Workshop on Hydro-Environmental Monitoring and Modeling in the New York Bight: Program and Abstracts

Waste Management Institute
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794-5000

February, 1991

Prepared for the U.S. Army Corps of Engineers
under Contract No. DACW-51-86-D0007

Approved for Submission

J. R. Schubel, Director

Working Paper # 49
Reference # 91-05

I. INTRODUCTION

Section 728 of the Water Resources Development Act of 1986 (P.L. 99-662) directed the U.S. Army Corps of Engineers to determine the feasibility of implementing an environmental monitoring and modeling program to evaluate the impact of air and water pollution on water quality in the New York Bight. The New York District of the Corps developed a multi-component program in response to this mandate, one element of which involved holding technical workshops on monitoring and modeling in the Bight. Two meetings were held at the World Trade Institute in New York City, the monitoring workshop on 28 and 29 June 1989 and the modeling workshop on 11 and 12 July 1989. The format for each worhshop involved series of prepared presentations followed by discussion sessions. Prior to each meeting a "strawman" was prepared and distributed to workshop participants to highlight salient issues to be dealt with at each workshop and to serve as a focal point for discussion. As further background for the monitoring workshop, an overview of current monitoring programs in the Bight was prepared (Waste Management Institute, 1991).

The goal of these workshops was to develop consensus recommendations concerning the appropriate monitoring and modeling stratgegies to be undertaken as part of the studies required by P.L. 99-62. The workshops were designed to assess the feasibility and specifications for a comprehensive hydro-environmental monitoring and modeling plan and information system that can be used to document and predict the effects of changes to the New York Bight ecosystem due to human activities and natural events. Participants at the workshop included representatives from federal, state, and local governments, citizens groups, university scientists, and interested others. A complete list of participants at each workshop is given in the Appendix.

The contents of these proceedings are organized as follows:

6. Model Studies of New York Harbor and the New York Bight by the Waterways Experiment Station (F. A. Herrman, Jr., p. 83)
7. Chesapeake Bay Three-Dimensional Model Study (C. F. Cerco, p. 84)
8. Physical Oceanographic Modeling in the New York Bight (A. F. Blumberg, p. 88)
9. Modeling of Surface Winds and Waves (V. Cardone, p. 89)
10. Hypoxia and Eutrophication in the New York Bight (J. L. Taft, p. 90)
11. Sediment Transport Models: A Review of Expectations With Respect to the New York Bight (H. Bokuniewicz, p. 92)
12. Modeling the Exchange of Nutrients Between the Water Column and Sediments (D. M. DiToro, p. 94)
13. Specifying and Modeing at the Bight Boundaries (G. Han, p. 95)
14. Modeling Floatable Waste Transport (M. L. Spaulding, p. 97)
15. Modeling Toxic Substances: The Long-Term Behavior of PCBs in the Hudson Estuary (R. V. Thomann, p. 99)

II. STRAWMAN PROPOSAL: NEW YORK BIGHT HYDRO-ENVIRONMENTAL MONITORING STUDY

The goal of the New York Bight modeling and monitoring study is to determine the feasibility and specifications for a comprehensive hydro-environmental modeling and monitoring plan and information system for the New York Bight. These studies are being performed by the Operations Division, New York District, U.S. Army Corps of Engineers under the authorization of Public Law 99-662, Section 728 as follows:

SECTION 728 NEW YORK BIGHT

(a) *The Secretary shall study a hydro-environmental monitoring and information system in the New York Bight in the form of a system using computerized buoys and radio telemetry that allows for the continual monitoring (at strategically located sites throughout the New York Bight) of the following: wind, wave, current, salinity and thermal gradients and sea chemistry, in order to measure the effect of changes due to air and water pollution, including changes due to continued dumping in the Bight*

(b) *In addition, the Secretary shall study a proper physical hydraulic model of the New York Bight and for such an offshore model to be tied into the existing inshore physical hydraulic model of the Port of New York and New Jersey operated by the United States Army Corps of Engineers.*

(c) *The Secretary shall coordinate fully with the Administrator of the Environmental Protection Agency in carrying out the study described in this section and shall report any findings and recommendations to Congress. The Secretary and the Administrator shall also consider the views of other appropriate Federal, State and local agencies, academic institutions and members of the public who are concerned about water quality in the New York Bight.*

(d) *There is authorized to be appropriated not more than $1,000,000 per fiscal for each of fiscal years 1987, 1988, 1989, 1990 and 1991.*

Funding for the studies was appropriated and the five year study began in fiscal year 1989. A map showing the extent of the New York Bight appears below (Figure 1).

The study is being coordinated with the U.S. Environmental Protection Agency (USEPA), other appropriate agencies, academic institutions and the public. The New York District is being assisted by the U.S. Army Corps of Engineers' Waterways Experiment Station (CEWES), Vicksburg, MS and the Waste Management Institute of the Marine Sciences Research Center, State University of New York (WMI, MSRC, SUNY) Stony Brook, NY.

Monitoring Workshop Goals

The goal of the monitoring workshop is to focus the direction of further monitoring feasibility studies. This will be accomplished by evaluating a list of monitoring needs, surveying existing monitoring programs in the New York Bight, determining possible data gaps, discussing database/information systems for the New York Bight and discussing innovative monitoring methods appropriate to the needs. The purpose of developing a New York Bight Monitoring Database and Information System is to be able to access relevant information for the New York Bight Modeling feasibility studies. The data would be used both to run and to verify hydrodynamic and water quality models of the New York Bight. The types of models best suited for further investigation will be discussed at the New York Bight Modeling Workshop 11-12 July 1989.

Monitoring Needs/Coordination With Other New York Bight Studies

Effective management of the New York Bight includes the evaluation of impacts caused by both human activities and natural events. The overall feasibility study will evaluate both modeling and monitoring the Bight. Numerical models will be evaluated for their ability to predict environmental and physical changes. This workshop (28-29 June, 1989) is concerned with monitoring. The list of monitoring and modeling needs were proposed for these Bight studies by the New York District. The list is based on impaired uses of the New York Bight which were identified by the USEPA New York Bight Restoration Plan and on other human activities. These monitoring needs were coordinated with the Dredged Material Disposal Management Plan Steering Committee, the Corps' Public Involvement Coordination Group and the New York Bight Restoration Plan members.

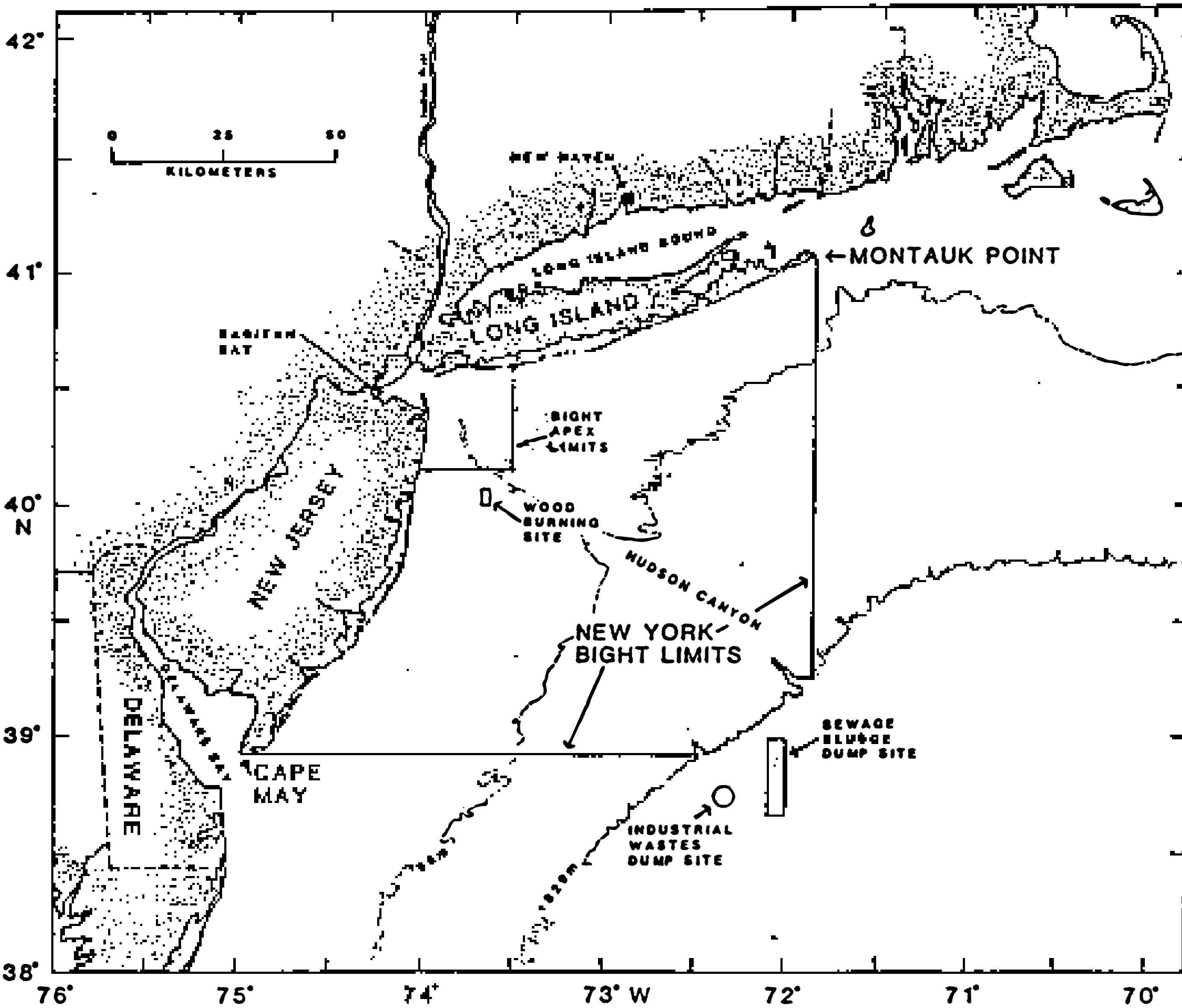

Figure 1. New York Bight and approaches.

This strawman lists oceanographic parameters which could be monitored, including those which should be measured in real-time via remote sensing and data telemetry in support of modeling efforts. Impaired uses of the New York Bight include:

a. Beach Closures
b. Unsafe Seafood
c. Adverse Impacts on Commercial/Recreational Navigation
d. Adverse Impacts on Commercial/Recreational Fisheries
e. Impacts to Birds, Marine Mammals, and Sea Turtles
f. Loss of Aquatic Habitat

Other human activities which are monitored in the New York Bight include:

a. Disposal at the New York Dredged Material Disposal Site, inlet disposal sites, and other future disposal sites.
b. Wood burning at sea.
c. Construction/modification of coastal structures and fill (both nearshore and offshore).
d. Sewage sludge disposal at the 106-mile site and impacts of the former 12-mile site.
e. Acid waste and chemical waste disposal.
f. Disposal of cellar dirt at the Cellar Dirt Disposal Site.
g. Coastal wastewater treatment discharges and combined sewer overflow.
h. Oil or chemical spills.

Coordination is underway between the New York District and the Chesapeake Bay monitoring and modeling program through the Waterways Experiment Station. The New York District is also coordinating with the Philadelphia District on their New Jersey Coastal Protection Feasibility Study. This will include the use of coastal data to evaluate potential areas for coastal erosion protection projects from Sandy Hook to Cape May, New Jersey.

Approach to Monitoring

Survey of Existing Monitoring within the Bight

Oceanographic studies conducted over the past 30-40 years have resulted in a large historical data base for the Bight. This data base, compiled from data sets originally collected for a variety of research and monitoring objectives, provides a basis for selecting the parameters to be monitored (Stoddard, et al., 1986). Table 1 contains an outline of these parameters.

Some of the existing monitoring programs include measurements at existing disposal sites and other locations where pollution problems have been observed. Sewage sludge is now discharged at the Deep Water Dump Site (106-mile). Dredged material is discharged some 6 nautical miles off the northern New Jersey Coast (Figure 2). For monitoring outside of the disposal site confines, some key areas which are early indicators of potential pollution (anoxia) are located in Christiansen Basin (Figure 3). Other regions where anoxia occurs almost regularly are just offshore of the New Jersey coastal inlets. A critical area for current measurement is just off the southeast coast of New Jersey where an occasional weak northward flowing current in summer meets the normal southward flowing plume from the Hudson-Raritan Rivers. A stagnant flow along the central Jersey coast results and anoxia conditions develop. The area within 10-20 miles east of the New Jersey coast is also where the "Green Tide" develops on occasion. A summery of existing monitoring programs has been provided by the Waste Management Institute.

Information System/Database Development

A Geographical Information System (GIS) is being established for the New York Bight to provide the Corps with digital cartographic data sets in GIS formats as a management tool. A GIS is an automated system for the capture, storage, retrieval, manipulation, analysis and display of geographical information. Data is made available as layers within a GIS, which may be combined or otherwise manipulated easily. This ability allows decision-makers to present the data base and to examine different scenarios related to monitoring needs in light of the vast quantity of relevant information.

The system will be developed at Hunter College using Calcomp and Altek hardware and software from Altek, ERDAS, ARCINFO and AUTOCAD and coordinated with existing data bases held by the New York District and CEWES. Some of the types of maps that will be included in the GIS include bathymetry, grain size, fisheries, benthic data and current and drift information.

An efficient data base would include only the essential parameters with sufficient spatial density to be able to discriminate among different locations in the Bight. It would also be able of containing time series of

Table 1. Physical and Environmental Parameters and Methods for Sampling.

Parameters	In-Situ/Sample Method	Remote Sensing	Comments
1. Dissolved Oxygen	Galvanic polarographic membrane probe, Benthos		Electronic methods require calibration and "Ground Truthing". Use method consistent with historical data.
2. Oxygen Demand (COD & BOD)	Wet chemistry Niskin bottles		Use established protocols for laboratory analyses. Includes chemical and biological oxygen demands (COD, BOD).
3. Suspended Sediment Concentration	Transmissometer Wet chemistry	Coastal Zone Color Scanner	Use established protocols for laboratory analyses.
4. Light Attenuation	In-situ light meter		Earlier chlorophyll data related to Secchi disk; newer data may rely on in-situ light meter. Both are currently needed.
5. Transmissivity	Transmissometer		Use transmissometer with proven track record.
6. Fluorescence	Brookhaven NL fluorometer		BNL fluorometer also set up to measure chlorophyll and primary production.
7. Chlorophyll Concentration	Moored BNL fluorometer Vertical profiler Wet chemistry	Satellite Color Images	Color scanner yields synoptic horizontal distribution of chlorophyll. These images need to be digitized at same location as for AVHRR.
8. Vertical Profiles: Temperature/Salinity Density/Ph	CTD Inductive conductivity cell Resistance temperature device Thermistor		Use CTD with good data transfer capabilities.
9. Sea Surface Temperature	CTD Resistance temperature device Thermistor	AVHRR Thermal IR Scanners Microwave Radiometers	These images need to be digitized at same location as for color images.
10. Eulerian Current Speed and Direction	Acoustic Doppler expendable probe Electromagnetic profiling current meter	Altimeters	This method does not resolve the upper few meters of the water column.
11. Lagrangian Current Speed and Direction	HF radar Drifting buoys drogued at 0-2 meters±	CODAR RADS (Acoustic)	This method supplements 7a by resolving the upper few meters of the

Table 1. (Continued)

Parameters	In-Situ/Sample Method	Remote Sensing	Comments
12. Water Level Height	Coastal tide gages Use available NOS stations	Altimeters	
13. Wind Speed and Direction From Coastal Stations	Use available NWS stations	Microwave Radiometer	
14. Wind Speed and Direction From Offshore Buoys	Inverted echo sounder Vane-mounted anemometer Propeller driven anemometer Cup-type anemometer	Satellites Meteorological Buoys	If additional wind stations are needed the vane-mounted anemometer has no moving propeller, is small, uses minimal power.
15. Wave Height and Direction	Ultra-sonic, infrared laser, inductive staff, capacitance staff, incremental digital, resistive staff, pressure gage, microwave doppler radar, inverted echo sounder	Imaging Radar (SAR or SLAR)	
16. Precipitation	WOTAN inverted echo sounder Use available NWS stations		
17. Sediments	Sediment grabs laboratory analysis	Multispectral Scanners RADS(Acoustic) UW Camera	Analyze the upper 2 cm to be consistent with EPA protocols.
18. Atmospheric Pressure			

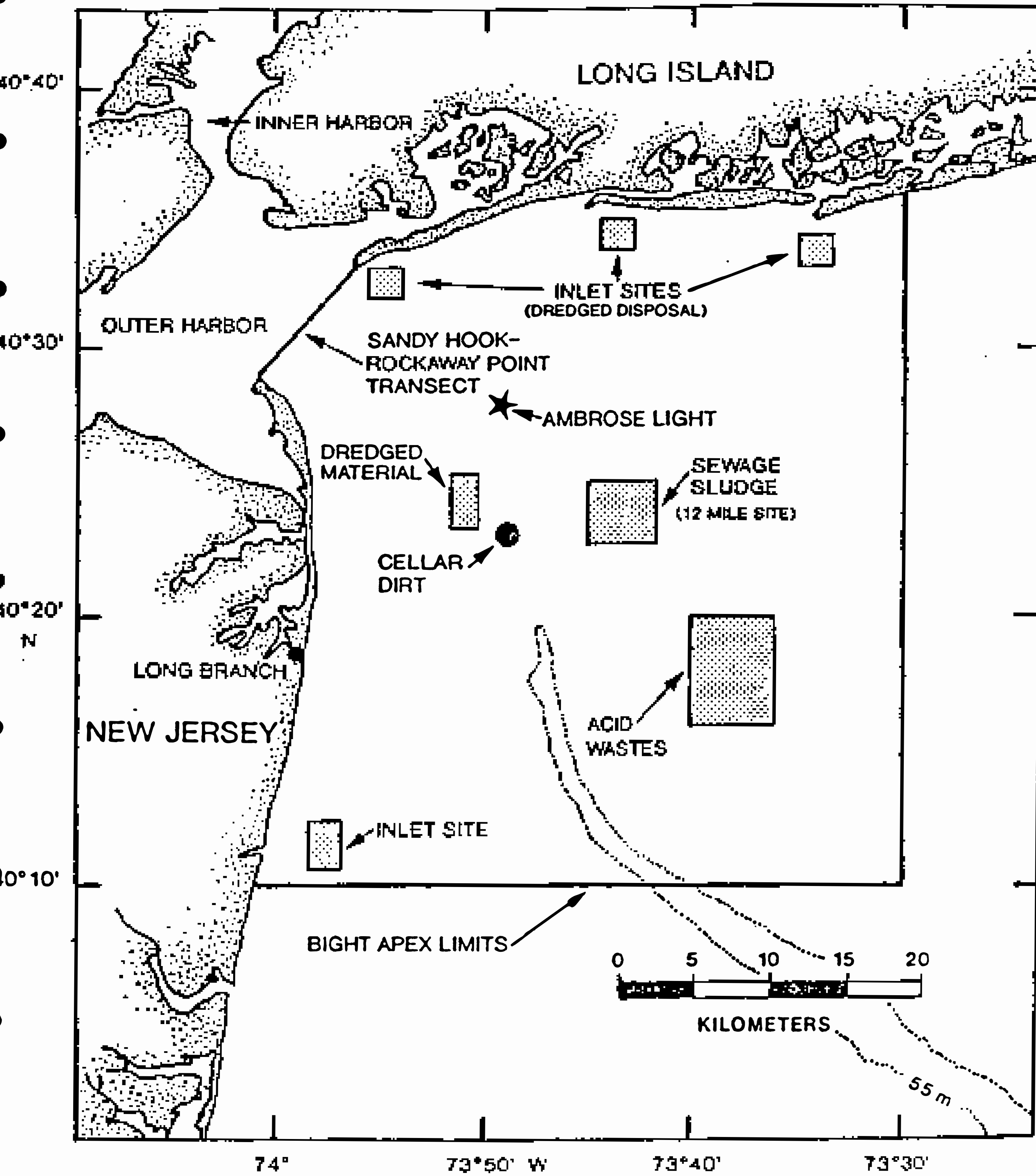

Figure 2. New York Bight apex and disposal sites.

