some surface expression and are so covered as part of the bathymetric effort. Deep structural changes are not expected to be associated with any emergency situations except earthquakes. Operational well records, downwell logging, and the International Seismological Station Network (ISSN) will be used in monitoring deep structural changes.

Most reduction, processing, and analysis of geological monitoring data will be ashore; some data reduction will be aboard survey ships. Products will include revised bathymetric maps, sediment type change maps, analyses of threats to structures, deep structure change reports, and earthquake focus locations with recommendation for action.

Figure 4 — Geological Monitoring: Data Handling



## *Physical Oceanography and Meteorology*

*Physical oceanographic and meteorological monitoring has four purposes: Assessment of changes in water quality, support for the chemical and biological measurements, preparedness for emergency conditions and input to pollutant trajectory forecasts. Only optical measurements are of significant direct use in measuring water quality.*

---

Physical oceanographic and meteorological monitoring will begin at the conclusion of baseline field data acquisition and will run concurrently with the last part of the analysis and model development phase (Fig. 5). Thus, monitoring procedures may change during the first 2 years due to continuing input from the baseline effort. Model verification studies, however, will be considered part of baseline data acquisition.

Observations in physical oceanography and meteorology for monitoring OCS environmental conditions comprise optical properties, currents and circulation, temperature and salinity structure, tide measurements, precipitation, wind, air temperature, solar insolation, cloudiness, and dew point (Table 3). These measurements should be not only simultaneous with other sample gathering but also in special time-continuous sampling periods in order to update estimates of variability.

For optical properties, instrumentation to measure both adsorption and scattering properties of sea water is needed. These data need to be taken only at a small number of selected stations in conjunction with the measurement of temperatures and salinity fields. A suggested observational package for optical measurements includes:

- o Alpha meter measurements of total extinction at selected depths, and
- o Nephelometric observations for normal scattering; both unfiltered and red and blue-filtered at standard wave lenths.

Two types of emergencies must be considered: spills and severe meteorological-oceanographic conditions. Synoptic measurements will be required of winds, waves, currents, surface barometric pressure, dew point, and air and sea surface temperatures over wide regions. If the regions are homogenous and adequately modeled by the baseline effort, only a few observational points are needed; otherwise, as is usual, the density of observations will vary inversely with the distance from the developed OCS area and the adjacent shoreline. These measurements must be available continually, preferably in coordination with usually synoptic weather data.

**Figure 5 — Physical Oceanography/Meteorology Overview**

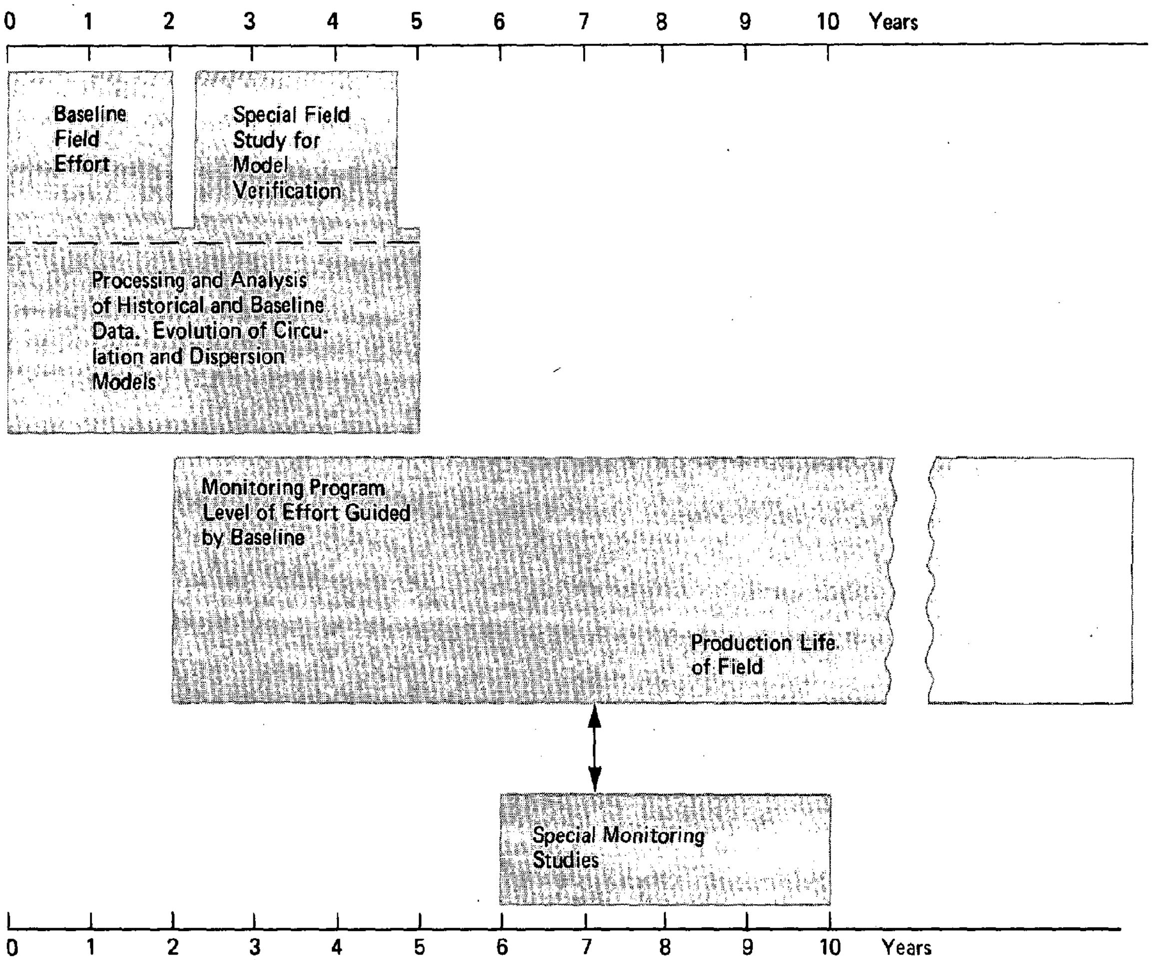



**Table 3 — Physical Oceanography/Meteorology Observational Elements**

| Primary | Secondary | Tertiary |
|---|---|---|
| • Optical properties<br>• Temperature and Salinity Profiles<br>• *Continuous meteorological data*<br>• Sea Ice<br>• Aerial monitoring: Temperature, water mass, sea state and oil slicks | • Tide measurements<br>• Currents and Circulation | None |