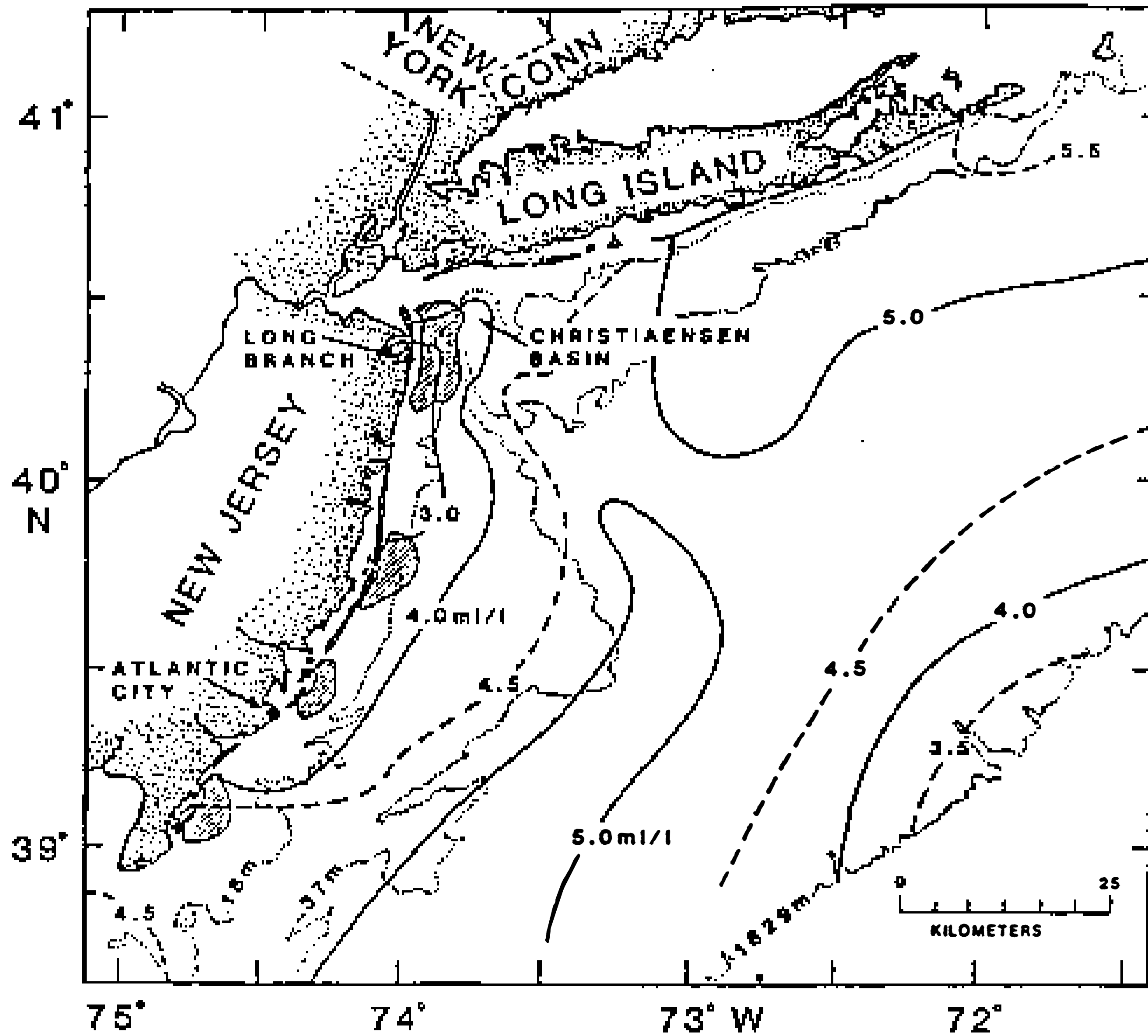

Figure 3. Contours of summer (July-Sept.) average concentration of dissolved oxygen near the bottom (adapted from Stoddard et al. (1986). Hatched areas indicate regularly occurring hypoxia.

measurements that had been made at a sufficient frequency to capture short-lived but significant events and over times long enough to determine the range of environmental variation. The measurements should be made in a form that is most directly applicable to the information system so that the data base could be used with the least amount of reduction, processing and analysis. The measured parameters must also be the appropriate ones for use in developing various mathematical models for two reasons. First, some measurements can only be made at a few locations and verified models provide a way to interpolate and extrapolate the point measurements to the entire region of interest. Second, abased on the present status, predictions of the future situation will be required. This can only be done with models.

In general, there are four types of oceanographic monitoring that can be considered.

1. Measurement of independent variables, such as water temperature, selected chemical contaminants, etc.;

2. Measurement of influencing factors, such as direction, intensity and constancy of winds;

3. Measurement of effects, such as fin rot disease, population changes; and

4. Measurement of response of indicator organisms, such as the presence or absence of organisms, bioaccumulation, etc.

Some of these types of measurements can be incorporated directly into an information system, while others, like the influencing parameters, will need to e used to calculate a range of relevant parameters. Wind speeds, for example, could be used to calculate shear stress at the water surface for use in hydrodynamic models. Directly measured effects or the response of indicator organisms might be used as a test of response of model predictions and an efficient information system must be able to handle all these types of observations and allow the necessary manipulation for their various applications.

Time Scales

The design of the monitoring information system/database will depend on the time scale of interest for modeling: daily changes, monthly variability, seasonal variability, interannual variability, and decadal variability.

1. Daily changes: Some events, such as storm resuspension or plankton blooms, are so intense that, although short-lived, they cause a substantial perturbation of the system that outlives the event itself. A monitoring program should capture such events to properly resolve the causes of long-term changes. Parameters in this class are probably the ones for which real-time, continuous measurements would need to be made.

2. Monthly Variability: At this time scale the interactions between environmental parameters are very important. The relations are quite complex requiring many measurements to quantify the processes. Many oceanographic studies belong in this category.

3. Interannual Variability: To examine the variability between years, investigators usually begin with monthly samples available during a decade.

4. Decadal and Long (Climatic) Variability: To examine the variability between decades, investigators often begin with annual summaries derived from long records of environmental parameters.

Synoptic measurements will likely be an important requirement for some of the parameters regardless of the time scale.

Areas to Monitor/Monitoring Scales

The information-system/data-base program should be designed with both broad regional coverage and specific observation of particularly critical or sensitive areas. The entire region should be broadly classified so that monitoring data can be accessed within these characteristic regions with widely spaced samples of a few parameters. The National Oceanic and Atmospheric Administration segmented the Bight in terms of distinctive and controlling bathymetric features as well as major areas of impact (Figure 4).

The critical areas for the monitoring feasibility studies depend on the objectives of the monitoring and modeling program. These may include:

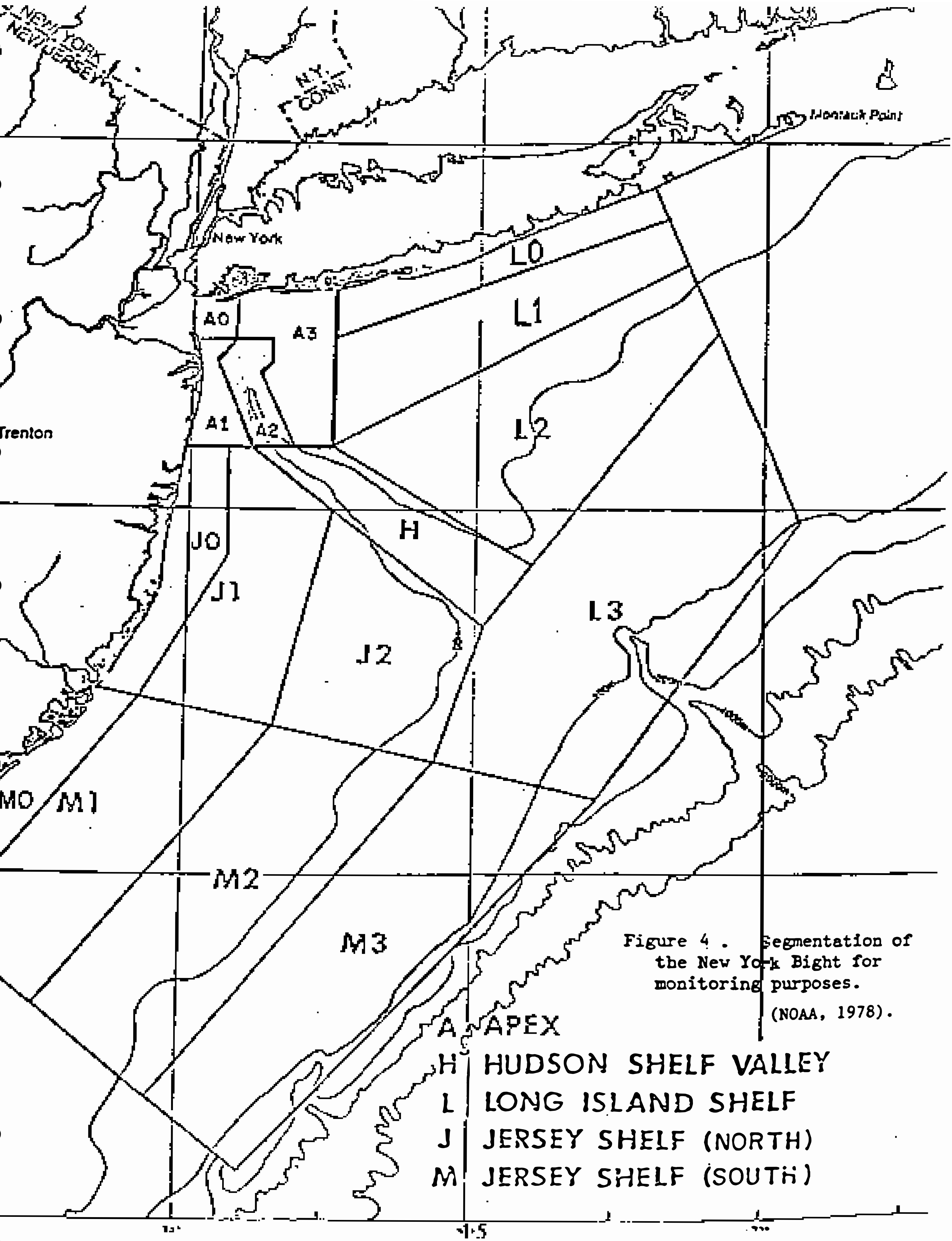

Figure 4 . Segmentation of the New York Bight for monitoring purposes. (NOAA, 1978).

Monitoring to provide in-situ data that can be used in conjunction with other types of data acquisition such as remote sensing to provide ground truth or subsurface data not sensed by the aircraft or satellite.

Monitoring to provide boundary conditions for input to a physical or numerical model, and to provide calibration/verification of model predictions at interior grid points.

Measurements in support of modeling are more difficult because the open boundaries occur in deeper water and greater distances from the coast. Also, a large number of sensors are needed to obtain adequate representation of conditions along each boundary. Critical areas for modeling the Bight include the longshore currents on both the eastern and southern boundaries of the Bight and the flux across the Sandy Hook-Rockaway Point transect (Figure 4). The currents in the Hudson Canyon are also an important part of the circulation within the Bight.

The data from a limited number of in-situ sensors in deep water can be supplemented by other routine or specially scheduled monitoring events. During periods of routine maintenance of offshore installations a ship may be available to perform limited oceanographic surveys. Aerial surveying can be performed on short notice to augment the surveys. Satellite sensing does not require mobilization. Coordinated surveys could be performed at critical times based on telemetered information.

A first level of effort would be a survey of existing monitoring programs. It would incorporate reliable data from other Federal, State, and local monitoring activities. It could also include data from special surveys or studies wherein physical, chemical, and/or biological process information has been obtained.

MONITORING INSTRUMENTATION

Computerized buoys and radio telemetry of some meteorological and physical oceanographic parameters have been in use since mid-1970's for weather-related purposes by the government. Remote sensing of winds, waves, tides and currents and in-situ dat processing and telemetry have been routinely used on offshore oil and navigational platforms by the oil industry, contractors, and various government agencies since the early 1970's. More sophisticated meteorological and physical oceanographic instrumentation at sea, in the air or on land requires greater data collecting, processing, storage and transmitting capability and represents the next step in the technological development and application to oceanic monitoring in areas such as the Bight.

On the other hand, chemical geological and biological parameters have been normally monitored using shipboard measurements due to the complexity of the parameters being measured. Analytical techniques have gradually evolved from classical wet and dry laboratory apparatus to electronic techniques capable of in-situ sensing. Some instruments capable of remote sensing and storage of biological, geological (suspended sediments) and chemical data are now being placed on moorings. Paralleling the course of development of the above physical parameters, real-time measurement and transmission of selected chemical, geological and biological parameters is the next step in the innovative process. This development also includes remote sensing from space.

It should be emphasized that presently, only a few meteorological and oceanographic parameters can be monitored using in-situ measurements or remote sensing and them transmitted back to land for immediate use. None of these parameters measure contaminants directly, but they may provide information useful in monitoring contaminants and water quality indirectly such as low dissolved oxygen, unfavorable currents, etc.

In general, desirable systems are those that make use of existing platforms (vessels, navigational aids, satellites). Moored systems may be used if other options are unavailable. Efforts should be made to telemeter data to shore to reduce the need for offshore maintenance, data processing and storage. Emphasis should be placed on sensors that have few or no moving parts and can obtain information from a number of water depths. To reduce costs, vessel-mounted systems should be minimized.

1. Remote Sensing

Remote sensing offers the potential for obtaining enormous amounts of information in near real-time for a fraction of the coast associated with vessels and moorings. It is possible to obtain synoptic measurements of selected oceanographic parameters several times per day using satellite sensors. The same sensors could be placed on aircraft to provide near-synoptic daily coverage of the Bight. Aircrafts offer greater schedule flexibility in surveying than satellites and have greater resolution due their proximity to the sea surface. Helicopters provide the same capability as fixed wind aircraft, but at increased costs. However, the helicopter has the capability of suspending instruments at given locations.

Both satellite and aircraft remote sensing suffer from water vapor in the atmosphere. Clouds cover more than a quarter of the sky during 60% of October, considered a clear month. In the next few years all of the AVHRR temperature and color data will be digitized for cloud free areas by members of the Northeast Area Remote Sensing System Association (NEARSS). Most sensors depend on reflected solar radiation and thus cannot function at night. In terms of monitoring pollution at critical areas, the remote sensing techniques that are currently available provide few quantitative measurements of pollutants. Several sensors can detect oil at the sea surface and the upper water column. Remote sensors also provide information that can be used indirectly n the analysis of pollutant transport as in the dispersion of disposed chemical sat dump sites or the movement of suspended sediments in the Hudson River Plume.

Several parameters near the water surface can be measured with varying degrees of accuracy (e.g., sea surface temperature (SST), altimetry, wave heights, water transmissivity, salinity, chlorophyll a). These properties are not measured directly, but are calculated from reflected solar radiation or radiated thermal infrared/microwave energy. Altimetry data will be available in the near future, but there are problems in the near-shore areas. Here the different heights. Thus, for altimetry data the direction of the orbit is important. To provide the best results, "ground truth" data are necessary to calibrate the received signals.

The remote sensors considered reliable and available (i.e., operational) have been included in Table 1 with respect to the environmental parameters suggested for the monitoring program. Included in this table for remote sensing capabilities are experimental or commercial systems using HF radar sensed currents (CODAR, MIROS, OSCR and U.S. Naval Research Laboratory systems). These systems will not provide direct measurements of marine contaminants, but sense the currents which may carry them to the shore.

Table 2 lists the relative ranging of the performance of sensors. This table was developed by participants at a recent workshop (Department of Commerce, 1987).

Table 2. Performance of Remote Sensors

Sensor	Platform	Veg.& Land Use	Biomass & Veg. Stress	Coast-line Erosion	Bottom Feat. SAV	Depth Profiles	Susp. Sed. Ptrns.	Susp. Sed. Concen.	Chlorophyll Concen.	Oil Slicks	Surf. Temp.	Water Sal.	Curr. Circ. Ptrns.	Wave Spectra	Surf Wind
Film Cameras	A	3	2	3	3	2	2	1	1	2	0	0	2	2	1
	S	2	1	2	2	1	2	1	1	1	0	0	2	2	1
Multispectral Scanners	A	3	2+	3	3	2	3	2+	2+	3	0	0	2	2	1
	S	2	1	2	2	2	3	2	2	2	0	0	2	2	1
Thermal IR Scanners	A	1	1	1	0	0	1	0	0	3	3	1	2	0	1
	S	0	0	0	0	0	1	0	0	1	3	0	2	0	1
Laser Profilers	A	0	0	1	2	3	1	0	0	1	0	0	0	3	1
	S	0	0	1	1	1	0	0	0	0	0	0	0	2	0
Laser Fluorosensors	A	1	1	0	0	0	2	2	3	3	1	1	1	0	0
	S	0	0	0	0	0	1	1	1	1	0	0	0	0	0
Microwave Radiometers	A	1	0	0	0	0	1	1	0	2	3	2	2	1	3
	S	0	0	0	0	0	0	0	0	1	2	1	1	0	2
Imaging Radar (SAR or SLAR)	A	2	1	3	0	1	1	0	0	3	1	1	2	3	2
	S	1	0	2	0	1	0	0	0	2	0	0	1	2	1
CODAR (Radar)	G	0	0	0	0	0	0	0	0	0	0	1	3	2	2
RADS(Acoustic)	G	0	0	2	3	3	2	1	0	1	0	0	3	1	0
UW Camera	G	0	0	2	3	2	2	1	1	1	0	0	1	0	0

Rating

3 - Reliable and Available (Operational)
2 - Qualitative and/or Needs Additional Testing
1 - Experimental and/or Not Widely Available
0 - Not Applicable

Platform

A - Aircraft (Medium or Low Altitude)
S - Spacecraft (Satellite)
G - Ground (Boat or Field)

2. In-Situ Sensors

Several new technologies fro measuring parameters are commercially available. Others developed for a specific project or parameter may be adapted for use in the Bight and perhaps for collecting a variety of parameters. Those still in the research phase may become available as the feasibility study progresses.

The following systems are revolutionary in that physical, chemical, and biological parameters can be measured electronically at the same time and location.

a. Dissolved Oxygen - Benthos has a new pulse probe which can be left unattended for about 3 months. Apparently it compensates for fouling by sulfides.

b. Chlorophyll and Primary Production - Fluorometer developed by Brookhaven National Lab. This sensor offers the first capabilities for physical and biological oceanographers to sample simultaneously electronically. This unit will be developed commercially by Sea-Tech of Oregon.

c. Currents - In the recent past Acoustic Doppler Current Meters have become reliable when used on a fixed platform (bottom tripods, dolphins, towers). An ADCP was calibrated at RD Instruments for measurement concentrations of medium sized zooplankton. Several new drifters are under development to mimic floatable materials. These include drifters developed by Russ Davis, Peter Niller, and Warren White (Tri-Star), MMS under contract to Greenhorn and O'Mara, and Draper Labs.

   The main advantage of these drifters is that they will eliminate wavage.

d. Winds and Precipitation - An Inverted Echo Sounder (IES) can be equipped with a device to measure in-situ noise (WOTAN). From the data, wind speed and precipitation can be measured.

3. Data Telemetry

The Bight may be outfitted with a suite of environmental sensors installed at distances of 100 meters to 200 kilometers from shore. There are four methods for relaying electrical signals from the sensors to a central location: hardwire, fiber optic, radio and direct optical.

To select a method, three considerations are necessary: 1) installation and relocation costs for hardwire and fiber optics can dwarf the costs for telemetry hardware; 2) only in the simplest, low-power systems will solar power be adequate to sustain telemetry (unless direct power is available, regular battery replacement must be assumed; the actual power requirements cannot be quantified without specific information as to range offshore and data transmission rate); and 3) some methods do not provide continuous, real-time output.

a. Hardwire

This means that the device at sea is connected directly by an electrical wire to some shore-based station for recording, data storage and transmission.

(1) Single Conductor - The simplest method of collecting data from any collection point utilizes a conducting wire. This type of connection is limited to a few hundred feet from shore and is subject to damage by commercial offshore activity.

(2) Multiple Conductor - This method uses a cable having additional, insulated signal conductors (up to 100). This connection is also limited to a few hundred thousand feet. However, in some applications there are advantages. The additional conductors can be used to carry power and control signals to buoys.

(3) Modems - Because the cable resistance and capacitance have a dramatic impact on signal quality, a carrier frequency technique must be used for long lengths of cable. The same wire pair can be used to simultaneously carry a voltage supply to the buoy.

b. Fiber Optic Light Pipe

A fiber optic light pipe provides the highest transmission rate and the least bulky cable. Cable may be expensive and not repairable in the field, as is the case for other hardwire systems. Fiber optic cables are manufactured with accompanying insulated conductors to also supply power to remote data collection sites.

c. Radio

There are four types of radio telemetry: high frequency (HF), very high frequency (VHF), ultra high frequency (UHF) and microwave. The range cost, power and directional requirements become less favorable with increasing frequency. However, licenses become easier to obtain with increasing frequency.

At the high frequency end, microwave's limited range and the directional nature of a high-gain antenna preclude the use of this band on an unstable platform such as a buoy. In the VHF and UHF bands, the differences are minor with some advantage to UHF band due to smaller antennae and channel availability.

Radio frequencies can be used in six modes of operation: 1) transmitter only - the simplest radio telemetry is operated under control of it's internal electronics; 2) transceiver at the buoy - this allows multiple buoys to be placed on a single channel but requires transceivers at both end of the radio link; 3) satellites - to overcome the range limitations imposed by the radio horizon, satellites may be used as a relay station. The low data rate usually necessitates on-buoy processing to summarize the sensor readings; 4) meteor burst - this method employs forward scatter of radio waves off meteor showers to accomplish over-the-horizon telemetry. This technique is not considered useful for a buoy application due to the high power and large antennae required; 5) aircraft fly by - a small aircraft can fly by the buoy sites. Although this is not a completely automated approach, it offers greater schedule flexibility; 6) cellular phone - options offered include "dial up" and interrogations from virtually any location. Data are then transferred using standard modems. Distance offshore is limited.

Using the above information, preliminary estimates of the usefulness of the various telemetry techniques can be made (Table 3). No single method appears optimal for all buoy locations within the Bight.

Table 3. Summary of Radio Telemetry Techniques

Parameter	Transmitter	Transceiver	Satellite	Meteor Burst	Aircraft	Cellular Phone
Range (miles)	10	10	1000's	500	100	5
Equipment Costs	2-3K	3K	1-5K	30K	3K	4K
Installation Costs	L	L	L	H	L	L
Operating Costs	L-M	M	L-M	H	H	M

Notes: Installation and Operating Costs (High, Low, Medium);
Medium indicates battery service.

d. Direct Optical

Infrared - data can be telemetered short distances (100-1000 feet) using the method of modulating the output intensity of a light emitting diode. These units are generally operated in the infrared portion of the spectrum to permit use n the presence of visible light. Highly directional and opaque objects, such as precipitation, severely attenuate the signal.

INSTRUMENT PLATFORMS

Platforms for sensors and/or data processing, storage and telemetry equipment include:

Shore-side piers, lighthouses and dolphins
Offshore towers or lighthouses (e.g., Ambrose Light)
Bottom tripods
Surface buoys with taut-wire moorings
Existing navigation, NOAA and Coastal Marine Automated Network (CMAN)

A number of measurement platforms currently exist within the Bight (Figure 5). NOAA's Data Buoy Center collects and processes the measurements made at Ambrose Light. Ambrose Light is currently maintained by the Coast Guard, has electrical power, is centrally located at the entrance to New York Harbor and has space for additional equipment. NOAA also maintains a number of shore-side platforms. Within the Bight there are two primary coastal weather platforms. Within the Bight there are two primary coastal weather stations (JFK Airport and Atlantic City), seven tide stations, and a number of stream flow gages. There are also a number of Coast Guard aids to nearshore navigation within the Bight.

Taut-wire moorings are traditional platforms for sensors of physical parameters. These moorings are normally outfitted with acoustic releases for water depths greater than 100 feet. These platforms, while able to accommodate many instruments needed for monitoring the Bight, would require surface buoys for telemetry equipment.

There presently exists a mooring for measuring currents at the 106-mile dump site. This mooring contains a surface buoy and currently telemeters

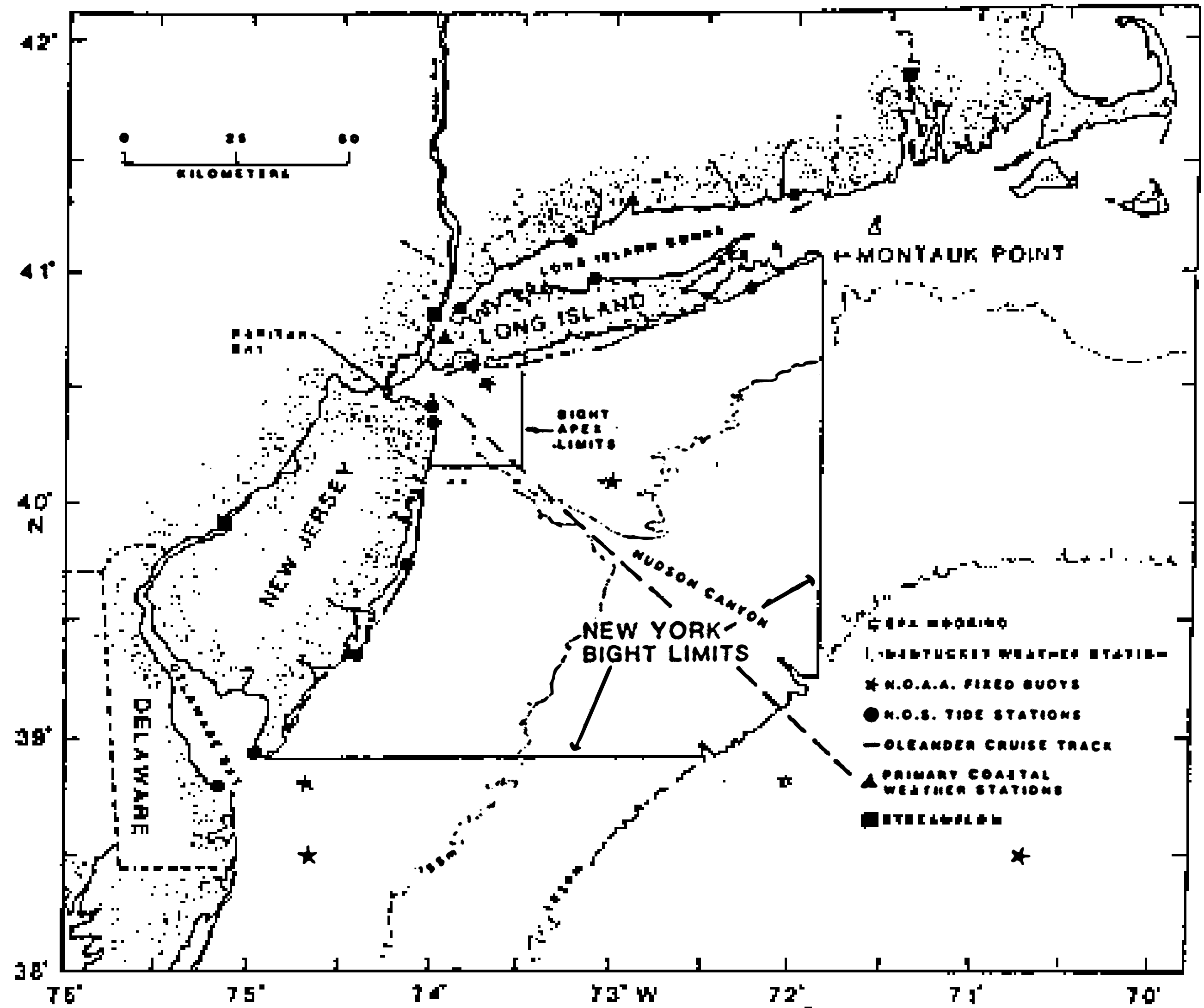

Figure 5. Existing measurement platforms in the New York Bight.

data to shore and will likely be in place a number of years. In addition a number of ships transit the area routinely; one vessel (Oleander) has been outfitted with oceanographic sensors.

WATER QUALITY

In developing a monitoring feasibility study, consideration must be given to the identification of the mass flux of contaminants from the waters of Hudson-Raritan system along with the wastewaters from primary and secondary treatment facilities that discharge into the Bight. In addition, to ascertain the sources and sinks for the various pollutants, the interactions between the water column and the sediments from particulate and dissolved constituents (e.g., heavy metals, PAHs, nutrients) must be determined and monitored. Considering the high nutrient loads to and the past history of anoxia in the Bight along with numerous nuisance algae blooms, specific attention must be given to delineating monitoring requirements so that data and information will be available for technical evaluations and management decision-making.

BIOLOGICAL RESOURCES

Obtaining quantitative information about a given fish or shellfish species or assemblage is difficult. Most sampling devices are selective in terms of size, causing a bias in the resulting estimates of density, species diversity or biomass. Considerable difficulty is often faced in obtaining replicate data. Variability n abundance of fish and shellfish species and variation in sampling equipment and methods makes comparisons of data from various sources imprecise over large areas.

Sampling of nektonic organisms (fishes, shrimps and crabs) is most commonly accomplished through the use of nets or traps of various types, although as acoustic methods for identifying fish populations becomes more sophisticated, such remote technologies may be important. Nets generally collect a generated diversity of organisms than do traps. Traps usually are designed to attract and capture a particular species (e.g., crab pots). The choice of sampling device(s) for monitoring depends on the type(s) of organism(s) of interest. Nets are either passive or active collectors of organisms. Passive nets are set in stationary position, collecting organisms which become entangled (e.g., anchored gill net, hoop net and fyke net) or entrapped within the confines of the netted area (e.g., fish traps) and may require extended periods of deployment, in-place and recovery time. Active nets (e.g., otter trawls and purse seines) are towed through the water and produce more immediate results.

Macrobenthos and submergent vegetation, because of their sedentary existence, require a tolerance of short-term variation in environmental conditions, and they may reflect long-term, integrated conditions. In addition, they can be quantitatively and efficiently sampled.

Benthic sampling devices come in a wide variety of designs and sizes. many were developed and used on a regional basis and as a consequence are little known outside their respective areas. However, certain commonly used samplers have had wide-spread application.

A number of trawls and dredges have been designed and used as qualitative samplers of epifaunal and infaunal organisms in a variety of habitats, particularly in water deeper than 10 m (e.g., epibenthic sleds). These devices are best used for the purpose of general description of the assemblages present (species presence/absence).

Grab samplers and box corers are usually the tools of choice for quantitative sampling of sessile epifauna and infauna (to the depth excavated). Some of the more commonly used grabs include the Peterson, van Veen, Ponar, Ekman and Smith-McIntyre grabs.

DATA ANALYSIS, DISPLAY AND ARCHIVE

The program should be designed to provide the manager with the needed information in the most direct form. Data reduction, processing and presentation should be automated whenever possible although the storage of raw data for its potential use in later analyses may also be desirable.

All data analyses will be documented and standardized as part of the monitoring system design. The display (video and hardcopy) formats of the monitored parameters should be designed and reviewed for applicability.

Possible devices and techniques used to store data during collection and afterwards are outlined below.

a. Existing Devices
   1. Floppy Disks

2. Magnetic Tape
3. Removable Hard Disks and Cartridges
4. Optical Disk Storage

b. Future Devices
1. DATS - (Digital Audio Tapes)
2. CD-ROM Disks - (Read Only Memory)

MONITORING CONSTRAINTS

The choice of instrumentation is critical and our ability to make a wide variety of measurements must be judiciously applied. In addition, investigations so far have indicated the following physical and logistical constraints would effect the monitoring program:

- In-situ instrumentation to monitor the water surface, especially for floatables, is not well developed. Most floatable measurement programs have been conducted from vessels.

- Maintaining in-situ gear in water shallower than 30-40 feet has proven difficult due to waves, storms and commercial traffic. Loss of gear is a major problem. However, it appears necessary for this monitoring program to measure parameters in-situ within the Hudson-Raritan plume, and to do so will likely require the establishment of fixed sensor platforms.

- Biological and sediment fouling and corrosion of gear may be a major problem in shallow areas and within the Hudson-Raritan plume, especially areas that may be anoxic.

- Platforms need to be designed to withstand breaking hurricane waves.

- When available all positioning should be done using NAVSTAR Global Positioning systems (GPS). However, until then, LORAN or SATNAV will probably be appropriate for use.

SUMMARY

The purpose of the strawman is to provide a starting point for discussion which will be useful in the evolution of the feasibility studies of monitoring and modeling in the New York Bight. It is the task of this workshop to catalog existing monitoring efforts in the Bight, to evaluate the usefulness of information and the reliability of data for modeling, to recommend additional measurements that are needed to fill data gaps and to identify the best, innovative techniques that may be applied to make these measurements (e.g., GIS's, satellite-borne sensors, telemetry, etc.). After the initial presentation concerning the continuing programs and the state-of-the-art of marine measurement systems, the workshop participants will join subgroups to discuss the best uses of the existing data and the most promising approaches for supplementing the data base. The subgroups response to the topics presented in this Strawman will then be integrated into a concensus opinion for the guidance of the next phase of these studies.

REFERENCES

Department of Commerce, 1987. "Remote Sensing of Estuaries, Proceedings of a Workshop." Editors: V. Klemas, J. P. Thomas and J. B. Zaitzeff. June 1987, Washington, D.C., 241 pp.

Stoddard, A., O'Reilly, J. E., Whitledge, T. E., Malone, T. C., and Hebard, J. F., 1986. "The Application and Development of a Compatible Historical Data Base for the Analysis of Water Quality Management Issues in the New York Bight." OCEANS 1986, pp 1030-1035.

National Oceanic and Atmospheric Administration, 1978. "Monitoring Plan for the New York Bight." MESA New York Bight Project, 63 pp.

III. STRAW-MAN PROPOSAL: NEW YORK BIGHT HYDRO-ENVIRONMENTAL MODELING STUDY

Introduction

The current law (Sec. 728a) under the Water Resources Development Act of 1986, PL 99-662, mandates that a feasibility study for a state-of-the-art monitoring and information system be conducted for the New York Bight. The study is to be coordinated with appropriate Federal, State, and local agencies, academic institutions, and interested members of the public. The goal of the study is to devise a monitoring and modeling strategy that can be used to document and predict the effects of changes to the New York Bight ecosystem. These changes include air and water pollution, other human activities, and natural events.

The purpose of the modeling workshop is to decide through consensus building what processes can be feasibly modeled, define necessary model capabilities, and then formulate the best plan for conducting the modeling feasibility study. This straw-man proposal is aimed at providing a starting point for workshop discussion.

Use impairments and human activities in the New York Bight that are of particular concern to the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, and other federal, state, and local groups have been identified. A list of use impairments includes the following:

a. Beach closures

b. Unsafe seafood

c. Adverse impacts on commercial/recreational navigation

d. Adverse impacts on commercial/recreational fisheries

e. Impacts to birds, marine mammals, and sea turtles

f. Loss of aquatic habitat

Impacts of the following human activities also are of special interest as are the relationships between these activities and the use impairments:

a. Dredged material disposal at the Mud Dump Site, inlet disposal sites, and any other future disposal sites

b. Wood burning at sea

c. Construction/modification of coastal structures in the nearshore zone as well as future construction of offshore structures built to accommodate solid waste disposal

d. Sewage sludge disposal at the 12-mile and 106-mile sites

e. Acid waste and chemical waste disposal

f. Disposal of cellar dirt at the Cellar Dirt Disposal Site

g. Coastal waste water treatment discharges and CSO's

h. Oil or chemical spills

Effective management of the New York Bight necessitates the development of certain planning and evaluation capabilities, and recommendations for applying these capabilities, to ascertain impacts caused by these activities.

The Section 728 feasibility study includes both modeling and monitoring components. The two components complement each other, and will be conducted interactively through an exchange of information. Measured data are needed as input during various stages of model testing and demonstrations of model feasibility. A major product of the modeling study will be an assessment of data needs for ultimately applying the modeling system as a planning and evaluation tool; these needs include information for specifying model boundary conditions, external forcing, and other model parameters. Model results can also be used to identify locations where special monitoring considerations may be warranted. These types of information will be incorporated into the monitoring strategy that evolves from the monitoring feasibility study. A separate straw-man proposal exists for the monitoring portion of the feasibility study; this straw-man proposal only addresses the modeling portion.

Numerical models have been successfully applied by the Corps in the past to investigate a variety of problems that require the study of hydrodynamic, water quality, and sediment quality interactions (for example, the Los Angeles/ Long Beach Harbors and Chesapeake Bay modeling studies). These same types of interactions are important in determining the impact of the aforementioned activities on the New York Bight environment. A next logical step is to investigate the feasibility of applying similar numerical modeling technology to the Bight to study potential impacts of these various operations. Other types of modeling approaches will be required to address the various issues of concern in the Bight.

Possible types of numerical modeling technology to be considered include those aimed at simulating the following processes:

a. Meteorology, particularly the generation of surface wind and surface atmospheric pressure information

b. Generation and propagation of surface wind waves

c. Hydrodynamics throughout the entire Bight, which are primarily driven by large-scale wind fields and atmospheric pressure gradients, astronomical tides, other wave phenomena along the continental shelf, and global oceanic circulation patterns

d. Hydrodynamics in the very nearshore zone driven by local wind, breaking waves, and effects of the larger-scale Bight hydrodynamics

e. Sediment transport in both the nearshore and offshore zones, and the interaction between sediment and water quality

f. Eutrophication

g. Contaminant transport and fate

h. Food chain uptake of contaminants

i. Higher trophic levels

j. Movement and fate of floatables

Given the rather intensive computational and data manipulation requirements needed to solve multi-dimensional water/sediment transport/quality problems using numerical models, it quickly becomes a formidable task to interface hydrodynamic, water quality, sediment transport and quality, particle tracking, and any other models so that high spatial resolution, time-variable, short-term, seasonal, and longer-term simulations are practical. Several different modeling technologies are required as are methods for model interfacing. Model applications are required to determine the feasibility of conducting both short- and long-term simulations of the important physical processes.

Primary Modeling Components

The primary modeling components considered in the straw-man approach are: hydrodynamics, wind wave generation and propagation, eutrophication and general water/sediment quality, sediment transport, contaminant transport and fate, particle tracking, food chain uptake, and descriptions of higher trophic levels. A brief description of each of the technologies considered for use in the study are presented, along with a description of the processes addressed by each and major input data requirements.

Hydrodynamic Models

Knowledge of the hydrodynamics within the Bight is essential to investigations of impacts associated with the activities mentioned above. A hydrodynamics model is needed to quantify the current patterns, transport, diffusion and dispersion, and bottom velocities. Current fields, particularly surface currents, are required in particle tracking techniques used to investigate the fate of floating debris. Current information throughout the water column is needed to assess water and sediment quality, and sediment transport during and after dumping operations.

The hydrodynamics model (HM) proposed for simulating hydrodynamics throughout the New York Bight is the three-dimensional circulation model being used in the Chesapeake Bay study. The model operates on an intratidal (less than a tidal cycle) time scale, employs boundary-conforming coordinate transformations in the horizontal plane, and two options for treating grid resolution in the vertical plane. One choice is the use of "sigma-stretching" in which the local total water depth at a particular horizontal location and particular time is resolved by some number of grid cells (the number of vertical cells remains constant throughout the horizontal domain). The second choice is the use of a constant vertical resolution (fixed at all times except in the upper layer) with the capability for varying the number of vertical layers at different horizontal locations. General curvilinear and stretched coordinates enhance model resolution in highly irregular geometries, and allows for better boundary condition approximations. The curvilinear grid generator (Thompson 1987) has the special capability to automatically concentrate grid resolution in regions of deep water, shallow water, or where the water depth changes abruptly.

A parameterized representation of a higher order closure scheme is incorporated in order to properly simulate vertical eddy transport, which ensures accurate representation of the physical processes that lead to vertical density stratification. The intratidal time scale considered in the model's formulation allows fine temporal resolution of current patterns, diffusion, transport, and bottom velocities.

Boundary and external forcing are required to drive the hydrodynamic model, and choices for each are proposed below. The extent of the hydrodynamic model boundaries, the selection of appropriate boundary conditions, and sources for boundary and external forcing information will be discussed at the workshop. One option for the offshore model boundary is to prescribe the free surface along most of the offshore extent of the HM. Free surface elevation fluctuations resulting from astronomical tide effects, and possibly other shelf wave phenomena, must be considered. Several techniques for predicting tidal characteristics along the continental shelf region have been developed (for example, Schwiderski 1980 and Kuo 1986). The offshore boundary will most likely be located in water depths where wind-induced contributions to the free surface can be reasonably assumed to be negligible and the effect of nonlinear processes on the astronomical tide are small.

The land/water model boundary is easily defined, and the offshore model boundary could be located along deep water isobaths. There may also be "lateral" model boundaries which extend from the shoreline, through shallow water, and meet the offshore boundary. Along these lateral boundaries, particularly in shallow water, specification of the current field (from measured or simulated data) or a boundary condition based on the velocity or transport gradient could be used. In deeper water a radiation type boundary may be needed. The optimal position of lateral boundaries is difficult to define and influences the choice of boundary conditions.

Possible choices for the lateral boundary positions are shore-perpendicular extensions from points located along the southern coast of Massachusetts or Rhode Island and the southern shore of New Jersey to the deep water contour(s) defining the seaward boundary. A subject for discussion could be whether or not to include the Delaware and Narragansett Bays in the domain to be modeled. For both the offshore and lateral boundaries, the choice of boundary condition will most likely depend on the particular process(es) being simulated, the time scale being considered, and the level of knowledge of the impact of oceanic circulation processes on hydrodynamics within the Bight for the particular processes being modeled.