## THE QUALITY ASSURANCE PROGRAM

### *Some General Considerations*

*An independent instrumental quality assurance program must be established: definite responsibility for such an effort must be assumed by program management.*

---

Assessment of the marine environment depends upon precise and accurate measurement of its physical, chemical, biological, and geological nature. The Commission on Marine Science, Engineering, and Resources has expressed concern for the quality of these data. 6/

> "At present, there is a wealth of data within the Nation that is of limited value because of low confidence in the data quality or because the data came from diverse sources and are not comparable. This is not only a national problem, but it increasingly is becoming an international one."

Basic components of a quality assurance (QA) program for OCS monitoring include standard reference materials, laboratory quality control, in situ instrumental control, and uniform sampling methods (as discussed in the appropriate section of the observational system). Routine practice of the four components of this quality assurance program will allow intercomparison of data sets derived from any of the oceanic areas monitored. Not only will the proposed QA program allow an areal intercomparison of data, but also more confidence can be placed in data collected over long periods of time. Furthermore, a rigorous QA program will allow advances in measurement technology to be accurately related to earlier measurements.

The OCS Task Team recommends that the implementation of a quality assurance program be unified with respect to the four elements mentioned above and a direct responsibility of the program manager. Otherwise, quality data and instrument systems will become only an afterthought and an unbearable system expense.

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6/ Our Nation and the Sea, A Plan for National Action. Report of the Commission on Marine Science, Engineering, and Resources. January 1969.

## THE QUALITY ASSURANCE PROGRAM

### *Standard Reference Materials*

*The analysis of a Standard Reference Material (SRM) having a matrix composition similar to the sample and certified for the constituent element in question has proved to be a simple and fast method for the evaluation and intercomparison of analytical accuracy.*

---

Standard Reference Materials (SRM) available from the National Bureau of Standards (NBS) are invaluable for quality control of analytical results. SRMs not only will provide a basis for interlaboratory comparison of results and evaluation of new methods, procedures, and instrments but also allow intercomparison of data over long periods of time. These materials normally are certified as absolute standards by two or more independent methods of measurement. To be most useful and accurate, they should be in a matrix similar to the one to be analyzed. Therefore, the use of three matrices is proposed: biological tissue, sediment, and sea water. Also, the concentration and chemical composition of the SRM must be similar to the material to be analyzed.

For trace metals, NBS does presently offer two trace element SRMs, Orchard Leaves and Bovine Liver, which are certified for a number of elements. A third biological matrix, Tuna Flesh, whose release as a SRM has been delayed by technical difficulties, may become available soon as a Research Material. Although not certified to the extent of the normal SRM, its interim use is possible for analysis of trace metals, petroleum hydrocarbons, and cholorinated hydrocarbons. In this capacity the Research Material would be used to intercompare laboratories participating in the monitoring program and to ascertain the accuracy of the analysis on material from OCS areas.

Although sophisticated analytical procedures have been developed for petroleum hydrocarbon studies, SRMs for these substances are not yet available.

## THE QUALITY ASSURANCE PROGRAM

### *Laboratory Quality Control*

*A program to insure the reliability of laboratory data is essential. A routine control program must be applied to every analytical test and must be under central control.*

---

Establishing uniform methods among cooperating laboratories is essential in comparing and the joint use of data among laboratories. Uniformity of methods is especially important where laboratories cooperate in field surveys or provide data to a common data bank. Uniform methods are also essential to the removal of analytical variability over long periods.

Physical and chemical methods should be selected under the following criteria:

- o The method will measure the desired constitutent with precision and accuracy sufficient to meet the data needs in the presence of the interferences normally encountered in polluted waters. Low levels of hydrocarbons anticipated in the samples necessitate the development of analytical techniques sensitive at the submicrogram per kilogram level.
- o The procedure will utilize the equipment and skills normally available in oceanographic laboratories.
- o The selected methods will be in use in many laboratories or have been proved valid.
- o The method will be fast enough for routine use for examining large numbers of samples.

Uniform methods in all laboratories will provide a common base for comparison between OCS areas and reinforce the validity of the results of the entire program.

## THE QUALITY ASSURANCE PROGRAM

### *In Situ Instrument Quality Assurance*

*Marine environmental quality monitoring data must be accompanied by a valid error statement and acquired by instruments that have been calibrated with a procedure traceable to a National Standard.*

---

With the ever-increasing emphasis on the exploration, exploitation, and protection of the marine environment, more instruments are being developed and introduced to marine monitoring programs. Increased emphasis on performance will necessitate a systematic quality assurance approach for all routinely used marine instruments. Instrument quality assurance is a prerequisite to measurement integrity as a basis for valid conclusions.

Depending upon scope, complexity, and duration of a monitoring project, a program of instrument quality assurance must include all or most of these elements:

- Measurement requirements must be carefully defined. They become yardsticks against which all other aspects of an instrument quality assurance program are compared.

- Performance specifications of instruments relate directly to measurement requirements and provide a means for determining the availability of instruments, suitability of the state-of-the-art designs, credibility of the measurement requirements, and potential cost savings accrued in the quality assurance operations.

- Acceptance testing based on an approved test plan establishes the desired instrument's ability to meet the performance specifications.

- Calibration by approved procedures insures accuracy and consistency of a measurement effort.

- Established maintenance and repair schedules insure that instruments will perform to specifications and withstand a stated operational environment. Instruments procured and operated in connection with the OCS monitoring program shall be tested, calibrated and accepted in accordance with the procedures of the National Oceanographic Instrumentation Center of NOAA and should be subject to qualification testing by that activity.

## THE MONITORING PROGRAM

### *Schedules and Facilities*

*Outer Continental Shelf monitoring is one part of a continuing effort to ascertain the environmental effects of oil and gas development. Where possible, the proposed system must rely on existing facilities to allow an early implementation at the lowest cost.*

---

The environmental studies program for OCS oil and gas development areas, according to the Bureau of Land Management, follows the schedule below:

Phase I --Summary of OCS Environmental Knowledge will compile and summarize all available information for inclusion in the Environmental Impact Statement as well as supporting further program design.

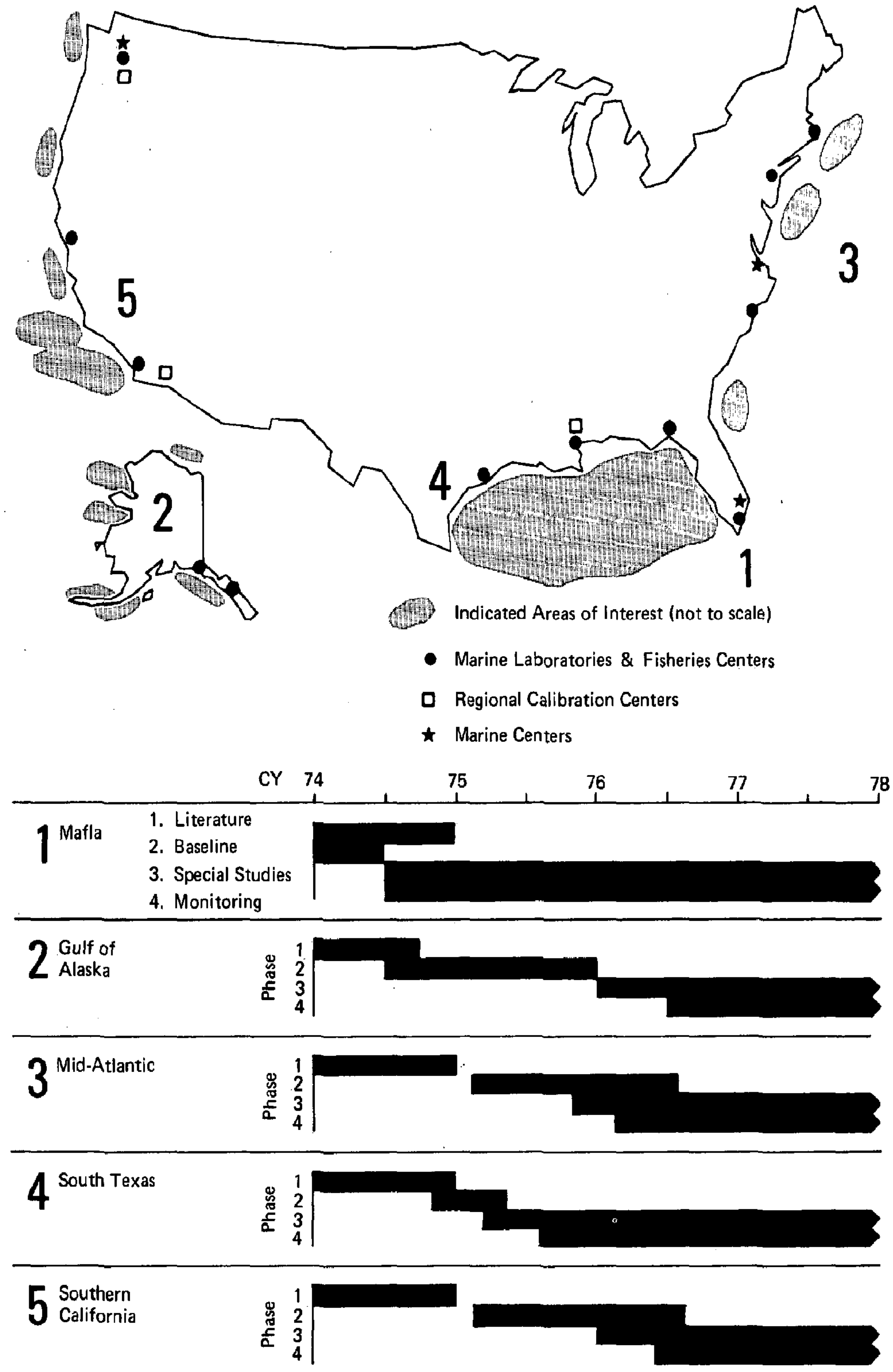
Phase II --Baseline Sampling will complete a data base with new information to establish predevelopment OCS conditions and an initial assessment of environmental impact.

Phase III --Special Studies will enable prediction of environmental effects through a study of poorly understood processes, dynamics, and causal relationships.

Phase IV --Environmental Monitoring will ascertain trends in environmental parameters caused by platform placement and the discharge of drilling muds, produced formation waters, disposal of drill cuttings, chronic oil leakage, and discharge of wastes from platforms and workboats. Monitoring will verify earlier impact assessments and predictions.

The Outer Continental Shelf monitoring program is expected to acquire data over a great many years, compared with a research experiment or a 2-5 year trend analysis program. Management, facilities development, and scheduling must therefore be designed not only for early implementation but also for supporting an extended area program. Careful consideration must be given to the utilization of existing resources; for example, NOAA facilities with ongoing marine environmental assessment activities. Generally, the location of these facilities corresponds favorably with locations of potential OCS exploration (Fig. 6).