The inshore open-water boundary, located at the Bight apex between Sandy Hook, N.J. and Rockaway Point, N.Y., is extremely important, not only in terms of hydrodynamics, but also water quality. Because of its importance, it is discussed in a separate section later in the straw-man proposal.

Other types of forcing must also be considered in hydrodynamic modeling of the Bight, for example: surface wind wave effects, surface wind speed and direction, and surface atmospheric pressure. Wind and pressure input, primarily wind, is needed to investigate wind-driven circulation at synoptic, seasonal, and longer-term time scales. Atmospheric pressure can also become an important forcing function during storm events, particularly for those storm systems that are tropical in origin. Surface wind wave effects are typically not considered in open-coast hydrodynamic studies, except in the generation of very nearshore and surf zone currents; however, depending on their wave length and the water depth, they may have important impacts on the bottom shear stress (critical to sediment transport estimates), vertical mixing and eddy transport which affect water quality, and net surface drift which may contribute to the movement and fate of floating debris.

Surface wind information for the Atlantic Ocean (including the New York Bight) was hindcast using planetary boundary layer modeling techniques for the twenty-year period 1956-1975 as part of the Coastal Engineering Research Center's Wave Information Study (WIS) which produced hindcast wave conditions for the same period (Corson et al. 1981 and Corson et al. 1982). Surface atmospheric pressure information is also available; it was used to drive the wind model. An extension of the hindcast beyond 1975 is being considered. The WIS also produced a hindcast of selected historical tropical and extratropical storm events within and outside of the twenty-year period. Wind, pressure, and wave information for these events are available as well. The WIS modeling technology can also be applied deterministically to simulate wind and wave conditions, assuming accurate atmospheric pressure information is available. Other sources of wind, pressure, and wind wave information, either measured or simulated, also should be investigated.

Nearshore hydrodynamics are also important in investigations of the impact of coastal structures and placement of dredged material close to shore. In the nearshore zone, breaking waves can induce a contribution to the velocity field, and certainly influence the bottom shear stress. A two-dimensional, depth-averaged finite difference wave-induced current model (WICM) exists and could be used to simulate the generation of nearshore currents. The effect of wind waves is included via the radiation stress terms (an additional external stress related to the excess momentum flux) and the bottom shear stress formulation (the total velocity includes the oscillatory wave motion at the sea-bed). The model can be applied on the same type of curvilinear grid as the three-dimensional hydrodynamics model. However, this type of model would only be applied at the site-, or project-, scale because resolution requirements are dictated by the spatial discretization needed to represent changes in the nearshore wave field, particularly where wave breaking is occurring. The model could be driven along its boundaries by information from the Bight hydrodynamics model.

Application of the WICM requires wind wave information as input. Any model that can treat the transformation of waves over irregular bathymetry and into the very nearshore zone could be used. Several appropriate models exist and are routinely applied at CERC (for example Ebersole et al. 1986 and Hughes and Jensen 1986). These models would also be applied at a specific site.

Sediment Transport Models

Sediment transport models are needed to evaluate the environmental suitability of proposed open water sites for disposal of dredged material. Two transport-related criteria must be met if a site is to be approved as environmentally acceptable. The first is concerned with the immediate effects of the disposal operation; material from the descending plume of sediments can not impact areas outside the designated disposal site. This short-term phase lasts for several minutes to several hours following the initial release of material from the dredge. The second criterion is whether or not material deposited within the disposal site can be eroded and subsequently transported out of the site by either typical ambient current fields or by currents generated during storm events. Both criteria are important in investigations of the impact of dumping "clean" material near environmentally sensitive areas, dumping contaminated material, and the effectiveness of capping operations. There are other considerations and questions that may be important and must be addressed, particularly interactions between sediment and water quality. (Sediment quality is covered under the descriptions of other types of models that follow.)

A dual sediment transport modeling approach could be adopted. Both components could be applied to investigate sediment transport processes at individual sites within the Bight. The Disposal From an Instantaneous DUMP (DIFID) model can be used to calculate the short-term fate of cohesive and non-cohesive material after completion of the dumping operation (Johnson, Trawle, and Adamec 1988). A sediment transport model coupled to the hydrodynamic model could be used to investigate long-term fate of placed material. One such model is presently in use at CERC for disposal site designation studies (Scheffner and Swain 1989).

The DIFID model computes the time history of a single disposal operation from the time the dredged material is released from the barge until it reaches equilibrium on the ocean floor. Three phases are modeled: the convective descent phase, the dynamic collapse phase, and the short-term transport-diffusion phase. Results from this short term phase are used as initial conditions for use in long-term sediment transport modeling.

Presently CERC is involved in the U.S. Army Corps of Engineers Dredging Research Program (DRP). Work is underway that is aimed at improving Corps technology for numerically simulating both short- and long-term response of placed dredged material. There is also a theoretical research component that is investigating fundamental relationships between bottom shear stress and wave and current parameters. Any new and tested capabilities generated by the DRP could be integrated into the presently available two-phase sediment transport modeling technology.

Eutrophication/General Water Quality Model

A three-dimensional (3D) eutrophication-water quality model (WQM) will be required to evaluate conventional water quality problems, such as anoxia, associated with excessive nutrient loadings to the Bight. In addition to the water quality processes and state variables usually included in eutrophication models, the model should include particulate, dissolved, labile, and refractory organic forms of carbon, nitrogen, and phosphorous, as well as inorganic forms. Multiple algae groups will probably be required. Additionally, the model must have a sediment quality component that interacts with the water column. The model must be able to evaluate long-term (seasons to years) changes in water and sediment quality as impacted by point and non-point loadings. The modeling technology being developed for the Chesapeake Bay (Dortch, et al. 1988, Dortch 1988, and Cerco 1989) satisfies most of the requirements for this model category and is recommended for modeling eutrophication/general water quality in the Bight.

The Chesapeake Bay modeling technology consists on the 3D hydrodynamic model (HM) discussed earlier, and an indirectly coupled water quality model including the sediment quality component. Both models use the same spatial grid resolution, but the WQM uses a much larger time step than the HM. A subroutine within the HM processes and stores HM information required to drive the WQM. The time step of the HM is on the order of minutes, whereas the WQM time step is on the order of hours. The HM flows and vertical diffusivities are averaged over periods of one or more tidal cycles and stored for subsequent use by the WQM. The flows are processed in a manner that preserves the proper residual currents associated with the tidal forcing without the need for tidal dispersion. The procedure involves approximating the Lagrangian residual currents and implementing the Lagrangian residual operator for the water quality mass transport equation.

The eutrophication water quality model requires five types of input data: 1) hydrodynamic transport information (i.e. flows and diffusivities); 2) boundary conditions and external loadings for modeled constituents; 3) meteorological influences, such as wind and solar radiation; 4) initial constituent concentrations; and 5) kinetics coefficients for transfers and transformations. Boundary conditions and external loads are the only requirements that pose potentially serious problems. Boundary conditions must be specified at the open ocean boundaries, at the mouth of New York Harbor, and at river inputs. External loads from point-source and nonpoint-source discharges and from the atmosphere must be identified and quantified.

Open-ocean concentration boundary conditions will be derived from observations or else obtained by invoking a zero-gradient boundary condition. In the latter case, boundary conditions reflect predicted concentrations just inside the computational grid. Zero-gradient boundary conditions require a spatially-extensive grid so that concentrations near the ocean limits are not influenced by the various simulation scenarios. Methods for handling New York Harbor boundaries are discussed in another section (Model Boundary Conditions at the Bight Apex). Riverine boundaries will be obtained from observations or else specified from proposed management scenarios. Point-source pollution loads will be identified and quantified through contacts with appropriate local regulatory agencies. Nonpoint-source pollution loads will most likely be estimated with a model which may range in sophistication from a simple regression model to a complex predictive watershed model. Atmospheric loadings are best specified as the product of rainfall pollutant concentration and rainfall volume. Significant atmospheric dryfall is also a possibility. Details on the specification of atmospheric loads requires contact with research and monitoring agencies to assess the nature of available data.

Exact specification of initial conditions for the water column is not critical since external loads and internal transformations overshadow the initial conditions in a short time frame (e.g. a few weeks). Specification of sediment initial conditions is more demanding since the conditions specified influence model calibration and prediction for a lengthy period (e.g. several years). Observations of initial sediment conditions are required for successful eutrophication modeling. Initial conditions for the entire grid can be obtained from a limited number of observations by employing the model to fill gaps in observations.

The lessons learned from the Chesapeake Bay study may suggest modifications to the model before applying it to the Bight. For example, significant computation efficiency can be realized by restructuring the model from a single-dimensional array of cells (box model format) to a fully three-dimensionally arrayed code. Some of the water quality kinetics and state variables may also be changed for the Bight. For example, pathogens may have to be added to the model. Overall, most of the Chesapeake bay modeling technology can be directly transferred to the New York Bight for modeling eutrophication and general water quality.

Contaminant Transport and Fate Model

Contaminants refer to the synthetic organic substances and trace metals that can be toxic to aquatic life. Two basic types of models can be used for contaminants: screening models and high-resolution models. Screening models involve simplifying assumptions (i.e. reduced spatial dimensionality) that decrease effort required for application. Screening models provide coarse-scale (usually in time and space), order-of-magnitude estimates of contaminant transport and fate. Both data input requirements and the time required for model application are much less than that for high-resolution models. High-resolution models provide detailed accounting of the processes affecting contaminant transport and fate, but such models are considerably more time-consuming and expensive to apply.

The model RECOVERY (Boyer and Chapra 1989) is an example of a contaminant screening model. RECOVERY is a user-friendly, menu-driven, PC model that was developed for WES and the U.S. Army Engineer Division, New England, to evaluate the time history of water column and bottom sediment contaminants in aquatic systems.

EPA's Environmental Laboratory, Athens, GA, is developing for WES a model to evaluate the transport and fate of contaminants associated with confined disposal facilities. This model is not necessarily classified as a screening model, but it will be fairly easy to apply.

As a minimum, contaminant screening models will be needed for the Bight. The relatively accurate transport information from the HM/WQM models used for eutrophication modeling can feed into contaminant screening model applications. For example, a hot spot of contaminants might be modeled by applying a screening model like RECOVERY with flushing characteristics, which are required as input, predicted by the more detailed HM/WQM.

High-resolution contaminant models usually have multiple spatial dimensions and are time-varying. These models simulate dissolved and particulate forms of contaminant(s) in the water column and the bed, as well as fine-grained suspended sediment transport. The best example of this type of model is EPA's TOXI4, which is in the WASP4 package (Ambrose et al. 1988). TOXI4 simulates up to three interacting toxic chemicals (either organic contaminants or trace metals) and up to three sediment size fractions. An empirically-based food chain model is linked to TOXI4 for calculating chemical concentrations in biota and fish resulting from predicted aquatic concentrations.

If a high-resolution contaminant model is required for the Bight, the recommended approach is to retain the 3D high-resolution technology associated with the indirectly-coupled HM/WQM used for eutrophication modeling, and incorporate the contaminant processes of TOXI4. This requires some code development. The modular framework of the contaminant processes within TOXI4 facilitates this development, however. Food chain uptake would be modeled within the contaminant transport/fate code in an empirical fashion as presently done in TOXI4.

Input data requirements for contaminant modeling are similar to requirements for eutrophication modeling but are more extensive. Additional data requirements for contaminant modeling include suspended solids concentrations and sediment deposition, resuspension, and burial rates. Additional required kinetics parameters include partition coefficients, degradation rates, and biological uptake rates. Magnitudes of these parameters are not nearly as well known as paramters in the eutrophication model. The distributions of contaminants in the bottom sediments must be specified as model initial conditions. Acquiring sufficient boundary conditions, loadings, and observations to calibrate and verify a complex contaminant model is a challenging and costly undertaking. Employment of relatively simple, screening models is recommended as a first approach to contaminant modeling.

Particle Tracking Model

The above modeling approaches are based on the continuum concept which assumes that dissolved and suspended matter move with the water as part of the water. With the continuum approach, substance concentrations are evenly distributed within each computation cell.

An alternative approach for pollution modeling is particle tracking. In particle tracking, discrete particles are introduced within the model grid to represent a pollutant that may be dissolved, suspended, or floated on the surface. HM currents are input to the particle tracking model, and each particle's movement is tracked on the grid throughout the simulation period. The number of particles within each computational cell can be related to a concentration if desired.

The advantages of particle tracking are: 1) floatables can be simulated to determine their path; 2) numerical diffusion associated with the advective terms of the continuum transport equation is eliminated since these terms do not exist in with the Eulerian-Lagrangian scheme of particle tracking; and 3) the transport of substances discharged from point sources is better simulated since that discharge is represented by particles introduced at a point rather than distributed uniformly in a model cell.

Particle tracking is not practical for water quality and contaminant fate models that include multiple state variables and kinetic processes. Particle tracking is the preferred approach however when modeling accidental spills, point source discharge plumes, and floatables. The trajectory of substances originating from ocean disposal sites can be accurately tracked with this approach. This type of modeling would not only be useful for evaluating the impacts of existing disposal sites, but it could be used to help determine preferred locations for new disposal sites.

The results from particle-tracking simulations could provide input for conventional water quality and contaminant continuum models. For example, the near-field spreading of a pollutant from an ocean disposal site might be simulated with the particle-tracking model, yielding initial concentrations for the far-field, longer-term continuum models.

A number of particle-tracking models exist. If this technology is needed for the Bight, these models should be reviewed and the most appropriate model selected and modified as necessary. If the model is to address floatables, it will be necessary to include additional forces such as wind drag and wave action which influence the path of floatables.

Models for Assessing Higher Trophic Levels Impacts

Simulating higher trophic levels (i.e., fin fish, shell fish, benthos, and zooplankton) in the New York Bight will require information generated by both the HM and WQM. Information provided by the models is required to describe temporal and spatial characteristics of the chemical and physical environment of the Bight. However, this information, by itself, is inadequate to assess the response of the higher trophic levels to different management scenarios. Higher trophic levels exhibit complex behaviors both as part of their life cycles and in response to many of the environmental problems present in the New York Bight. There are no single models that can be used to generically and completely predict the response of these organisms. Optimum approaches for simulating higher trophic levels depend upon the specific issues being addressed, the species (or life stages) of concern, and the available time and funding.

Inadequate information is presently available to make these decisions. However, it is reasonable to assume that output from both the HM and WQM will be required to simulate the responses of the higher trophic levels. The information can be used to quantify available chemical and physical habitat conditions, or the information can be used to adjust population dynamics parameters or bioenergetics rate functions. Therefore, for the present time, we will proceed with the HM and WQM with the understanding that information provided by these two model components will be required later for simulating higher trophic levels. Modeling strategies for this latter part of the project will be better defined after further issue delineation has been completed.

Model Boundary Conditions at the Bight Apex

The usefulness of the model(s) applied to the New York Bight will depend on the accuracy of the boundary conditions. Boundary condition data must be supplied for the model(s) of the New York Bight at the mouth of the New York Harbor and along the external Atlantic Ocean boundary (discussed earlier to some degree) of the computational grid. The mouth of the harbor is defined as the transect between Rockaway Point and Sandy Hook (also call the Bight Apex).

The information that will be required at the transect will include water levels, current velocities, salinity, temperature, suspended sediment concentrations, and water quality concentrations. The information for the transect must include both lateral and vertical variations and provide sufficient long-term information to define the material fluxes as they vary over tidal range and seasonally with changing river inflows to the harbor.

The potential sources of data mentioned above can include models, either physical or numerical, and field data collection programs. Several extensive modeling efforts have been undertaken for the New York Harbor and adjacent waterways. Work has been performed by Federal agencies as well as by universities and private companies. The Corps of Engineers has conducted numerous studies in the physical scale model of New York Harbor constructed in 1957 located at WES. Topics of study have included salinity intrusion, sedimentation, tidal circulation, sewage outfall dispersion, structural modifications on circulation, and channel deepening studies. The Corps also has developed a comprehensive numerical model of the harbor for the study of physical processes. Oey, Mellor, and Hires (1985) have also conducted 3D modeling of the harbor for physical processes.

The existing models of the physical processes in the harbor and at the harbor mouth may prove adequate for the development of boundary conditions for the HM of the Bight; however, the extent of water quality data and modeling may prove inadequate. The possibility of additional modeling work in the harbor must be addressed in the workshop. Alternative technical approaches that incorporate sensitivity of the Bight models to harbor loadings may prove to be appropriate for the demonstration purposes of the 728 study.

The boundary condition information at the transect can be developed in several ways. Time series of variables can be developed from field and model data. The harbor limit of the New York Bight would then be located at the transect. In order to develop boundary condition data for the long-term periods anticipated for the Bight study, extensive interpolation and extrapolation both space and time will be required.

An alternative approach to developing the boundary condition data at the transect is to conduct statistical analysis of the data at the transect. A correlation could be developed and potentially a functional relationship between the environmental forcing and the required boundary data could be established. This approach would be used in conjunction with some aspects of the direct time series approach.

Of particular concern will be the specification of the various mass fluxes across the transect as they vary over the tidal cycle. The numerical model should specify the concentration of any constituent only when it is entering the model grid (such as during ebb tide). On "flood" flows, the concentration that crosses the transect must be that which the water carries into the harbor from the Bight. Any discrepancy between the boundary specification (ebb) and the model solution (flood) at the transect will cause inaccuracies in the simulations. A technique for avoiding these problems can be developed whereby a mixing volume is used to adjust the ebb boundary specification based on the mass that crosses the transect on flood flow. This approach would be an analytical adjustment. Another approach would be to add computational cells to the grid for the lower bay strictly as a buffer zone, which could be adjusted to obtain desired conditions at the transect. This would also simplify the complexity of the actual boundary condition formulation at the Bight apex by retreating the boundary locations back to the Narrows, the mouth of Raritan River, of Arthur Kill, and the entrance to Jamaica Bay, if necessary.

A third option is to include the link between the Bight and Long Island Sound in the models and simulate the actual interaction between the two water bodies. This approach would avoid the need to specify boundary conditions at the Bight apex; however, boundary conditions would still be required at other locations. The need for this connection is certainly a subject for discussion at the workshop.

The goals of the 728 study are to demonstrate the modeling approach for the New York Bight. To meet that purpose it may be sufficient to perform some sensitivity analyses on the techniques applied at the Bight apex boundary and on the best available field data to estimate boundary conditions. The sensitivity analyses would define the impact of perturbations in the boundary conditions at specific points in time and space on the overall solution in the Bight. This analysis could give guidance in the final plan to rigorously develop boundary condition strategies and data for the Bight models.

Modeling Strategy

Space and Time Scales To Be Considered

The major problem areas of interest to the Corps encompass a wide range of spatial scales. For certain problems related to sediment transport, the area of interest may only be a local disposal site. However, for many problems, particularly those pertaining to water quality, the area of study may need to be the entire Bight. The workshop will define the space scales that must be considered in attempts to model the different processes in the Bight. The strategy will involve studying the important spatial scales required to model the important processes; and knowing these, investigations including sensitivity analyses of the following will be conducted: model resolution requirements, locations of model boundaries, and formulation of boundary conditions.

Many investigations concerning short-term simulations of hydrodynamics and water/sediment quality have been conducted in the past. Short-term implies simulations lasting on the order of days up to a few weeks, at most, and typically encompass storm events or predominant tidal variations. Response of the Bight system to processes acting over a much longer time period are also of key interest. Long-term includes time scales that range from monthly or seasonal to a few, and possibly many, years. A product from the workshop will be a definition of the time scales that must be considered in the different modeling aspects.

Model Interfacing

A conceptual view of how the various modeling technologies may interact is presented in Figure 6. Various modeling components may be linked via input-output (i.e. output from a model or a pre-processor is stored for direct input to another model), direct coupling, or a loose coupling. Direct coupling here refers to using one modeling process to drive another modeling process with the same spatial and temporal scales. This is usually accomplished within the same model code through subroutines. For example, the WQM transport module can be used to transport general water quality, pathogens, and contaminants; or suspended sediment transport can be treated during the simulation of hydrodynamics. Loose coupling refers to using results from a modeling process to supply general

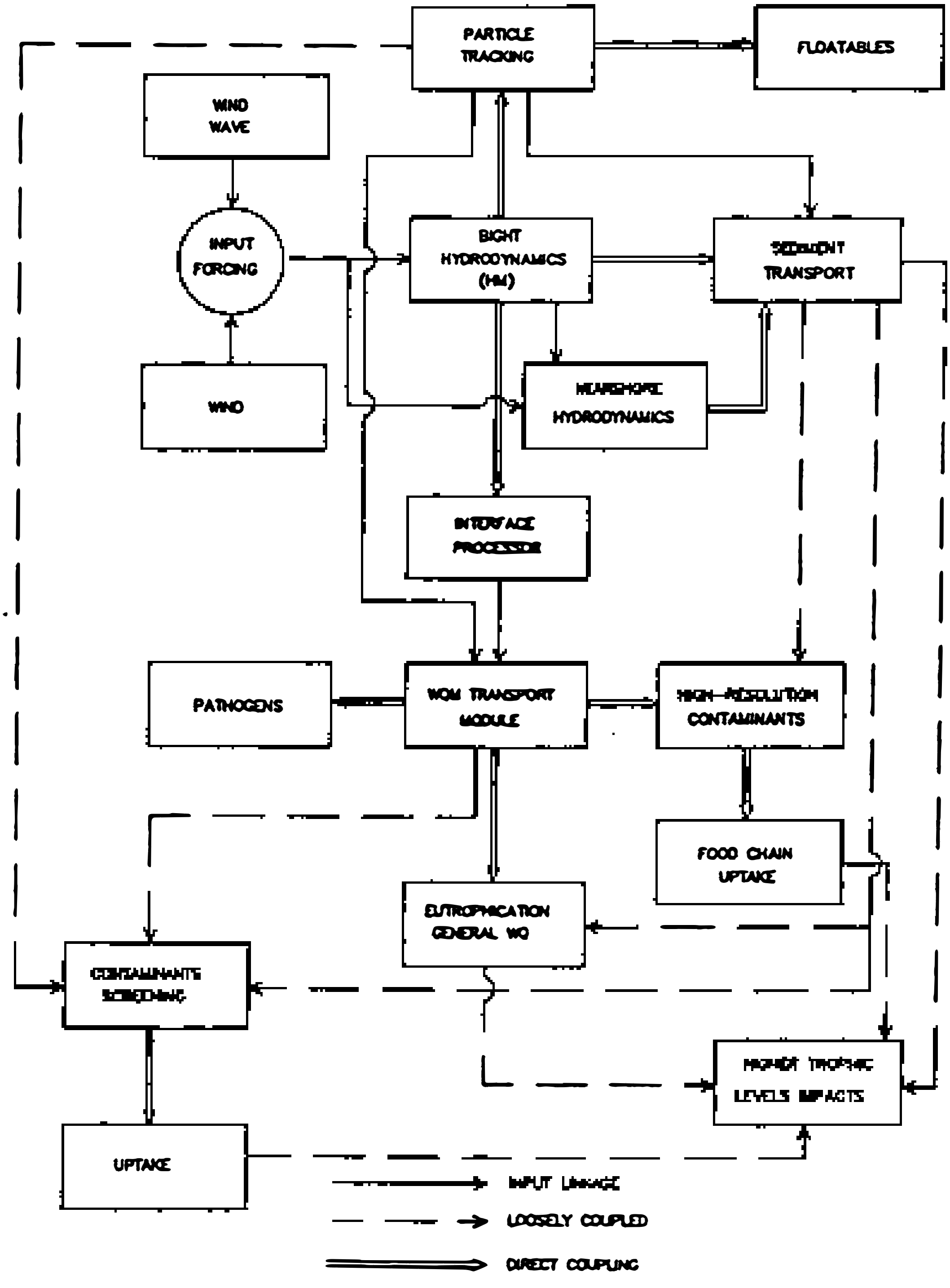

Figure 6. Model Components and Interfacing.

input information required to perform another modeling process. Intermediate processes may be performed, such as inference or time-averaging, prior to supplying input information. For example, long-term (i.e. steady-state) suspended solids concentration required for a contaminants screening model may be inferred from results produced by a sediment transport simulation. Also, conclusions drawn from general water quality, contaminants, and sediment transport simulations might be used to draw conclusions about impacts on higher trophic levels.

From studying Figure 6, it is obvious that the HM and WQM transport module are the main engines of the overall modeling strategy. Other models , such as the particle tracking model, are secondary engines and are only needed to address specific issues. As stated earlier, the modeling technology developed for the Chesapeake Bay can be transferred to the Bight; thus, the main engines will be fairly well developed at the beginning of the project. These include the hydrodynamics and WQM transport module (which includes eutrophication/general water quality and bottom sediment quality). Methods for treating wind-wave effects on vertical mixing, and bottom shear stress exist but must be incorporated into the 3D HM. Presently available technology for treating cohesive material must be integrated into the cohesionless sediment transport module, and the module must be directly coupled with the HM. The pathogens and high-resolution contaminants components must be built into the WQM framework. Details of the contaminant screening models and the higher trophic levels impact evaluation procedures can not be described until more details of the specific needs are defined during and following the workshop.

Long-Term Simulations

The computation costs and feasibility of applying the main engines (i.e. the HM and WQM) depend on specific needs for grid resolution and length of the simulation period. Many of the water quality/contaminant issues may require long-term simulations (seasons to years) over a large spatial domain. Grid resolution and model time steps must be carefully chosen so that long-term simulations are feasible without sacrificing required accuracy. Steps should be taken early in the project to make the main model engines as efficient as possible.

Long-term simulations pose many unique problems that depend on the availability of boundary and external forcing (such as wind and wave) input data of all required types, as well as the availability of input that must be generated by other models (which depends on the feasibility of conducting long-term simulations using each model that is supplying input). Two options are available for generating the necessary input. The first is to deterministically produce a continuous time series from measurements or model simulations. This is probably only feasible for shorter time periods (months and seasons) and for certain types of input data. The second option is to combine a series of shorter, representative time series to form a much longer input data string (years). A stochastic procedure could be used to "knit" periods together for use in long-term simulations. The selection of individual periods would be made in such a way as to preserve known statistical event magnitudes and durations; event recurrence intervals; short-term, seasonal, and perhaps longer-term trends if such trends can be extracted from the data base(s) used to determine the statistical characteristics. Use of this procedure maintains the natural structure in the boundary and forcing data and maximizes use of available data.

Model Demonstration

Development of properly interfaced models to address the impacts of the activities of concern in the New York Bight is a formidable task. To establish confidence in the modeling approacehes, demonstrations of the modeling technology will be conducted. These demonstrations will focus on the particular issues that can be addressed with the modeling system, and will include simulations at space and time scales required to address potential impacts of the activities being investigated. Measured data will be utilized when needed and where available to facilitate the model demonstrations. However, full scale model calibration, verification and application will not be attempted. These are not the goals of the feasibility study.

Summary

The straw-man proposal, as presented, attempts to briefly outline the human activities in the New York Bight that are of concern to the U.S. Army Corps of Engineers. The proposal is intended to provoke discussion and develop, through consensus building, a broad strategy for demonstrating the feasibility of using numerical models to study the important environmental impacts of these activities. Various types of models that are perceived to be needed are identified; those that may be feasible for use in investigating the impacts are presented; their capabilities and input requirements are briefly outlined; and a framework is proposed for interfacing the models to study the different important processes that are pertinent to evaluating the impacts of the human activities. The following important issues pertaining to model applications were also raised: definition of time and space scales that must be modeled, location of model boundaries and formulation of boundary conditions, and procedures for conducting long-term simulations. The workshop will provide a forum for discussing all the modeling questions raised in the straw-man proposal. It is intended as a starting point for discussion.

REFERENCES

Ambrose, R. B., Wool, T. A., Connolly, J. P., and Schanz, R. W. 1988. "WASP4, A Hydrodynamics and Water Quality Model-- Model Theory, User's Manual, and Programmer's Guide," EPA/600/3-87/039, Environmental Research Laboratory, Athens, GA.

Boyer, J. M., and Chapra, S. C. 1989. "RECOVERY, A Mathematical Model to Predict the Temporal Response of a Surface Water to Contaminated Sediments," Working Paper No. 1, A Report to the US Army Corps of Engineers, New England Division and Waterways Experiment Station, by the Center for Advanced Decision Support for Water and Environmental Systems, University of Colorado, Boulder, CO.

Dortch, M. S., Cerco, C. F., Robey, D. L., Butler, H. L., and Johnson, B. H. 1988. "Work Plan for Three-Dimensional, Time-Varying, Hydrodynamic and Water Quality Model of Chesapeake Bay," Miscellaneous Paper EL-88-9, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Dortch, M. S. 1988. "Approach for 3-D, Time-Varying Hydrodynamic/Water Quality Model of Chesapeake Bay," Hydraulic Engineering, Proceedings of the 1988 National Conference, Edited by Steven R. Abt and Johannes Gessler, American Society of Civil Engineers, Hydraulics Division, Colorado Springs, CO.

Cerco, C. 1989. "Chesapeake Bay Three-Dimensional Model Study," Coastal Zone 89: The Sixth Symposium on Coastal and Ocean Management." Charleston, SC. (in press).

Corson, W. D., Resio, D. T., Brooks, R. M., Ebersole, B. A., Jensen, R.E., Ragsdale, D. S., and Tracy, B. A. 1981. "Atlantic Coast Hindcast, Deepwater, Significant Wave Information," WIS Report 2, US Army Engineer Waterways Experiment Station, Hydraulics Laboratory, Vicksburg, MS.

Corson, W. D., Resio, D. T., Brooks, R. M., Ebersole, B. A., Jensen, R.E., Ragsdale, D. S., and Tracy, B. A. 1982. "Atlantic Coast Hindcast, Phase II Wave Information," WIS Report 6, US Army Engineer Waterways Experiment Station, Hydraulics Laboratory, Vicksburg, MS.

Ebersole, B. A., Cialone, M. A., and Prater, M. D. 1986. "Regional Coastal Processes Numerical Modeling System Report 1: RCPWAVE - A Linear Wave Propagation Model for Engineering Use," Technical Report CERC-86-4, US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS.

Hughes, S. A. and Jensen, R. E. 1986. "A User's Guide to SHALWV: Numerical Model for Simulation of Shallow-Water Wave Growth, Propagation, and Decay," Instructional Report CERC-86-2, US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS.

Johnson, B. H., Trawle, M. J., and Adamec, S. A. 1988. "Dredged Material Disposal Modeling in Puget Sound, " Journal of the Waterway, Port, Coastal, and Ocean Division, American Society of Civil Engineers, Vol 114, No. 6, pp 700-713.

Kuo, J. T., Chen, Nei-Mao, and Chu, Yu-Hua. 1986. "Time-Domain Total Tides and Currents of North Atlantic Ocean with New York Bight Included," Proceedings of the 10th International Symposium on Earth Tides, Madrid, Spain, pp 577-586.

Oey, L.-Y., Mellor, G. L., and Hires, R. I. 1985. "A Three-Dimensional Simulation of the Hudson-Raritan Estuary. Part I. Description of the Model and Model Simulation," Journal of Physical Oceanography, Vol 15, pp 1676-1692.

Scheffner, N. W. and Swain, A. 1989. "Evaluation of the Dispersion Characteristics of the Miami and Ft. Pierce Dredged Material Disposal Sites," US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS, (in preparation).

Schwiderski, E. W. 1980. "Ocean Tides, Part II: A Hydrodynamic Interpolation Model," Marine Geodesy, Vol 3, pp 219-255.

Thompson, J. F. Project EAGLE - Numerical Grid Generation User's Manual, Vol. 3: Grid Generation Code, USAF Armament Laboratory Technical Report, AFATL-TR-87-15, Eglin AFB, April 1987.

A1. HISTORICAL OVERVIEW OF MARINE PROGRAMS IN THE NEW YORK BIGHT

R. Lawrence Swanson
Waste Management Institute
Marine Sciences Research Center
SUNY @ Stony Brook
Stony Brook, NY 11794

The Bight extends across the continental shelf from an apex adjacent to the Hudson-Raritan Estuary at the Sandy Hook-Rockaway transect. It is within the Apex that most of the ocean dumping activities, including sewage sludge and contaminated dredged material, have taken place. It is also the area that is heavily impacted by the river-borne effluent from the Estuary. The most severe ecological impacts in the Bight are observed within the Apex. As a consequence, the area has been the center of attention for research and monitoring programs.

A number of oceanographic research and monitoring programs have been conducted in the New York Bight since the late 1940s. The Woods Hole Oceanographic Institution studies centered in the Apex and contributed to the early understanding of the flushing characteristics of the Apex. The work of the mid-1950's involved the potential use of the Estuary as a port facility for a nuclear-powered commercial fleet.

Over the past two decades several major environmental and ecological investigations have been conducted in the Bight--the U.S. Army Corps of Engineers investigations in the late 1960's and the National Oceanic and Atmospheric Administration's Marine Ecosystems Analysis (MESA) Program of the 1970's are two examples. The National Marine Fisheries Service of NOAA has continuously sought to improve our understanding of this complex marine ecosystem and society's impact on it. All these studies identified and documented numerous indications of marine environmental degradation, along with the nature and routes of contaminants to this major marine ecosystem. These studies led to an understanding of the impact of ocean dumping, determination of sources and transport routes of floatables to area beaches, knowledge of the causes of hypoxia and benthic mortalities, identification of contaminants threatening the environment, and formation of a scientific basis for marine environmental monitoring in the Bight.

The recommendations of these studies have to some degree been followed. The mechanism to implement many of them, so that restoration of the Bight might be realized, was not established until recently. Some progress was made as a consequence of other programs, such as those associated with the Clean Water Act. In 1987, as part of the United States - Japan Fisheries Agreement Approval Act (Public Law 100-220, Section 230), the Environmental Protection Agency was authorized and funded to develop a New York Bight Restoration Plan. This requirement for a comprehensive management plan now provides the management framework to commence the restoration process. The plan draws upon the past research endeavors and incorporates more recent findings to identify impaired uses and adverse ecosystem impacts of the Bight's resources and their social and economic consequences.

The National Oceanic and Atmospheric Administration also has introduced a long-term monitoring program in the Bight as part of its National Status and Trends Program. The National Marine Fisheries Service of NOAA is examining the recovery of the 12-mile dump site following the cessation of the ocean dumping of sewage sludge there in 1987. The State of New Jersey has also initiated an intensive near-coastal monitoring program concerned with such issues as beach water quality and noxious phytoplankton blooms.

Most data available on the Bight come from the 1970's and, in many ways, the Bight is data-rich. Pollutant data has increased with time since the early 1970's but is still limited. The quality of the early data is also of concern. New instrumentation and better understanding of pollutant transport processes indicates the earlier pollutant data may be of lesser quality than that obtained today. Much of the data on the Bight is on file in the National Oceanographic Data Center. A bibliography summarizing and cataloging much of the literature on the Bight has been published in a two-volume set, "Annotated Bibliography of New York Bight, Hudson-Raritan Estuarine System and Contiguous Coastal Waters: 1973-1981", by the Marine Sciences Research Center, SUNY at Stony Brook.

A2. THE PURPOSE AND FUNCTION OF MARINE MONITORING

R. Lawrence Swanson
Waste Management Institute
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794-5000

Monitoring, as paraphrased from the Interagency Committee on Ocean Pollution Research, is the systematic observation of predetermined parameters or pertinent components of the marine ecosystem over a length of time that is sufficient to determine the existing level, trend, and natural variations of measured parameters in the water column, sediments, or biota.

In general, there are four types of marine monitoring programs. These are:

> Compliance monitoring -- conducted for the purpose of establishing whether or not a pollutant source is meeting the requirement of a permit or regulation;
>
> Environmental monitoring -- measurement of environmental variables that leads to assessment of the ecosystem, pollution conditions, and pathways;
>
> Ecological effects monitoring -- monitoring of biological responses, from the individual to the ecosystem (including people), to detect ecological consequences of pollutants and environmental stress;
>
> Human health monitoring – monitoring for the presence of pathogenic or indicator microorganisms in water and shellfish for the purpose of determining potential health risks to consumers.

To be effective, a monitoring program must have a well-defined audience, specific goals and objectives, and a statistically rigorous design to meet the objectives. In pollution monitoring programs, it is important to be able to relate measured environmental responses to pollution sources if management decisions based on the data from the monitoring program are to withstand judicial scrutiny. This requires the establishment of criteria against which to measure change.

A critical step in designing and implementing a successful monitoring program is that of converting data into information--information that can be understood by environmental and resource managers, managers of regulated activities, elected officials, and the public. Static maps and data tables are not sufficient, as the process of summarizing and compiling often distort the original data. In fact, a truly useful monitoring program should be accompanied by professional staff to aid in the use and interpretation of data and information.

Monitoring programs typically are expensive to conduct and in many cases have little intrinsic value because the data collection program is or becomes the center of interest. It is imperative that the goals and objectives drive the monitoring program. One should not fall into the trap of collecting data solely because new sampling and analytical tools or instrumentation are available. Monitoring programs undertaken to support developing and running models or representations of the marine ecosystem is also an important function. But such programs must also be made to meet specific requirements and specific models. Otherwise, the data collection and analysis are usually cost-prohibitive.

Finally, there is a need to continuously evaluate the effectiveness of the monitoring effort and/or check the adequacies of the science behind the monitoring program--due, perhaps, to adoption of alternative disposal practices, or a changing legal, scientific, or management requirement. Relative cost-benefit analyses should also be routinely conducted. One of the best tests of the effectiveness of a monitoring program is an analysis of what management decision(s) the monitoring program has impacted.

A3. EPA MONITORING PROGRAMS IN THE NEW YORK BIGHT

Mario Del Vicario
U.S. Environmental Protection Agency
Region II
Marine & Wetlands Protection Branch
26 Federal Plaza
New York, NY 10278

Ocean Disposal Site Monitoring

Introduction

Disposal of various wastes at open water sites in the New York Bight is an old practice. During the 1980's, these sites, with the exception of the historic woodburning site, were given official site designation. The purposes of EPA's ocean disposal site monitoring program are to verify compliance of site users with permit conditions and to confirm that compliance with permit stipulations does, in act, protect the environment of the site. Activities conducted under the ocean disposal site monitoring program include:

* baseline site surveys
* characterization of permitted waste(s)
* constituent determination
* acute and chronic bioassay tests
* determination of discharge rates and establishment of permissible concentrations
* monitoring of behavior of waste during and following disposal
* determination and assessment of any water quality violations within or outside the site
* assessment of short- and long-term impacts of disposal activities

Permit applicants collect and provide date to EPA under the latter's direction for most ocean disposal monitoring activities, except those associated with the 106-mile Site.

106-Mile Site

The monitoring strategy used at the 106-mile Site to assess the impacts of sewage sludge disposal uses a four-tiered approach as follows:

Tier 1 - sludge characteristics and disposal operations
Tier 2 - nearfield fate & short-term impacts
Tier 3 - farfield fate
Tier 4 - long-term impacts

Date collected in each tier help determine the scope of activities undertaken in the next tier. The results of Tier 1 & 2 investigations are being used to make decisions on permit conditions (e.g. disposal rates) and continuing monitoring needs. Tier 2 activities will help determine adverse impacts at the site, while Tier 3 work will allow estimation of the transport direction and a real distribution of sludge constituents. Tier 4 results may not be conclusive by 1991 due to the confounding effects of other pollutant sources in nearshore areas and the difficulty of determining effects in the open ocean environment.

Results of monitoring activities conducted at the 106-mile Site to date are presented below.

Sludge Characteristics - total solid concentrations in material disposed at the site range from 2% to 10%. The metals content of the material varies. The concentrations of PCB's in the sludge averages 25 ppb, while pesticide concentrations are generally less then 250 ppb. In bioassay tests, mysid shrimp were the most sensitive organism tested, with LC 50's of 1-3% whole sludge.

Short-term Impact at Site - immediate dilution of the material is 1000 to 2000-fold. A slow settling of particles has been observed but, over conservation periods of up to 8 hours, was not observed to extend below the pycnocline. Plumes from disposal operations may be transported offsite within 4 hours.

Compliance with Disposal Regulations - rapid lateral transport of material can cause water quality criteria (WQC) to be exceeded at the site boundary. Copper and lead are the most likely contaminants to exceed WQC. Disposal of sludge does not appear to impact ambient dissolved oxygen or pH levels at the site during an initial 4-hour mixing period.

Far Field Fate of Material - although mean transport in the area is to the southwest, plumes have been observed moving in various directions. Intrusions of slope water and warm-core rings may affect plume transport. Particle settling rates are slow and apparently hindered by the pycnocline. Current meter and near-surface drifter studies will provide additional information on far field fate of disposed sludge.

Additional monitoring activities suggested for the 106-mile Site include: 1) drifter and current meter studies to better understand physical transport processes; 2) effects of dumping on fish and shellfish, both endemic and migratory species; 3) relationship between disposal activity and levels of pathogens in organisms from the site and nearshore waters; and examination of the settling of particles and the impact on continental shelf and slope benthic communities.

New York Bight Water Quality Monitoring Program

Established, this program is designed to improve the ability to predict environmental crises in the Bight, such as anoxia events, floatables wash-ups, green tides, etc., to provide information on the origins of these crises, and to generally direct decisions concerning the protection of water quality in the Bight. Sampling is done from helicopter and vessels. The following water quality parameters are routinely measured: dissolved oxygen, temperature, salinity, fecal coliform, phytoplankton abundance and species composition and chlorophyll.