Figure 6 — Schedule for Environmental Studies Program



## THE MONITORING PROGRAM

### *Program Organization and Schedules*

*Outer Continental Shelf environmental assessment will be most effective with common management established for the baseline and monitoring efforts. A monitoring function office should be established immediately because of the present accelerated development of OCS activities and to plan early for procuring long-lead-time observational systems.*

---

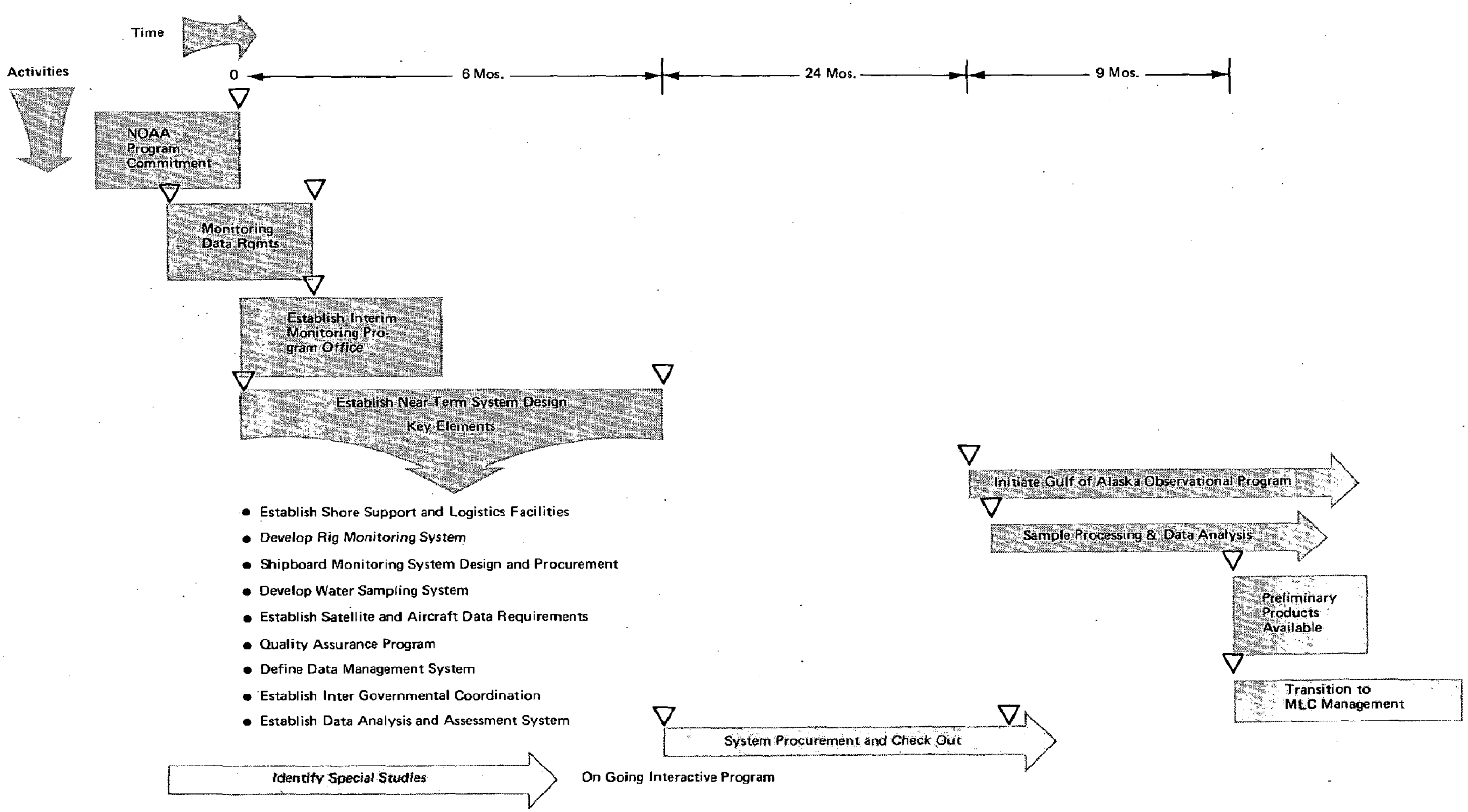
The following characteristics of the proposed environmental monitoring program specify the need for a unified management structure for both baseline and monitoring programs:

- o Potentially wide geographic dispersion of both baseline and monitoring activities is likely.
- o Constant governmental coordination is needed for both the baseline and monitoring activities.
- o Recurring use will be made of significant resources of several NOAA Major Line Components for OCS marine environmental assessment.

A single management structure can best effect a solid interaction between the baseline and monitoring programs. A monitoring group within the office responsible for the baseline investigation should begin to plan and acquire long-lead-time items, e.g., satellite and buoy systems, and should coordinate with baseline planning. It would also be responsible for the development of proposed monitoring system design, the establishment of interfaces with the existing baseline program and interested State and Federal agencies, and the implementation of the observational program.

A generalized sequence of events is described as a possible course of action for the management of the monitoring effort (Fig. 7). Such activities are, of course, affected by the technical outcome of relevant baseline studies, and schedule changes dictated by the leasing authority.

Figure 7 — Major Milestone Schedule



## THE MONITORING PROGRAM

### An Evolving Technology

*An effective OCS environmental monitoring system must phase technology available in the near term (2-5 yrs) into future systems (10+ yrs) that are presently undeveloped or under development.*

---

An analysis of available observational platforms, sensors, and capabilities suggested to the OCS Task Team that the main data-gathering platform for the near-term (2-5 yr) monitoring system should be the research ship. However, the role of the research ship as a sample-acquisition platform will decrease with time as the monitoring system evolves (Fig. 8). The Task Team anticipates that, over the course of the entire program, personnel requirements aboard these ships will be changed from scientists to technicians. Personnel, the number of shipboard sensors, and the requirements for physical sampling will decrease as the feasibility of remotely acquired data is established. As shown for midterm, (5-10 yrs), aircraft, buoy, and satellite systems will begin to play an important role.

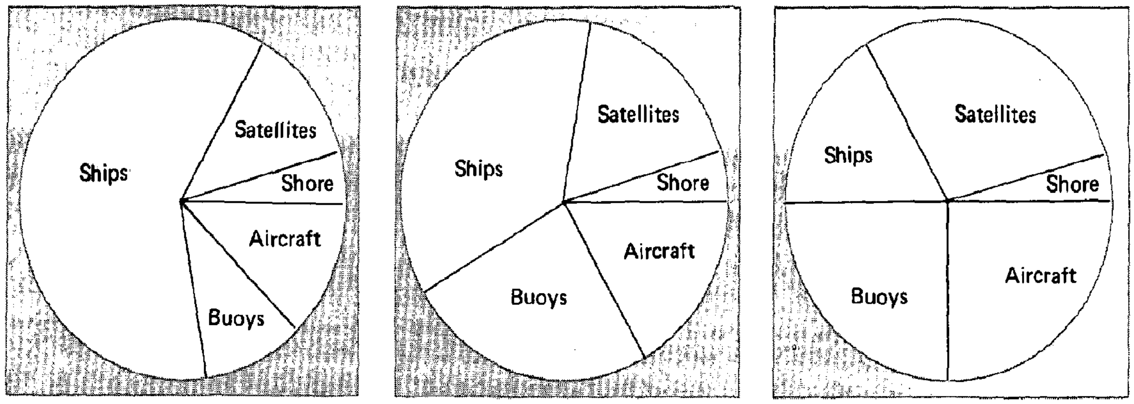
Buoy technology for the midterm system is that developed by the National Data Buoy Office for deployment as part of ongoing NOAA programs. Operationally, these buoys now measure only meteorological parameters but will measure some surface and subsurface oceanographic parameters in the midterm.

Satellite involvement in the near-term relies on NOAA 3, the Geostationary Orbiting Environmental Satellite (GOES), and the Earth Resources Technology Satellite (LANDSAT). These satellites now provide atmospheric temperature profiles and cloud, water surface, and sea ice spectral coverage of many OCS frontier areas. In the midterm and future the NIMBUS G, and SEASAT will provide additional significant information on sea surface states, and ocean circulation.

Because of the long procurement cycles required for satellite sensors and systems, the impact of satellite data will become significant only in the future system. Consequently, aircraft used in the midterm will provide the primary platform for development, test, and evaluation of future satellite sensor systems.

Onshore and nearshore effects are potentially the major indicators of offshore oil and gas development. To better assess these effects, mobile, containerized shore-based laboratories should be built which will contain biological and chemical analysis equipment for coastal monitoring. These mobile containers also may be deployed from small boats and in remote locations in response to emergency situations. The system will be transported by air, or parts of the system could be designed in a modular fashion so they could be removed from the basic container and placed aboard larger research ships or aircraft.

**Figure 8 — OCS Monitoring System - Evolving Technology and Platform Utilization**




### Near Term (2-5 yrs)

**Ships**
- Biological, Chemical Geological Sampling and Processing
- Physical Oceanography
- Meteorological Observations

**Aircraft**
- Remote Sensing-Oil Slicks
- Air Deployed Water Samplers-Surface
- Remote Surface Currents

**Satellite**
- Water Color

**Shore Stations**
- Biological and Chemical Samples

**Buoys**
- Waves
- Meteorological Observations

### Mid Term (5-10 yrs)

**Ships**
- Biological and Chemical Sampling
- Geological Sampling and Processing

**Aircraft**
- Wide Area-Remote Sensing-Oil Slicks
- Remote Rig Monitor-Oil Slick Detection
- Air Deployed Water Samplers-Surface and Subsurface
- Remote Water Color
- Remote Currents-Surface and Subsurface

**Satellite**
- Water Color
- Chlorophyll

**Shore Stations**
- Biological and Chemical Samples

**Buoys and Drilling Rigs**
- Meteorological Observations
- Expanded Physical Oceanography
- Water Quality

### Future (10 + yrs)

**Ships**
- Biological and Chemical Sampling
- Geological Sampling and Processing

**Aircraft**
- Wide Area Oil Slick Remote Sensing Rig
- Remote Currents
- Expanded Spectral Measurements
- Air Deployed Water Samplers

**Satellite**
- Surface Effects
- Oil Signature Detection
- Water Color

**Shore Stations**
- Biological and Chemical Samples

**Buoys and Drilling Rigs**
- Meteorological Observations
- Expanded Physical Oceanography
- Water Sampling
- Chemical and Biological Measurements

## *Near-Term Platform*

*The research ship and its associated observational and data acquisition systems will predominate in the near-term. Other near-term Outer Continental Shelf data collection platforms will be satellites, buoys, existing fixed platforms, aircraft, and shore stations.*