In addition to the above, sediment and benthic samples are taken for analysis of viruses and other pathogens and heavy metals. Originally conducted year-round, the program is now undertaken from May through October, 5 days per week, except during July and August, when samples are taken 6 days per week.

Helicopter stations are located along Long Island and New Jersey beaches (66), in the New York Bight Apex (20), and along 12 transects perpendicular to beaches in the region. Additionally, 90 stations extending from Christiansen Basin to 50-60 miles offshore along the Hudson Canyon are sampled by vessel for metal contamination of sediment and benthos.

Annual reports are produced for the New York Bight Water Quality Monitoring P, including 5-year running aveages of selected parameters.

Floatables Monitoring

The floatable wash-ups in the region during the summers of 1987 and 1988 led to increased surveillance of the waters of the New York Bight and New York Harbor for floating wastes. Using helicopter overflights supplemented by vessel sampling, these efforts are being undertaken by EPA, the Coast Guard and the states of New York and New Jersey. Related to this, EPA has joined other federal agencies and the two states in implementing a short-term floatables action plan for New York Harbor, wherein Harbor waters are monitored for slicks of floating material, which are cleaned up before they escape into the open waters of the Bight. This short-term plan is preliminary to the development of a long-range plan to address the elimination of the sources of floatables to the region's marine environment.

A4. ON-GOING MARINE MONITORING PROGRAMS OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Hal M. Stanford
Office of Marine Assessment, National Ocean Service
National Oceanic and Atmospheric Administration
6001 Executive Boulevard, Rm. 323
Rockville, MD 20852

NOAA, the National Oceanic and Atmospheric Administration, conducts a number of marine monitoring programs. Three monitoring programs administered by the Office of Marine Assessment (OMA) will be discussed.

The National Tidal Data Program records long-term and short-term tidal elevation data at a number of locations around the New York Bight, including Montauk Point, the Battery, Atlantic City, New Jersey and Sandy Hook, New Jersey. Data collected at these stations are used to calculate times of high and low tide, sea level, and tidal range at each station.

Under the provisions of the Ocean Dumping Ban Act, OMA will be undertaking monitoring activities to assess the impact of sewage sludge disposal, and the cessation of this practice, on marine environmental quality in the area of the 106-mile Disposal Site.

NOAA's National Status and Trends Program was established in 1984 to document spatial and temporal variation in environmental conditions in U.S. coastal waters and to assess whether contaminant levels in the marine environment are increasing, decreasing, or remaining stable. The Program is divided into two components, the Benthic Surveillance Project and the Mussel Watch Project, the former monitoring levels of toxic substances in surficial sediments and benthic fishes, the latter monitoring the presence of a similar group of substances in the tissues of mussels and other filter-feeding bivalve shellfish. There are no stations of the National Status and Trends Program in the open waters of the Bight, although they are located in several of the inshore bays & estuaries adjacent to the Bight in both New York and New Jersey.

In assessing the need for additional monitoring programs focussed on the New York Bight in response to Section 728, a number of key concerns need to be understood and addressed:

1. What are the goals and objectives of the prospective monitoring program, other than simply meeting the requirements of Section 728? If the data and information derived from the monitoring program are to be used as input to a modeling program, what is the purpose of the modeling program?

2. What area is to be defined as the "New York Bight?" I recommend that the definition for the purposes of this program include the Long Island Sound, the Hudson-Raritan Estuary, and perhaps even Delaware Bay. The Delaware Bay can have a significant influence on the southern portions of New Jersey's ocean coast.

3. The specification of what information is needed for management decisions, information that would be, in part, developed through a monitoring program, is impossible until the overall purposes of the monitoring program are clearly established.

4. The Section 728 effort should not rely on current or past monitoring/modeling programs as a point of departure. Rather, an independent, comprehensive program should be designed and, then, the extent to which existing programs "fit" into the design scheme should be assessed. Where the "fit" is good, those programs should be incorporated, if possible.

5. The impact of historical and current monitoring programs/projects in the New York Bight on important marine resource management decisions and policies should be assessed.

6. The program should not focus on developing a single hydro-environmental model of the New York Bight system. Rather, there should be several independent models, each covering a portion of the overall region (e.g. Long Island Sound, Bight Apex, New Jersey inshore ocean, etc.). These models can then be linked to provide coverage of the entire Bight region.

A5. MONITORING PROGRAMS OF THE NORTHEAST FISHERIES CENTER AND OTHER AGENCIES IN THE NEW YORK BIGHT

John B. Pearce
Northeast Fisheries Center
National Marine Fisheries Service
Woods Hole, MA 02543

As the regional research unit of the National Marine Fisheries Service, the Northeast Fisheries Center (NEFC) regularly monitors the distribution and abundance of principal finfish and shellfish stocks distributed from the Canadian border to Cape Hatteras. The Center also undertakes cooperative monitoring with other NMFS research centers to deal effectively with pelagic species which range over the entire eastern seaboard of the United States.

In addition to monitoring the distribution and abundance of principal living marine resources, the NEFC regularly conducts monitoring activities which measure parameters such as water temperature, salinity, warm-core ring systems, chlorophyll, primary production, phytoplankton assemblages, irradiances, etc.

Additionally, variables that are commonly associated with marine pollutant and contamination are examined. Beginning in 1978, under the Ocean Pulse and Northeast Monitoring Programs, NEFC personnel have measured the distribution and concentration of inorganic and organic contaminants in sediments, water, and biota collected between the Virginia capes and the Bay of Fundy. These efforts indicated that there were " hot spots" for most contaminants studied, most frequently in the region's major urbanized ports and harbors. Some smaller, non-maritime harbors, such as Salem and Massachusetts, also had high sediment contaminant levels. Moreover, it was determined that the incidence of disease in finfish and certain shellfish was much higher in areas which were demonstrably polluted as indicated by elevated contaminant levels in sediments and indigenous fauna. These programs have primarily emphasized biological effects monitoring.

As NOAA implemented the National Status and Trends Program in 1985 to supplement other monitoring efforts, NEFC continued to pursue the measurement of contaminants, incidence of disease, other biological effects, and associated variables in those areas which had been shown by the earlier work to represent pollution "hot spots". Data and information derived from these monitoring programs are being reported in special technical memoranda and published papers as well as being permanently filed with the NOAA National Ocean Data Center (NODC).

NEFC scientists are currently using data on the distribution and abundance of living marine resources, data on the distribution and abundance of various pollutants, and information on the pollutant-induced responses of various organisms in predictive models which will demonstrate the effects of a range of variables on the health of fish and shellfish stocks. This information is being used in site characterization updates for specific geographic areas, including the 12- and 106-mile sewage sludge disposal sites in the Bight.

The philosophical aspects of monitoring have been recently discussed in conferences organized by the International Council for the Exploration of the Sea (ICES) as well as the United Nations Group of Experts on Scientific Aspects of Marine Pollution (GESAMP). Emerging from these meetings are the following realizations:

* progress in long-term environmental studies includes the use of existing or generic information and data in developing assessments;

* these assessments should provide the basis for future monitoring within regions such as the New York Bight;

* future monitoring efforts should be undertaken through a coordinated program involving those agencies active in marine monitoring in a particular area.

The data that are used is assessments, along with new data being procured through new, innovative technologies, should point the way forward and direct future research and monitoring programs. Scientists involved in monitoring oceanic and coastal resources should keep in mind that there are a limited number of variables that are probably sufficient to assess changes in water quality and which would be important in monitoring long-term changes in the marine environment. More importantly, resulting data should be of the type that is relevant to managing living marine resources and the other tangible assets that exist within coastal environments.

A6. A SUMMARY OF CORPS OF ENGINEERS MONITORING PROGRAMS: DAMOS AND NEW YORK BIGHT SITE DESIGNATION INVESTIGATIONS

Joseph D. Germano
Science Applications International Corporation
221 Third Street
Newport, RI 02840

A brief review of both the DAMOS program, which is the monitoring program sponsored by the New England Division of the COE, and the recent monitoring being done in the New York Bight by both the NY District COE and EPA Region II was presented. Both programs share a common approach to monitoring which has proven to be highly effective in producing data which are useful to environmental resource managers.

The DAMOS program of the New England Division is without a doubt one of the most comprehensive, long-term monitoring programs sponsored in this country for monitoring the impacts of open-water dredged material disposal. There are 9 active disposal sites in the New England region which are monitored under DAMOS from Maine to western Long Island Sound; the program has been around a little over 10 years, and has evolved over the years both in its approach to monitoring and the sampling tools being used to conduct the monitoring; the program has always involved the use of precision navigation to conduct all sampling tasks and state-of-the-art monitoring tools. High resolution precision bathymetry and REMOTS sediment-profile photography have been particularly effective sampling techniques.

However, the one aspect of DAMOS that makes it truly unique among monitoring programs is its approach to field monitoring tasks. Over the past 3 years, both SAIC and NED have been working to develop a tiered monitoring approach that is integrated to management objectives. The way this is accomplished is by using monitoring techniques which have a quick data return (e.g., sidescan, bathymetry, and REMOTS) so that regulators can really use field data to make active management decisions. The other difference to this approach is that instead of blindly measuring all parameters possible during monitoring as is typically done, the DAMOS field efforts focus on the parameters designed to address specific management objectives. In this way, the defined program objectives are determining the sampling and analyses to be performed, not the opposite. This achieves 2 important goals:

1. Cost-effective monitoring

2. Analytical results that provide useful information to regulatory managers.

The tiered monitoring approach which we've developed under the DAMOS program also has been applied to the recent site designation investigations done in the New York Bight. The main management objective during site designation investigations is to verify that the disposal site is indeed a containment site, a low energy, depositional environment. The framework for organizing the field effort to accomplish this is to concentrate only on characterizing the physical energy regime initially before any chemical or biological campling tasks are performed. This is accomplished using sidescan or sub-bottom sonar, precision bathymetry, current meter deployments, and REMOTS; this approach was used to organize the field efforts this past March on EPA's research vessel the ANDERSON.

Six sites were evaluated in the New York Bight (four nearshore chosen by the NY COE, two offshore sites chosen by EPA Region II). A dual-frequency 100 kHz sidescan integrated with a 3.5 kHz sub-bottom profiler were used to survey close to 900 km of tracklines, and a total of close to 200 REMOTS stations were occupied in all six areas. Current meter arrays were deployed by Battelle Ocean Sciences in four areas.

The results were not all that surprising, and confirmed the results of the considerable field work done in this general vicinity by scientists at USGS, NOAA, CERC, and Woods Hole over the past 20 years. The reports in the literature show that sediment inshore of the 60 m isobath consist of 98% sand, with some local areas of gravel and muddy sand. All these sites are located in less that 60 meters of water; the 4 nearshore sites range in depth from 20 to 42 meters, while the 2 offshore sites are in water depths between 40 - 50 meters.

The Hudson Shelf Valley is the major physiographic feature in the area, and cuts across the continental shelf from the Bight apex to the head of the Hudson Canyon; the valley serves as a sediment trap and a barrier to the general southwest transport of fine-grained sediment across the shelf. Both the side-scan and REMOTS confirmed the existence of sediments ranging from fine to medium sand, with some localized areas in the nearshore sites consisting of muds.

The only evidence of fine-grained muds were found at 2 of the nearshore sites (C-1 and C-2); the muds were very reduced at depth, indicating a high organic content. Even though it was possible to outline areas within these 2 nearshore sites that appeared to have the lowest near-bottom energy, it is important to remember the shallow depth of these two sites. These sites are located in a storm-dominated shelf of relict holocene sands with very little new sediment input. Resuspension and transport of sediments in the nearshore environment is quite common and occurs as a function of tides, regional drift, and wind-waves. As the seafloor features become larger and water depths greater (such as the large 1 - 3 meter sandwaves documented at the 2 offshore sites), erosion and transport become more episodic and are related more to peak storms rather than tidal events and windwaves. It was easy to see evidence of former bedload transport in many of the REMOTS images from these nearshore sites, where intercalated laminations of sand overlying muds were seen in the cross-sectional profiles.

The two offshore sites showed all medium to coarse sand or gravel with extensive bedforms over most of the areas. There was one small region in the most northern offshore site (E-1) characterized by fine sands; although the results of the current meter arrays are not in, if transport does occur in this region, any landward movement of sediment would probably result in emplacement within the Hudson Valley and subsequent seaward transport. On the other hand, mid-shelf sediment can also be disturbed during peak storms, with some movement landward depending on the direction of the storm. Again, the almost complete lack of fine-grained sediment in the mid-shelf seafloor is a clear indication that sediment is not contained locally in these offshore areas.

In summary, using this tiered approach to disposal site monitoring, whether it's for initial site designation investigations or for post-disposal monitoring, and also capitalizing on monitoring techniques which have a rapid data return are the best way to structure a field monitoring program. In this case, monies were not wasted performing biological or chemical characterization in any of the six areas; if they did not satisfy the initial physical requirement of a low-energy, depositional environment, there is no need to spend money for data that aren't required for a

management decision. A hierarchical design with sampling tasks that are structured to address null hypotheses is the most cost-effective approach; we've had a great deal of success on the DAMOS program with this method, and it has also proved effective for these initial investigations in the New York Bight region.

A7. MONITORING PROGRAMS IN NEW JERSEY'S MARINE WATERS

David Rosenblatt
New Jersey Dept. of Environmental Protection
Division of Water Resources
35 Arctic Parkway
Trenton, NJ 08638

Cooperative Coastal Monitoring Program

The County Environmental Health Act (NJAC 7:18 et seq.) authorizes the New Jersey Department of Environmental protection to sponsor the Cooperative Coastal Monitoring Program for the general analysis of coastal water quality. The adoption of the program's procedures for field monitoring and water analysis and its criteria for beach closures in the State Sanitary Code initiated the dual functioning of the program for the Departments of Environmental Protection and Health. The program has provided a constant format for water quality analyses and their application to coastal zone management strategies and rapid response to public health concerns.

The program monitors the presence and abundance of fecal coliform and Enterococcus sp. bacteria in New Jersey marine waters. Coliform data are retrieved from 340 stations, 170 ocean stations in the surf zone and 170 bay/estuary stations. Enterococcus sampling is conducted at 51 stations. Sampling is done a minimum of once weekly from 01 May to 15 September. Data from the CCMP is maintained on the STORET system.

Marine and Estuarine Water Quality Monitoring Network

The objective of this program is to provide information on background levels of nutrients and selected contaminants from the nearshore ocean waters of New Jersey. Water column nutrients and metals are sampled 4 times per year, while water column PCB's, pesticides, acid extractables, base neutrals and purgeables are sampled twice annually. Sediments are sampled at each station annually for selected metals, PCB's and pesticides. The program monitors the above parameters at 28 stations, all but one of which are in the Atlantic Ocean. Data storage is on STORET.

Marine Water Classification/Analysis for Shellfish Growing Areas

The objective of this program is to monitor bacterial water quality trends for shellfish harvesting. The abundance of total and fecal coliform bacteria are measured at 174 stations from Sandy Hook to 'Cape May. Stations are from 0.25 to 2 miles offshore. Approximately 2850 samples are taken annually through monthly sampling. Data storage is on STORET.

Marine Fisheries Toxic Monitoring Program

This program involves analysis of the levels of selected toxicants in the edible portions of striped bass and bluefish to identify trends and t support accurate seafood consumption advisories. The toxicants include metals, pesticides, and PCB's From each of two reaches along the New Jersey coast, Sandy Hook to Barnegat Light and Barnegat Light to Cape May, the program examines 6 single striped bass in the fall and in the spring, coinciding with the species' migration through the region. 30 single bluefish are examined from the area around Barnegat Light are also examined. Data storage is on STORET.

A8. NEW YORK STATE MONITORING PROGRAMS IN THE NEW YORK BIGHT

Charles de Quillfeldt
NYS Dept. of Environmental Conservation
Building 40
SUNY @ Stony Brook
Stony Brook, NY 11794

The State of New York and several local governments conduct monitoring programs in New York territorial waters (to 3 mile limit) of the New York Bight. Most of the sampling is part of public health monitoring programs designed to ensure that bathing beach and shellfishing water quality criteria are met.

The Division of Marine Resources of the Department of Environmental Conservation has two bureaus that are actively involved in monitoring programs in the Bight. The Bureau of Shellfisheries monitors bacteriological water quality in the approximately 1.2 million acres of shellfish growing areas of New York's Marine District to ensure that areas are properly classified as certified or uncertified for the taking of shellfish. Total and fecal coliform bacteria are the primary parameters measured, but surface water temperature and salinity are also monitored less routinely. The majority of the Bureau's sampling program is concentrated in the highly productive inshore bays adjacent to the Bight and in Long Island Sound. However, routine bacteriological water quality monitoring has been conducted in the productive surf clam area between Rockaway and East Rockaway Inlets for at least 15 years.

Since 1982, the Bureau of Shellfisheries has conducted about 20 sampling runs per year off the Rockaways. The Interstate Sanitation Commission aided the Department with 15 runs in the 1988 sampling year. It is expected that sampling in this area will be maintained at about 10 runs annually. In 1986, 24 new stations were established as part of a sampling program designed to determine whether year-round disinfection of the effluent from New York City's sewage treatment plants would result in improved bacteriological water quality in the area. The study indicated that water quality did improve and seasonal certification for 16,000 acres of shellfish lands was extended by 3 months (from May 15-September 30 to May 15-December 15) in 1987. The area became certified year-round in 1988.

In the New York Bight between East Rockaway Inlet and Fire Island Inlet, the Bureau's effort has been less frequent, with most sampling focused on two ocean outfalls from the Wantagh-Cedar Creek and Bergen Point sewage treatment plants. East of Fire Island Inlet almost no monitoring occurs, except for samples collected at Moriches and Shinnecock Inlets. The Bureau's goal is to sample the ocean east of East Rockaway approximately 5 times per year.

The Bureau of Finfish and Crustaceans conducts several monitoring programs in the New York Bight. The Ocean Haul Seine Project, ongoing since 1987, assesses biocharacteristics of striped bass collected at eastern Long Island beaches from September through early December. The 1987 samples were analyzed for PCBs. PCB analysis may also be scheduled for 1990. Temperature, salinity, and dissolved oxygen measurements are taken. Catch and biocharacteristic data are also collected by the Winter and Summer Flounder Investigation through party boat surveys (weekly since 1986). No water quality data is collected. The Artificial Reef Project of the Fisheries Access Program will be in collecting fisheries statistics in 1989.

The City of New York, Nassau and Suffolk Counties, and the Town of Hempstead conduct bathing beach water quality monitoring programs for coliform bacteria along the Atlantic Coast. Additionally, the Nassau County Department of Health has monitored water quality for over 15 years at 11 stations located approximately one-quarter mile offshore between East Rockaway Inlet and Tobay Beach (approximate Nassau-Suffolk border). Coliform bacteria, dissolved oxygen, and nutrient data are collected. The

Interstate Sanitation Commission also has collected data at two stations between Rockaway and East Rockaway Inlets for coliform, dissolved oxygen, nutrients, and some toxic substances.

A9. REMOTE SENSING OF PHYSICAL AND BIOLOGICAL PROPERTIES OF COASTAL WATERS AND ESTUARIES

Victor Klemas
College of Marine Studies
University of Delaware
Newark, DE 19716

Remote sensors combined with ship measurements can provide synoptic observations of coastal and estuarine phenomena which vary rapidly in time and space. Coastal applications of remote sensing require a wide assortment of sensors, including: aerial film cameras for beach erosion and vegetation mapping; multispectral scanners for wetlands, biomass and estuarine water property studies; thermal infrared scanners for mapping surface water temperatures and currents; microwave devices for salinity or wave measurements; and underwater cameras and acoustic systems for benthic observations. The effectiveness of these techniques is summarized in Table 4. Meaningful observation of physical and biological processes in estuaries (e.g., turbidity maximum dynamics or phytoplankton bloom development) requires the close coordination of satellite, aircraft, and ship data acquisition.

Recent progress in optical modeling and instrument design is making estuarine remote sensing quite effective. Multispectral solid state video cameras and other sensors are being developed which can be flown on inexpensive, small aircraft. Deployed in conjunction with satellites, these airborne sensors can observe tidal, seasonal, and annual variations, and the spatial distribution of phytoplankton blooms, sediment plumes, estuarine fronts, and circulation patterns. New hydrologic and optical data bases are being used to refine and invert practical models, such as the singly-scattered irradience model, to detect chlorophyll, suspended sediment, and dissolved organics in turbid estuaries. Inexpensive microcomputers and user-friendly software are facilitating the analysis of Landsat MSS, TM, SPOT, NOAA/AVHRR, Nimbus/CZCS, and other satellite data at small, local laboratories and research centers. These new techniques are enabling scientists to monitor the environmental quality of coastal waters and to compare the susceptibility of estuaries to degradation (e.g., eutrophication).

A10. OCEAN DATA TELEMETRY: WOODS HOLE OCEANOGRAPHIC INSTITUTION'S UNIVERSITY RESEARCH INITIATIVE PROGRAM

Daniel E. Frye
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Woods Hole Oceanographic Institution, in cooperation with Harvard University, MIT, and the Charles Stark Draper Laboratory, is developing techniques for real-time data collection from in situ oeean instrumentation. The thrust of the development is the design and subsequent testing of hardware to

Table 4. Performance of Remote Sensing for Estuarine Studies.

Sensor	Platform	Veg.& Land Use	Biomass & Veg. Stress	Coast-line Erosion	Bottom Feat. SAV	Depth Profiles	Susp. Sed. Ptrns.	Susp. Sed. Concen.	Chloro-phyll Concen.	Oil Slicks	Surf. Temp.	Water Sal.	Curr. Circ. Ptrns.	Wave Spectra	Surf. Winds
Film Cameras	A	5	2	5	4	3	4	3	3	4	0	0	3	3	2
	S	4	2	4	3	2	4	3	2	3	0	0	3	2	1
Multispectral Scanners	A	5	4	5	4	3	5	4	4	5	0	0	3	3	2
	S	4	3	4	3	3	4	4	3	3	0	0	3	2	1
Thermal IR Scanners	A	1	1	2	0	0	2	1	0	4	5	2	4	0	2
	S	0	0	1	0	0	2	1	0	3	5	0	4	0	1
Laser Profilers	A	0	0	3	3	4	1	0	0	1	0	0	0	5	2
	S	0	0	1	1	2	0	0	0	0	0	0	0	2	0
Laser Fluorosensors	A	1	0	1	0	1	2	3	4	4	1	2	1	0	0
	S	0	0	0	0	0	1	1	2	1	0	0	0	0	0
Microwave Radiometers	A	1	0	1	0	0	1	1	1	4	4	4	3	2	4
	S	0	0	0	0	0	0	0	0	1	3	3	2	1	3
Imaging Radar (SAR or SLAR)	A	4	2	4	0	1	2	0	0	4	2	2	3	4	3
	S	3	1	3	0	1	1	0	0	2	1	1	2	3	2
CODAR (Radar)	G	0	0	0	0	0	0	0	0	0	0	1	4	3	3
RADS(Acoustic)	G	0	0	3	3	3	2	2	0	1	0	0	4	2	0
UW Camera	G	0	0	3	3	3	3	2	2	3	0	0	1	0	0

Rating

5 = Operational
4 = Functional, Not Yet Operational
3 = Demonstrated Potential, Field Tests Required
2 = Potential Utility, Research Needed
1 = Limited Utility
0 = Not Applicable

Platform

A = Aircraft (Medium or Low Altitude)
S = Spacecraft (Satellite)
G = Ground (Boat or Field)

t.1A
vk/lh

telemeter data from instruments in the water column to the surface. We are using commercially available satellite or radio links to get the information from the surface of the ocean to the user. Design goals are to develop techniques which can be used in any water depth with a variety of instrumentation from anywhere on the globe. As part of this effort, we have evaluated several available satellite and radio links and have implemented the most promising of these in a series of experimental moorings. This presentation will describe the mooring and in situ telemetry techniques we have developed and the results of our evaluation of available RF telemetry links.

We have evaluated various RF telemetry links and our conclusions on the use of each of these systems are summarized below.

Argos — The Argos System provides the most versatile and easy-to-use telemetry option for most oceanographic systems. Primary limitations are low data rate, cost of data collection, and lack of a two-way capability.

GOES — The GOES System offers the least expensive option for telemetry of environmental data. It may be a very viable option for a New York Bight monitoring program. It is limited by lack of any position information and by a potential shortage of allocations.

GEOSTAR — GEOSTAR is a new commercial satellite system offering position, data, and two-way communication. It is inexpensive and may be a good choice for a monitoring program in the New York Bight. Its present coverage is limited to areas near the U.S. coast (within 600 miles).

VHF Radio — VHF radio links for line-of-sight ranges (10-20 miles) are a very practical and inexpensive alternative to satellite links. High data rates are practical, but considerable effort is usually required to maintain the shore-based receive stations.

HF Radio — These techniques offer few advantages over the Meteorburst satellite linkages discussed above, but may have applications where large networks of fixed stations can be monitored over medium-sized areas. The New York Bight is probably an appropriate size for consideration of these methods.

Standard -C — This is a new service of the INMARSAT system. It offers world-wide, two-way communication with reasonable size/cost hardware. It does not appear to be competitive with GEOSTAR or GOES for the New York Bight area.

We have conducted limited testing with all of the above systems except Standard-C, which is only now becoming available. Specific information on those tests is available from the author.

WHOI efforts to develop moored telemetry methods on the URIP can be grouped into three areas: hardware techniques; acoustic techniques; and inductive techniques. The hardware systems use an electromechanical cable to connect instruments along a mooring to a controller and transmitter located in a surface buoy. We have successfully demonstrated both Surface Telemetry Mooring and S-Tether Mooring in open ocean deployments. These systems are designed to allow telemetry from moorings which are very similar to our standard surface and taut wire intermediate moorings which have been used successfully in a wide range of water depths and ocean environments.

The acoustic technique uses an acoustic modem at each instrument level to transmit data to a surface receiver. This hardware is in the prototype stage and early tests indicate that reliable links are realizable over full ocean depths in the 15kHz frequency band at 1200 baud with transit powers of 1-10 watts. We anticipate having hardware ready for long-term deep ocean tests early in 1990.

A project to develop and inductive link has recently begun at WHOI. This technique involves the use of an inductive modem at each instrument level which uses the standard steel mooring cable to telemeter data to the surface. This eliminates the need for special cable and electrical breakouts, which are expensive and prone to failure. Tests of an initial prototype indicate that the technique is feasible at 1200 baud using relatively low power signals. Prototype testing in the deep ocean is scheduled for 1990.

A11. INNOVATIVE MONITORING TECHNIQUES

James D. Irish
Institute for the Study of Earth, Oceans and Space
University of New Hampshire
Durham, NH 03824

New technology developments have lead to new oceanographic monitoring systems which employ new sensors and utilize microprocessor-controlled data systems. These data systems are based on low-powered microprocessors with solid state memory (either Random Access Memory [RAM] or Erasable Programmable Read Only Memory [EPROM] for data storage. Such systems are easily powered for years with lithium batteries. The software control of sampling and conditional processing techniques make these user-friendly systems even more powerful data collectors. With the addition of real-time telemetry of data, the instrument can remain in place for long periods of time sending data back to the laboratory. The next generation of computer models will be combined with the real-time data to make the biggest impact on oceanographic monitoring. These new systems should be utilized in future studies leading to a monitoring program in the New York Bight.

The new generation of oceanographic monitors will have three basic parts: 1) the sensors; 2) the intelligent data system; and 3) the telemetry link.

Sensors

Temperature (T) is measured in most instruments by thermistors or platinum resistance thermometers. The measurements are simple, stable and easily done. Conductivity (C) measures the amount of dissolved ions in the water and is used with temperature and pressure to calculate salinity. Electrode sensors are used for the most accurate measurements. The major limitation of these measurements is the contamination of the electrodes by biological growth (biofouling). This can be slowed somewhat by anti-fouling compounds. Finally, pressure (P) is measured by strain gauge or quartz sensors. Pressure can give data on instrument depth, the tides and by high frequency sampling in shallow depths, the wave field. With T, C and P, salinity, density and derived quantities can be calculated to do water mass analysis, stability and dynamic height estimates, etc.

Water velocity is the next-most common physical measurement and is most often determined with momentum transfer devices such as the rotor or propellor, as in the VACM or VMCM current meter. Although they have problems, these instruments have been very well-studied and the VMCM may almost be considered a standard since its response is so well known. Recently, the Acoustic Doppler Current Profiler (ADCP) has been developed to obtain profiles of current velocity by using the Doppler principle. It has in bottom-mounted, mid-water moored and shipboard applications. In all cases, it records vertical profiles of current velocity, either as a function of time or space. A problem with moored current measurements is the flux gate compass, which is not sufficiently accurate for large-scale ocean programs.

Currents are also measured by drifters. These devices have a drogue which follows the current and drags an ARGOS transmitter along with it; the Draper LCD and Scrips Tri-Star are two examples of low-windage drifters. The RAFOS float sinks and is advected at depth before surfacing and relaying an integrated velocity measurement back to shore. Finally, integrated measurements of geostrophic velocity have been made by bottom pressure combined with moored temperature and conductivity measurements to obtain pressure gradients (dynamic height) time series between two moored instruments.

Optical sensors have been used to record in situ light levels to relate to primary productivity. Optical transmissometers and backscatterance sensors have been used to measure the amount of suspended particulate matter. They have the problem that quantitative measurements require calibration with the actual sediment load, measured directly. New technology is developing low-powered fluorometers which can determine in situ chlorophyll levels. Fiber optic sensors which can determine in situ chlorophyll levels. Fiber optic sensors which utilize tip coatings whose optical properties change with varying concentrations of dissolved gases, pH, etc., are used in monitoring the human bloodstream and are being adapted to oceanographic use.

Acoustic measurements from ships with high-frequency depth recorders and in situ instruments are measuring the spatial and temporal variability of sediments and organisms. Again, quantitative measurements require physical collection of samples to calibrate the instrument with the actual scatterers. The "chirp" sonar is now producing results identifying the kind, size, and number of fish and shows much promise for fisheries and related work. Acoustic tomographic techniques may be developed to the level that they can be used for monitoring in shelf regions, perhaps with an autonomous underwater vehicle as a source with multiple moored receivers.

A final kind of sensor is the one-time sensor which takes a single sample and then is done. These include sediment traps, chopstick samplers and Niskin bottles. The new twist in using these sensors is to control their use with an intelligent date system. Pumps can suck fixed volumes of water through filters to collect samples of sediment and small organisms and through resin columns which bond certain chemicals. Cameras can also be triggered by the data system; for example, when the water column clears after a resuspension event to determine bedform movement or alteration.

Other new sensors which are being tested include oxygen sensors for moorings and vertical profiling and pH sensors. These show promise, but need to demonstrate robustness and accuracy before they become standard sensors.

Intelligent Data Systems

There are a number of low-powered CMOS 8- and 16-bit microprocessor boards and controllers on the market. They all have accurate quartz clocks, 8- to 16-bit A/D converters, and integrating counters. They access RAM or APROM for data storage and have the ability to utilize the new WORM optical storage devices, when these become proven technologies. The microprocessor system has fewer components and is, thus, more reliable than its component counterpart. The system is also smaller and uses less power, yet has the processing power to preprocess dat for telemetry and storage. The sampling program can be controlled by user-friendly software. These systems are easily interfaced to a personal computer to transfer data for analysis, eliminating the need for a specialized tape drive. Finally, such systems are easily expanded and modified as experience and demands change.

The sampling program shows the power of the microprocessor. It can sample data and average it to low-frequency intervals (hourly) to obtain knowledge of long-term variability of parameters. It can also "conditionally sample" the same sensors for high energy events which occur over a short time and may be responsible for most of the mixing of water masses, resuspending and transporting sediment, etc. The intelligence of the microprocessor controls the sampling program to record these high energy events at a faster rate. In addition, the "conditional sampling" algorithm can control "one shot" samplers such as the water sampler, tripping a sediment sample only when the suspended sediment load reaches a predetermined level. This, during storm you could have the water sample for subsequent analysis and calibration of the optical or acoustic measurement. The limits of application of this technology lie principally in the imagination and inventiveness of scientists and engineers.

With a telemetry link, the intelligent data system can be a more effective monitor, since it can compress data and relay it to shore. The instrument can identify events and alert the shore station to their occurrence. It can also inform the shore station that the instrument is in trouble, for example, that its battery power is low. It can indicate that a resuspension event is underway and provide a signal to activate other components of the monitoring program, perhaps shipboard or plane/helicopter sampling.

The ultimate element in the monitoring program is combining the real-time conditionally-sampled data with suitable computer models to predict the physical, chemical, geological and biological variability of the Bight. This element is also, presently, the least developed component.

A12. SENSING PLATFORMS FOR USE IN MONITORING PROGRAMS

Ray Canada
National Data Buoy Center
National Space Technology Laboratories
National Oceanic & Atmospheric Administration
NSTL, MS 39529

The National Data Buoy Center (NDBC) began in 1967 as a project of the U.S. Coast Guard which was transferred to NOAA and moved to NASA's National Space Technology Laboratories in 1970. NDBC's mission lies in four primary areas:

Ocean Engineering Operations - provision of buoys to support NOAA requirements and provision of technical/logistic support to national ocean engineering programs;

> Environmental Data Buoy Technology - conduct buoy engineering development, testing, and evaluation and act as source of technical information on buoys;
>
> Environmental Data Buoy Application - provision of long- and short-term measurement applications and assist user organizations; and
>
> Automated Meteorological Observing Systems - development, testing, evaluation, and pilot operations of automated meteorological observing systems.

NDBC has deployed and maintains moored buoys at numerous locations along the nations Atlantic, Pacific, and Gulf Coasts. No buoys are currently located in the New York Bight proper, although several are on the margins of the Bight.

Standard (discus) buoys come in 3-, 10-, and 12-meter sizes, each size being used for a specific application. Payload data on moored NDBC buoys is shown in Table 5. Under development is a 2.3-meter coastal buoy for one-dimensional wave studies.

Drifting buoy technology has improved considerably since its introduction in the early 1970's. Buoys are currently available that measure and report data via satellite links on air pressure and temperature, surface wave height and period, and surface and subsurface water temperatures.

Table 5.

MOORED BUOY PAYLOAD DATA

PARAMETER	REPORTING RANGE	REPORTING RESOLUTION	SAMPLE INTERVAL	SAMPLE PERIOD	TOTAL SYSTEM ACCURACY
WIND SPEED	0 TO 62 M/S	1 M/S	1 SEC	8.5 MIN	± 1 M/S OR 10%
WIND DIRECTION	0 TO 360°	10°	1 SEC	8.5 MIN	± 10°
WIND GUST	0 TO 82 M/S	1 M/S	1 SEC	8.5 MIN	± 1 M/S OR 10%
AIR TEMPERATURE	− 40° TO 50° C	0.1° C	90 SEC	90 SEC	± 1° C
BAROMETRIC PRESSURE	900 TO 1100 hPa	0.1 hPa	4 SEC	8.5 MIN	± 1 hPa
SURFACE WATER TEMPERATURE	− 7° TO 41° C	0.1°C	1 SEC	8.5 MIN	± 1° C
SOLAR RADIATION*	0 TO 2150 WATTS/M²	0.5 WATTS/M²	1 SEC	8.5 MIN	± 5%
RELATIVE HUMIDITY*	0 TO 100%	0.03%	1 SEC	8.5 MIN	± 6%
SIGNIFICANT WAVE HEIGHT	0 TO 35 M	0.1 M	0.39 SEC	20 MIN	± 0.2 M OR 5%
WAVE PERIOD	3 TO 30 SEC	1 SEC	0.39 SEC	20 MIN	± 1 SEC
NONDIRECTIONAL WAVE SPECTRA	0.03 TO 0.40 Hz	0.01 Hz	0.39 SEC	20 MIN	—
DIRECTIONAL WAVES*	0.03 TO 0.35 Hz	0.01 Hz	1.0 SEC	20 MIN	± 5° OF AZIMUTH

*PARAMETER REPORTED ON SELECTED BUOYS

EAM 6/89

Table 6.

C-MAN MEASUREMENT REQUIREMENTS

MEASURANDS (NOTE 1)	REPORTED DATA	REPORTING RANGE	REPORTING RESOLUTION	MINIMUM AVERAGING PERIOD (NOTE 2)	TOTAL SYSTEM ACCURACY
BATTERY STATUS	BATTERY VOLTAGE	10 TO 16 V	0.1 V	(NOTE 3)	5% RDG.
CHARGER STATUS	CHARGE CURRENT	TBD	0.01A	(NOTE 3)	5% RDG.
AIR TEMPERATURE	AIR TEMPERATURE	−40° TO +50°C	0.5°C	1 MIN	±1.0°C
DEW POINT*	DEW POINT TEMPERATURE	−31° TO +86°F	1.0°F	1 MIN	−31° TO −11°F: ±4°F −10° TO +29°F: ±3°F +30° TO +86°F: ±2°F
SEA SURFACE TEMPERATURE	SEA SURFACE TEMPERATURE	−5° TO +40°C	0.5°C	1 MIN	±1.0°C
WIND DIRECTION	TRUE WIND DIRECTION	0° - 360°	10.0°	2 MIN	±15° TRUE (±10° DESIRED)
WIND SPEED	AVG. WIND SPEED (NOTE 4) PEAK WIND GUST	0-120 KN 0-160 KN	1.0 KN 1.0 KN	2 MIN (NOTE 5)	±2.0 KN OR 5% ±2.0 KN OR 5%
BAROMETRIC PRESSURE	SEA LEVEL PRESSURE	900-1100 hPa	0.2 hPa	2 MIN	±1.0 hPa ABSOLUTE
WAVES	WAVE PERIOD (T)	2.5 TO 35 SEC	1 SEC	(NOTE 6)	±1 SEC
	SIGNIFICANT WAVE HEIGHT ($H_{1/3}$)	0 TO 49 M (NOTE 10)	0.5 M	(NOTE 6)	0.5 M
	PROBABLE MAXIMUM WAVE HEIGHT*	0 TO 49 M	0.5 M	(NOTE 6)	0.5 M
TIDE	TIDE LEVEL	0 TO 99.99 FT	0.01 FT	(NOTE 9)	TBD
PRECIPITATION	CUMULATIVE PRECIPITATION	0 TO 999 MM	1 MM	(NOTE 7)	±0.2 IN. OR 4%
SECTOR VISIBILITY*	VISIBILITY RANGE	0 TO 8 STATUTE MI	(NOTE 8)	2 MIN	0 TO 3 MI: ±10% 3 TO 8 MI: ±1 MI

*GROWTH CAPABILITY

NOTES

1. ALL MEASURANDS ARE TO BE SAMPLED AT A RATE ≥1 HZ.
2. AVERAGING PERIOD SHALL BE SELECTABLE FROM 1-10 MINUTES (FIXED STATIONS—2 MINUTES, LNBs—8 MINUTES).
3. SAMPLING TO BE DONE UNDER LOAD.
4. REPORTED WIND SPEED IS A SCALAR AVERAGE. WIND DIRECTION IS A UNIT VECTOR AVERAGE.
5. REPORTED PEAK WIND GUST IS THE HIGHEST 5-SEC AVERAGE TAKEN DURING THE WIND SPEED AVERAGING PERIOD.
6. SELECTABLE FOR 10-, 15-, 20-, OR 24-MINUTE PERIOD.
7. RESET TO ZERO AT 0000, 0600, 1200, 1800 UTC.
8. REPORTABLE VALUES: 0, 1/16, 1/8, 3/16, 1/4, 3/8, 1/2, 5/8, 3/4, 7/8, 1, 1-1/8, 1-1/4, 1-1/2, 1-5/8, 1-3/4, 1-7/8, 2, 2-1/4, 2-1/2, 2-3/4, 3, 4, 5, 6, 7, AND 8+ STATUTE MILES.
9. POINT SAMPLE FOR LEUPOLD STEVENS GAUGE.
10. RANGE 0 TO 49 M FOR BUOYS. RANGE ON FIXED STATIONS IS SITE-SPECIFIC.

In addition to buoy-derived environmental information, the Coastal Marine Automated Network (C-MAN) operates through instruments maintained at more than 50 permanent navigation aids throughout U.S. coastal waters. In the New York Bight region, the Ambrose and Buzzards Bay Light Stations are part of C-MAN. Data available through C-MAN is noted in Table 6.

B. REVIEW OF THE NEW YORK BIGHT MONITORING WORKSHOP

Andrew Stoddard
Creative Enterprises
112 Orchard Circle
Hamilton, VA 22068

The objectives of the workshop on monitoring activities in the New York Bight, sponsored by the U.S. Army Corps of Engineers on 28-29 June 1989 included:

1) To identify historical monitoring programs in the New York Bight;

The New York Bight and the larger mid-Atlantic Bight have been intensively studied for four decades. Most of the research and monitoring programs that have been undertaken have focussed on the physical oceanography of the region or on hydrography and water quality. Table 7 lists a number of the principal such programs.

2) To determine key parameters requiring additional measurements;

The above studies notwithstanding, the monitoring workshop identified a number of parameters for which additional measurements were required to enable the development of accurate and useful predictive models of various components of the Bight ecosystem. These additional information requirements are listed in Table 8.