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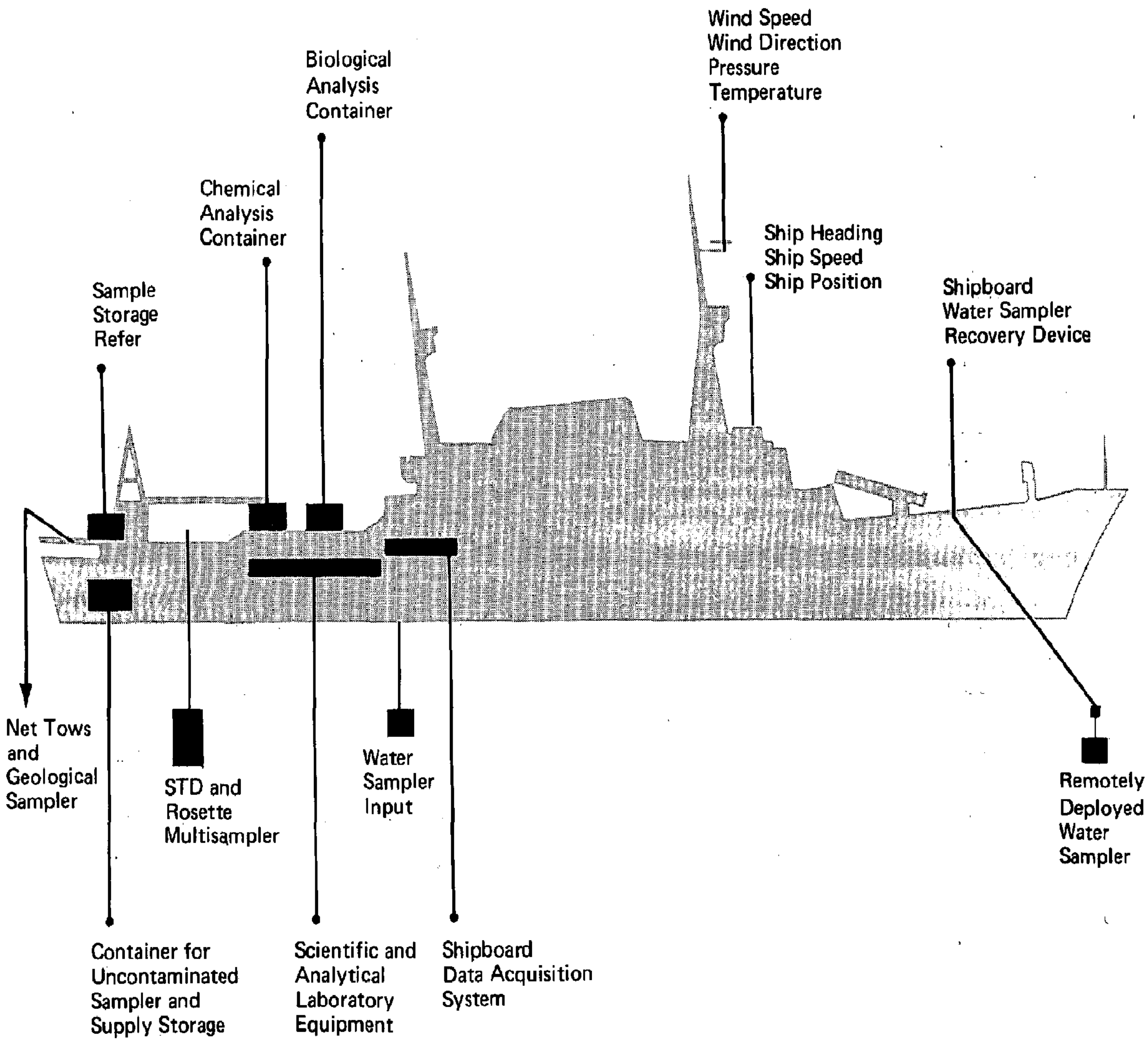
Potentially severe weather conditions in some OCS areas and extensive observational requirements require a ship of the size and capability of NOAA research ships DISCOVERER and MILLER FREEMAN. Basic shipboard observational systems for this type of vessel are depicted (Fig. 9). Such a system comprises:

- A recovery system for remotely deployed water samplers.
- A meteorological and ship systems sensor suite.
- Chemical, geological, and biological containers with associated storage and refrigerator-freezer containers.
- Sampling systems (including STD's, Rosette multisamplers, in situ pumping systems, nets and geological samplers).
- Central data acquisition system.

Most data will be processed on board with the use of a minicomputer to provide engineering units with preliminary results by the end of the cruise. No further processing at sea is anticipated, i.e., no analytical processing will be attempted before arriving at the data processing center.

To prevent contamination of water samples by ship effluent, samples will be recovered from aircraft or a remotely deployed (perhaps by aircraft) sampling device. Those samples that require freezing and subsequent analysis ashore, it is proposed to bring sampling devices aboard the ship in a sterile package or in a large deck container. The large container would be equipped with a self-contained refrigeration system (or refrigeration coupled with the ship's system) in order to freeze the samples as they are placed in the shipboard container. The container would then be removed from the ship and transported to the nearest shore-based analytical laboratory for processing.

Figure 9 — Basic Shipboard Observational System



# DATA FLOW AND DELIVERABLES

## *General Data Management Considerations*

*The monitoring phase of the marine environmental assessment program requires active data management consistent with the standards, procedures, and requirements developed and implemented during the baseline phase of the program.*

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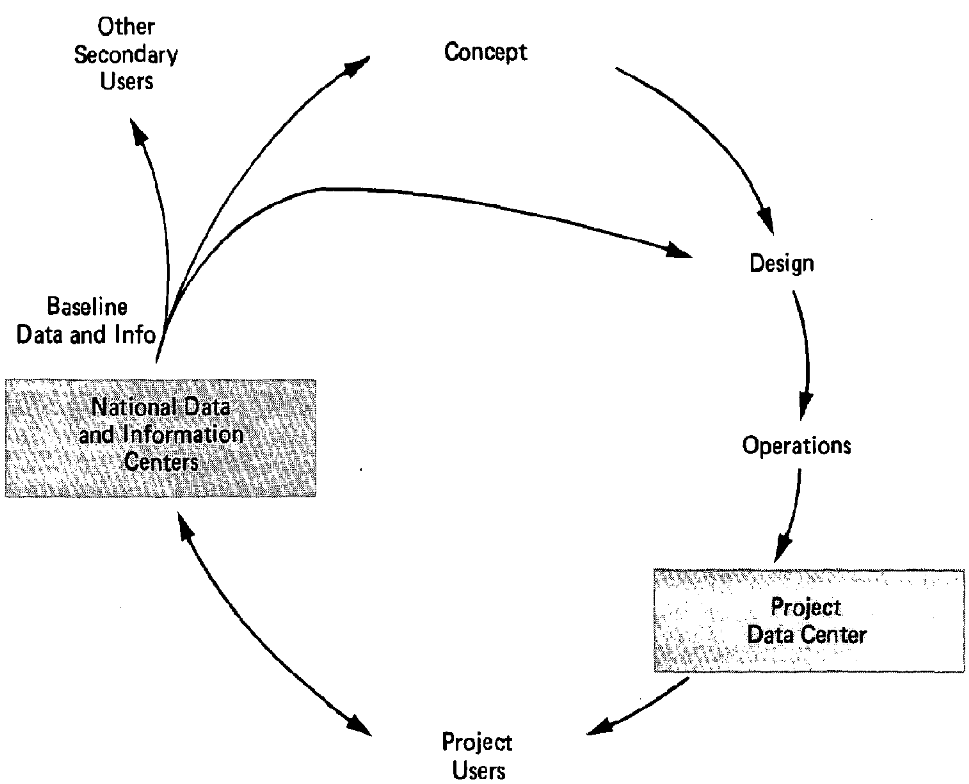
Large amounts of marine environmental assessment data are likely to be collected, stored, retrieved, and applied by State and Federal agencies, coastal zone managers, legislators, the scientific and engineering communities, industry, and the public. Data management techniques and procedures must be developed and used to assure that all data are properly accounted for, processed and archived.

Data management during the monitoring phase will utilize plans and procedures developed for the baseline phase as much as possible. These plans and procedures are comprehensive and are concerned with such diverse aspects of the program as contract stipulations; data acquisition, processing, and analysis; instrument calibration, data documentation, dissemination, and archival; and quality control.

Proper management of data during the monitoring phase provides additional benefits to the program. It will indicate field instrumentation problems and failures, assist program management in exercising control over scheduling and products, and provide additional support and information for the processor and analyst. A generalized project data management cycle is illustrated (Fig. 10).

Figure 10 – Data Management Cycle



## DATA FLOW AND DELIVERABLES

### *Project Data Flow*

*In any marine environmental assessment program, the management of data flow is critical to the entire effort. Data must be collected and processed in a manner that encourages rapid and effective transformation from the sensor to the finished product.*

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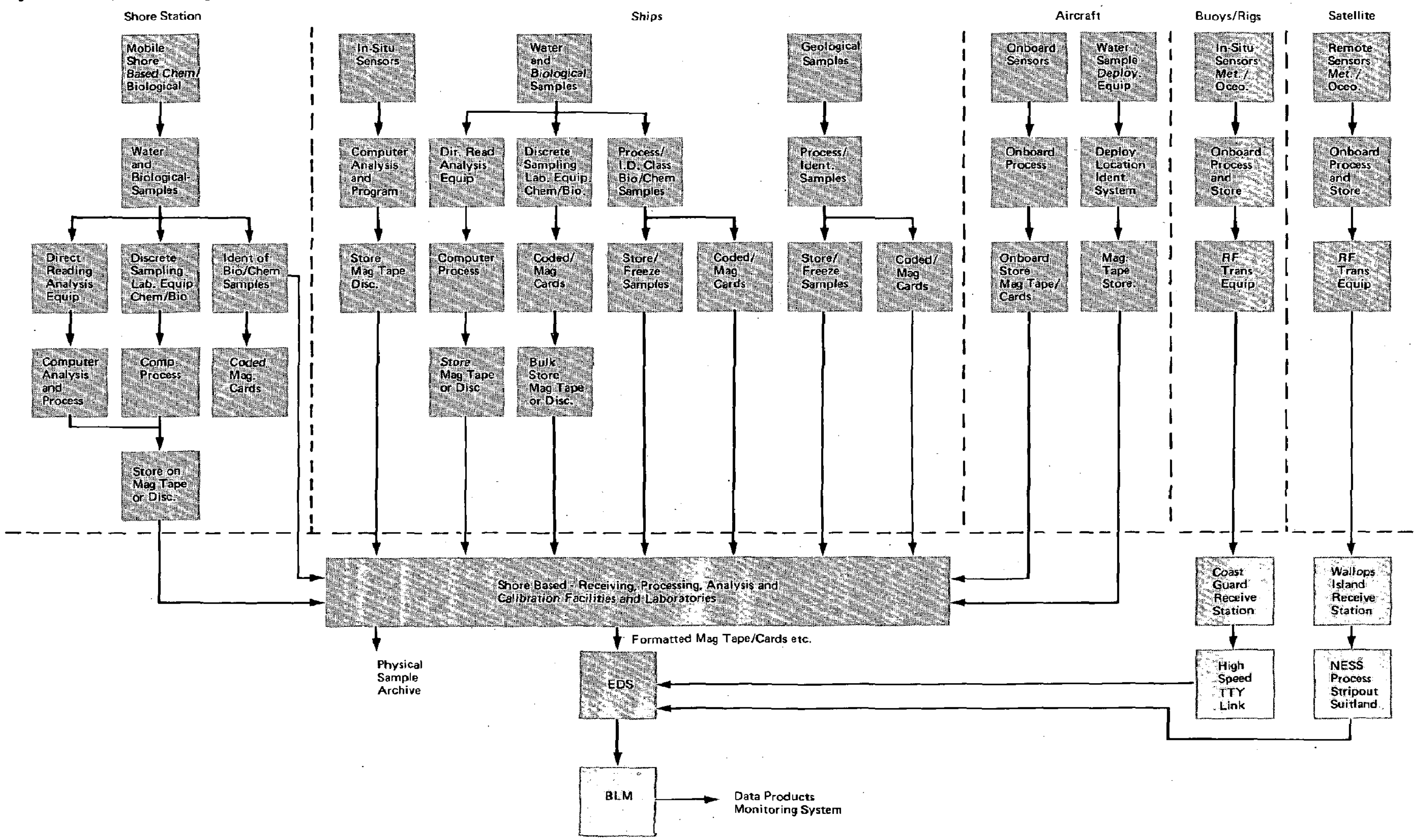
A general data flow scheme is portrayed showing basic system elements (Fig. 11). The diagram provides a framework for the flow of data, within which the details will be elaborate or simple as required.

The basic data system concept for all platforms concerned with monitoring emphasizes onboard machine recording, processing, and analysis, while maintaining a backup system that will allow preservation and retrieval of the unprocessed data if equipment fails. In addition, "quick-look" test equipment must be provided to establish that the incoming data is within acceptable limits and that the recording and processing system is operating correctly. For in situ sensors (physical oceanography, meteorology, etc.) there will be a direct interface between the analog or digital output of the sensor and an automated data acquisition system employing a minicomputer. The sensor signal will be conditioned and sampled commensurate with program requirements and the variability of the input or system being sampled. Within reasonable limits the data should leave the platform on magnetic tape or disc in as close to a finished product as possible.

For water and biological samples processed on board or that require tagging, counting, or identification, it is proposed to code laboratory results and species information on optically coded cards. This will minimize keypunch and coding time after the cruise and speed the delivery of the finished product.

For samples that require analysis and processing on shore, it is proposed that the final laboratory product or results be coded and formatted on mutually compatible tape in order to facilitate merging with other data for the final product and delivery to archive centers.

Figure 11 – Data System Block Diagram - OCS Monitoring System



## RELEVANT RESEARCH

*Research and development activities are identified in direct support of the Outer Continental Shelf monitoring program. Research and development will serve to raise the level of monitoring technology by improving data quality and credibility, increasing the areal coverage of the system, reducing required professional expertise, and reducing the time delay between data collection and the products.*

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The research and development considered in this section represents the OCS Task Team's initial assessment of relevant lines of endeavor required in direct support of monitoring. Activities are grouped as follows: remote unmanned platforms, shipboard sampling systems, acute and chronic effects experiments, and quality assurance.

### Remote Unmanned Platforms

Buoy and rig monitoring systems should be developed in order to acquire salinity and temperature profiles, current data, certain biological samples and perform chemical analyses.

Aircraft and spacecraft systems now operating have demonstrated their capability for certain marine environmental quality observations. The multispectral camera capability aboard the LANDSAT lends itself to periodic observations of surface water color which can in turn be extrapolated to water quality conditions. Further development of these techniques should be encouraged. Also, the wave measuring capability scheduled for the SEASAT system should provide valuable information for safe and efficient operations in OCS areas.

### Shipboard Sampling Systems

Techniques for the rapid and accurate determination at sea of certain toxic contaminants should be developed. Systems which have definite potential for facilitating marine environmental quality measurements in this area include:

- Remotely deployed surface water sampling devices retrieved by vessels.
- Noncontaminating in-situ pumping systems.
- Noncontaminating towed samplers.
- Development of easily transportable containers for chemical and biological analytical work. These modules should be designed for easy transport and for use at sea and ashore.

- o A containerized data processing capability should be developed for at-sea processing, interfacing, and encoding environmental data in computer-compatible formats.

Quality Assurance

With a methodology developed for trace hydrocarbon analysis, research and development of trace hydrocarbon standard reference materials can be initiated. This research divides into two tasks: (1) An investigation of market compounds to be used as petroleum indicators (a marker compound is one which is readily identifiable and associated with crude oil pollution), and (2) development of standard reference materials composed of specific matrices of interest: marine sediment, oyster tissue, finfish tissue, and macroalgae.

Special Studies: Acute or Chronic Effects

Experimental research is a continuing and essential component of the marine monitoring program. The causal relationships among the various interacting elements of the ecosystem must be understood before one can interpret the significance of fluctuations and trends in the marine environmental parameters that are being monitored. This understanding evolves from information existing prior to and generated during the baseline studies.

Information Required from Special Studies:

- o Environmental requirements for "normal" survival, reproduction, development, growth, and productivity of marine organisms.
- o Processes influencing the distribution of contaminants and therefore the modes of exposure of organisms to the contaminants associated with the environmental alteration being monitored.
- o Accumulation and turnover of contaminants in representative organisms, after exposure through various pathways.
- o Direct effects of contaminant exposure on survival, behavior, physiology, and reproduction of selected marine organisms.
- o Effects of deliberate contaminant release and exposure on entire ecosystems and ecosystem components under controlled or monitored conditions.

## REQUIRED RESOURCES

*Resources required for the OCS environmental quality monitoring program have been estimated for two programmatic categories: research and development, and operations. It is estimated that monitoring operations cost will amount to 1/3 the annual expenditure for the baseline, or $15 million annually for the total OCS effort. Within this amount funds are available for special studies.*

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The environmental quality monitoring program accompanying oil and gas resource development on the U.S. Continental Shelf has been designed to include operational observational components and a monitoring equipment and methodology research and development program. The development and availability of new and improved observational methods is a cornerstone of this concept. These systems potentially offer the most cost-effective system possible, in terms of eventually requiring the fewest professionals, improving data quality, and offering the broadest areal coverage of the Continental Shelf.

Development of monitoring equipment and methodology includes support for remote and unmanned observational systems and for fast and accurate acquisition and analysis of samples. Research and development funds for this purpose will be available initially (FY 1975) and over the succeeding four years in the amount of approximately $1,050 million as energy research funds from the Environmental Protection Agency.

Until the ongoing environmental assessment studies are complete, it is impossible to accurately determine the cost of the follow on operational monitoring program. It is known, however, that the program will require significant ship and aircraft operations and costly hydrocarbon and associated analyses. With these factors in mind, it is estimated that monitoring operations costs will approximate one-third the annual expenditure of the baseline effort or about $15 million per year. Of this, approximately one-half will be spent on specific source monitoring, and the other half will continue general environmental monitoring of the OCS. Within this amount, funds are available for special studies required to set and verify acceptable contaminant release levels.

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