3) To identify new and emergent equipment and technologies applicable to marine environmental monitoring; and

The vast majority of hydro-environmental monitoring data assembled on the New York Bight has been derived through shipboard observation as measurement. Cost considerations and the desirability of synoptic observations suggest that various emerging technologies providing remotely-sensed or buoy collected data telemetered to shore-based stations should be considered in the development of a comprehensive New York Bight hydro-environmental monitoring program. Some of these technologies are presented in Table 9.

4) To provide initial direction in the assessment of the feasibility of establishing a New York Bight monitoring program.

Key problems and critical data gaps exist that must be addressed if additional hydro-environmental monitoring efforts in the New York Bight are to provide effective and useful inputs to models designed to predict anthropogenic impacts on the water quality and general environmental health of the New York Bight. These include:

*characterization and quantification of the flux of materials through the Rockaway-Sandy Hook transect;

Table 7.

MIDDLE ATLANTIC BIGHT RESEARCH & MONITORING PROGRAMS

Physical Oceanography

1979-80	NSF/WHOI/Nantucket Shoals Flux Experiment (NSFE)
1973-80	NOAA/AOML/ Marine Ecosystems Analysis Program (MESA)
1983-89	DOE/BNL Shelf Edge Exchange Processes (SEEP)
1984-86	MMS/SAIC Mid Atlantic Slope and Rise (MASAR)
1980-81	NOAA/NOS New York Harbor Measurement Programs
1974-78	DOE/BNL Coastal Boundary Layer Experiment (COBOLT)
1984-87	NSF/Univ Maryland Microbial Exchange and Couplings in the Coastal Atlantic System (MECCAS)
1985-89	EPA/NOAA Apex Recovery Study
1984-	EPA Deepwater Dumpsite 106 (DWD-106)

Table 7 Continued.

MIDDLE ATLANTIC BIGHT RESEARCH & MONITORING PROGRAMS

Hydrography and Water Quality

1948-49	NAS/WHOI New York Bight/Apex
1956-61	AEC/WHOI New York Bight
1966-70	US Army Corps of Engineers/Sandy Hook Lab/Apex
1970-71	ONR/SUNY-Marine Science Research Center
1973-80	NOAA Marine Ecosystems Analysis Program (MESA)
1976	NJDEP/NOAA "Fishkill 1976"
1976	BLM/VIMS Outer Continental Shelf Program
1974-81	DOE/BNL/Atlantic Coastal Experiment (ACE 0-7)
1974-	NOAA/NMFS/MARMAP Program
1980-85	NOAA/OAD/Northeast Monitoring Program (NEMP)
1985-89	EPA/NOAA Apex Recovery Study
1984-	EPA Deepwater Dumpsite 106 (DWD-106)
1983-88	EPA North Atlantic Incineration Site (NAIS)

Table 7 Continued.

MIDDLE ATLANTIC BIGHT RESEARCH & MONITORING PROGRAMS

Hydrography and Water Quality (continued)

1983-89	DOE/BNL Shelf Edge Exchange Processes (SEEP)
1984-86	MMS/Mid Atlantic Slope and Rise (MASAR)
1986-	EPA Hudson-Raritan Estuary Program
1978	DOE/Coastal Boundary Layer Experiment (COBOLT)
1984-87	NSF/Univ Maryland/ Microbial Exchange and Couplings in the Coastal Atlantic System (MECCAS)
1974-75	PSEG/EG&G Atlantic Generating Station Study
1973-74	PASNY/Grumman Ecosystems New York Field Studies
1986	NJDEP "Green Tide" Program
1974-	EPA Nearshore Coastal Waters
1987-89	EPA Floatables Study
1989	EPA/COE Apex "Mud Dump" Site Designation
1978-82	City of New York Apex Monitoring
1974-	EPA Coastal Monitoring in the Apex
1977	University of Delaware, TransX
	NJDEP coastal monitoring/coliforms/water quality
	NYDEC coastal monitoring/coliforms

*improved hydro-environmental data during storm events;

*improved survivability of in-situ instrumentation located in the New York Bight;

*Lagrangian measurements;

*improved measurements from surface and bottom boundary layers (i.e. within 1-2 m of the boundary) and the pycnoclune;

*clearer definition of the Bight's boundaries;

*better estimates of the influence of adjacent waterbodies (NY/NJ Harbor, Long Island Sound, Delaware Bay) on the Bight; and

*better quantification of the nature and extent of pollutant inputs to the Bight, both point sources and non-point sources.

Improved data on these and other parameters and phenomena from the New York Bight will be fed into a comprehensive geographic information system (GIS), being developed at Hunter College. The GIS will integrate the major components of a combined hydro-environmental monitoring and modeling program: hypotheses; observations and measurements; models and modeling techniques; and data/model output analysis.

C1. PHYSICAL PROCESSES WITHIN THE NEW YORK BIGHT

James H. Churchill and Robert C. Beardsley
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Here we will briefly consider dynamical processes in effect within the New York Bight, presenting aspects of these processes that are well and poorly understood.

Stratification - the vertical stratification over the Bight has two basic states. In winter, intense storms and convective motion brought about by surface cooling vertically mix shelf water over the entire water column. During this season, a sharp front in temperature, salinity, and density extends from the surface to the bottom at the shelf break, separating shelf water from the warmer, saltier, and denser slope water offshore. From mid-spring to mid-autumn, Bight waters are vertically stratified with a pycnocline situated between surface and bottom mixed layers. During this period, a horizontal front in temperature and salinity, but not density, is present at the shelf edge. Recent theoretical work indicates that this front is maintained by convergent circulation due to bottom friction and the rapid change in bottom depth at the shelf edge. Observations have indicated that large-scale exchange of shelf and slope waters within the Bight is effected primarily along density surfaces and occurs mainly during the period when the water column is vertically stratified and these surfaces are nearly horizontal.

Mean flow - numerous current meter and drifter observations have revealed that water over the Bight shelf drifts to the southwest with a mean longshelf velocity of about 5 cm/s. Recent analysis of oxygen isotope data has indicated that this flow may be an extension of the Labrador and Greenland Currents driven by buoyancy effects due to glacial meltwater and river runoff entering the shelf along the coasts of Greenland and Labrador.

Table 8.

KEY PARAMETERS REQUIRING ADDITIONAL MEASUREMENTS

PHYSICAL

tides
winds
waves
currents
temperature
salinity
oxygen/turbidity
estuarine influents
flux/exchange at boundaries
shelf/slope effects

GEOMORPHOLOGICAL

directional wave information
transect flux
suspended sediment distribution
bottom velocities/shear stress
bottom composition
deposition/resuspension rates

BIOLOGICAL

colliform levels
key indicator organisms
habitat changes
chlorophyll

CHEMICAL

* suspended metals
* suspended organic pollutants
* suspended nutrients
boundary fluxes
- metals
- organics
- nutrients

dissolved oxygen

(* Sediment and water)

Table 9.

NEW AND EMERGING MEASUREMENT EQUIPMENT/TECHNOLOGY

- Remote Sensing
  - Satellite
    - Direct

      suspended sediment
      chlorophyll
      surface temperature
      light attenuation
    - Indirect
  - Low-Cost Airborne Sensing (coupled to satellite)
- Telemetry
  - In Situ Instrumentation
- Conditional ("smart") Sampling Capability
  - In Situ Instrumentation
  - Event Driven
- NOAA Platforms
  - NDBC

Local buoyancy effects - the major local sources of freshwater to the Bight are the discharges of the Connecticut, Hudson, and Delaware Rivers. Numerous studies have shown that estuarine circulation produces a net outflow to shelf waters near the surface and extracts shelf water near the bottom. Estuarine-shelf interaction has recently been studied near Chesapeake and Delaware Bays. The results demonstrate that both the inflow to and outflow from the estuary mouth are strongly affected by the earth's rotation, bottom friction, and bottom slope. The near-surface fresh water discharge generally turns to the southwest after exiting the estuary. The near-bottom inflow essentially extracts a portion of the mean southwestward flow over the shelf, over a distance of up to 30 km from the river mouth.

Tides - tides are responsible for a large portion of the total current variance within Bight waters, up to 40% near the bottom at some mid-shelf locations. Most of the tidal energy is due to currents at the semidiurnal frequency. Over the "open" shelf, the semidiurnal tide behaves like a standing wave propagating shoreward, with the tidal ellipses oriented roughly perpendicular to the isobaths. In coastal waters, however, semidiurnal tidal ellipses are strongly altered by the shoreline configuration, particularly at an estuary mouth. The behavior of tides at the Bight Apex, where they are likely to be greatly affected by the coastal geometry, has not yet been studied substantially. Within the Bight, the semidiurnal tide's frequency lies above the Coriolis frequency and it may thus propagate as an internal wave. There is limited current meter evidence which indicates that very strong internal tides are generated at the shelf edge of the Bight, producing near-bottom currents which are sometimes in excess of 60 cm/s--strong enough to resuspend bottom sediment.

Wind-driven currents - much of the variance of current fluctuations over the Bight in the period range of 2 - 12 days is due to forcing by the surface wind stress. The large-scale response to the wind consists of a directly forced current and a free continental shelf wave. The directly forced response travels with the storm, generally to the northeast, whereas the shelf wave propagates to the southwest at a phase speed of roughly 500 km/day. The shelf wave is generated primarily by the alongshelf component of wind stress and arises due to alongshelf variation in the component. The changing orientation of the Bight's coastline will introduce spatial variation in the longshore wind stress. How this affects the generation of shelf waves is not yet understood. In coastal waters, the response to wind forcing will also be influenced by the "setup" produced when a wind-driven current encounters the shore. Analysis of current meter data taken off the New Jersey coast indicates that setup is important in the Bight Apex, but sheds little light on the details of the three-dimensional wind-driven flow in this area

If the fate of floatables within the Bight is at issue, then the very near-surface wind-driven current must be of concern. Drogue and drifter measurements in Lake Huron and Cape Cod Bay have shown that the wind- and wave-induced vertical shear of currents can be very large in the upper few meters of the water column, such that the surface current is sometimes directed nearly opposite to the flow 2 m below. There are very little data on near-surface currents in the Bight.

Discussion

Many of the processes affecting the fluid dynamics over the Bight remain poorly understood. This is particularly true in the region of the Apex where the varying shoreline orientation should significantly influence the wind-driven response, tides, and the estuarine-shelf interaction. We recommend that a study dedicated to understanding physical processes in the Bight Apex be considered before a monitoring program is undertaken. In preparation for such a study, a careful examination of the MESA data would be appropriate.

C2. CHEMICAL PROCESSES, TIME SCALES, AND THE DEFINITION OF CONCENTRATION

Iver W. Duedall
Dept. of Oceanography and Ocean Engineering
Florida Institute of Technology
150 W. University Blvd.
Melbourne, FL 32901

In considering the needs or requirements of monitoring, it is useful to have knowledge of basic processes involved and to have an understanding of the meaning and limitation of measured concentrations of various natural or anthropogenic materials in the coastal ocean. This brief presentation describes a general class of chemical oceanographic processes occurring in the ocean, some factors affecting these processes, their time scales, and the definition of concentration. The processes are: absorption/desorption, oxidation-reduction, complexation photochemical, neutralization, volatilization and radioactive decay.

Factors affecting these processes include the kind, form, and speciation of components entering the sea, biology, temperature, alkalinity, and oxygen concentration, to name a few. Time scales for the processes range from less than seconds for neutralization to billions of years for radioactive decay of some isotopes.

While chemical processes are illustrative of the time scale of transformations for a particular element, the residence time estimates the time an element remains in the water column before becoming permanently lost to the seabed. Residence time varies from a few hundred years to several hundred million years.

Data on concentrations of contaminants in seawater are normally instantaneous values, but are frequently interpreted as mean values. The monitoring program must determine at the onset whether instantaneous or time-averaged values are needed, since they can be very different.

C3. THE BIOACCUMULATION OF POLLUTANTS BY MARINE ORGANISMS

Nicholas S. Fisher
Waste Management Institute
Marine Sciences Research Center
State University of New York at Stony Brook
Stony Brook, NY 11794-5000

There are several important points to make regarding the bioaccumulation of pollutants by marine organisms.

Organisms cannot respond to pollutants outside them -- i.e. dissolved in seawater or sorbed to particulate matter. Organisms only respond to pollutants on or in their cells or bodies. Thus, it is essential to measure the bioaccumulation of pollutants in marine organisms rather than total or dissolved fraction pollutant levels in seawater. It is also more appropriate to express a toxic response as a function of the body burden of the pollutant in question, rather than as a function of ambient levels of that pollutant.

Pollutants can speciate very differently in seawater, depending on the chemical traits of the pollutant element and on the chemistry of the seawater. As a broad generalization, with many exceptions, dissolved organic matter can bind or complex pollutants, particularly certain metals such as copper and mercury, making them less available for biological uptake. Thus, a total load of copper in water low in dissolved organic matter would likely be accumulated by biota to a much greater extent and have a much greater toxicity than in water that is rich in organic matter.

Organic pollutants, such as the chlorinated hydrocarbons, accumulate (and are subsequently toxic) in marine organisms in proportion to their solubility in seawater, or their octanol-water partition coefficient. Generally, those compounds with high coefficients are accumulated to a greater degree than compounds with low coefficients. These compounds typically localize in the organs rich in lipids, such as the liver and hepatopancreas.

Metals bind to single cells roughly in proportion to their affinity for hydroxyl groups. Many metals associate with proteins and can be assimilated in organisms, although other metals (particularly non-essential metals such as lead) pass through animals largely unassimilated. Many animals "package" non-essential, particle-reactive metals so that very little of the metal remains in the organism, but is deposited in biogenic debris (e.g.. fecal pellets) which rapidly sink through the water column.

As a rule, the association of pollutants with marine organisms is reversible. If placed in pollutant-free water, contaminated organisms will depurate themselves of the pollutants, with this process often following a two- or three-compartment model. Depuration may take hours or months, depending on the organism and the type of pollutant. Generally, organisms reach an equilibrium with their environment with respect to pollutant concentrations, with bioaccumulation and depuration occuring simultaneously. At equilibrium, concentration factors for some pollutants in some organisms can be well over 10^5.

C4. MEASURES OF UNREASONABLE DEGRADATION

Joel S. O'Connor
Water Management Division
U.S. Environmental Protection Agency, Region II
Jacob K. Javits Federal Building
New York, NY 10278

Several speakers have emphasized the need for clear monitoring objectives; I raise one more voice for the importance of defining clear objectives for the Section 728 program before deciding what to model and monitor.

Based upon the enabling legislation, monitoring may well emphasize better understanding of water transport and fate of pollutants. This is fine, but I would encourage those defining the program to go beyond these things: to also monitor pollutant effects -- to establish that specific effects are serious, marginal, or not even detectable.

The Water Resources Development Act gives only very broad guidance about what should be monitored. Sec. 728 of the Act emphasizes monitoring the physics and chemistry of the Bight in order to measure the effects of air and water pollution. Apart from specific guidance regarding physical and chemical measurements, choices of what to monitor seem to be left entirely to the Corps of Engineers.

This is the typical position of agencies funded to monitor marine pollution effects; they are empowered to do it, broadly, -- not how to do it.

How do these agencies decide what to monitor? Typically, they ask scientists what to monitor. What could be more scientific and defensible? The result? Most monitoring programs fold up within 5 to 8 years. Why? Because the monitoring programs measured variables of little or no interest to the scientists who guided design of the program - not surprisingly. There are other reasons, of course, for failure of monitoring programs, but this is a common one. This is apparent in Larry Swanson's Summary of NY Bight Monitoring Programs: ten programs are continuing, nine of these are tightly linked to management decisions; four programs are now terminated, none of these were tightly linked to management decisions. The mean life span of the latter four programs was only five years.

I suggest an alternative way to decide what to monitor. Agency decision-makers should consult with others who have the broadest perspective on what is important to monitor, and decide primarily on the basis of what is important to know, secondarily on what is technically neat or scientifically conventional.

I define "what is important" as those things important to the public and/or important in making environmental decisions. For instance, monitoring indicators of pathogen concentrations in shellfish areas is important -- to the public and to the agencies that must decide when to close shellfish areas; regular measurements of lead or PCB concentrations in sediments are much less important to the public and to agency decisions. Continuing measurements of lead or PCB concentrations in sediments are very important to scientists who study lead and PCBs. More than coincidentally, many marine monitoring programs measure sediment lead and PCBs. (I do not question the importance of understanding the distribution, cycling, and effects of toxicants -- but these are more research than monitoring tasks.)

I have suggested some criteria for "the most important" monitoring measurements. (I often hear agreement with the criteria, whereas in practice the selections don't seem to me to match the criteria.): 1. socially relevant or socially important - environmental characteristics of interest to people and their governments; 2. simple, easily understood by laypersons and policy makers; 3. scientifically defensible - who could argue?; 4. acceptable in terms of cost.

All these criteria are valuable, but I stress that continuing, nearly always expensive, measurements should be socially important. Indeed, I suggest that useful monitoring measurements should generally be important enough to have management consequences. For instance, PCB concentrations in fishes are important -- mean concentrations of about 2ppm trigger management actions to protect human health. In contrast, sediment PCB concentrations of 1 -2 ppm (dry wt) (as exist in the Bight Apex) cause concern and provide some insight; but sediment PCB concentrations of even 10 ppm probably would not trigger management actions. Why? In themselves they are not perceived as that important; we are more interested in how sediment burdens influence edible fishes or water column concentrations that are regulated. Environmental features not specifically regulated or not widely perceived as important are unlikely to be useful 'measures of change in the Bight due to air and water pollution,' as outlined in Sec. 728.

So, if measures of environmental change are really important, they are generally important enough to help characterize "unreasonable degradation." The notion of unreasonable or unacceptable degradation is written into several of our environmental laws and regulations. Although the laws, and often the regulations, don't specify just what is "unreasonable," the intent is evident: some impacts can become serious enough to be socially unacceptable and justify management action of some kind.

To be more specific about what I consider important effects to monitor (or continue monitoring) in the Bight, I suggest the following list:

- Bottom dissolved oxygen concentrations, and effects on sensitive resource species
- Toxicant/carcinogen concentrations in food organisms
- Pathogen indicators in coastal shellfishing areas
- Pathogen indicators in the Bight Apex (the relevant measure(s) is that used by FDA as criterion for opening the area)
- Floatables on the open ocean and on beaches
- Resource abundance, including disease prevalence in fish and shellfish
- Reproductive success and population size of marine birds
- Benthic invertebrate community composition and abundance
- Visual quality of bathing waters

Past experience would indicate that costs will preclude monitoring all these effects. This only underlines the need for careful choices of what is really important.

C5. EPA-SPONSORED MODELING EFFORTS RELATED TO THE NEW YORK BIGHT

Kevin Bricke
Water Management Division
U.S. Environmental Protection Agency, Region II
Jocob K. Javits Federal Building
New York, NY 10278

Region II of the U.S. Environmental Protection Agency is involved in three major planning efforts to study the New York Bight: 1) The New York Bight Restoration Plan; 2) the Long Island Sound Study; and 3) the New York/New Jersey Harbor Estuary Program. When discussing and studying the New York Bight it is essential to incorporate all three waterbodies -- the Bight proper, the Harbor, and the Long Island Sound--as a single, interactive system. In discussing modeling of this system from a management perspective, three aspects of models are important: 1) prejudice; 2) the use of models as analytical tools for better understanding the system; and 3) models can be used to help develop rational plans for managing environmental problems in the system.

The extent to which models and modeling techniques are required hinges on a prior assessment of the nature of the environmental problems to be addressed. EPA's approach to problem identification involves the assessment of the use impairments and other adverse ecosystem impacts in the waterbody in question, the identification and characterization of factors responsible for these use impairments, and, lastly, the selection of planning modules around which to organize the planning response. The issue modules developed in the Long Island Sound Study include nutrients, toxic substances, pathogens, and floatables. The Harbor Estuary Program and Bight Restoration Plan each address these same issues plus critical habitat

With identification of the issues providing the planning framework for these studies, decisions regarding the appropriate use(s) of models direction require a full characterization of the problem, including its severity, geographic extent, and known or probable causes, followed by an assessment of the capability of existing or developing programs to answer the critical questions. Where these programs appear to fall short and there is a need for a sophisticated analytical tool to effectively address the problem, use of a model may be appropriate.

The documentation of very low dissolved oxygen levels in the western reaches of Long Island Sound suggests that anthropogenic nutrient enrichment of these waters may be exacerbating whatever natural hypoxia/anoxia historically occurred. In 1976, the New York Bight experienced a severe and widespread anoxia event, but this was shown to be largely unrelated to anthropogenic influences. For neither waterbody were there extant or developing programs that could provide information on the influence of nutrient loadings on dissolved oxygen levels. The Long Island Sound Study has been documenting nutrient and dissolved oxygen levels in the Sound and a water quality model linking the two is being developed by HydroQual, Inc. The model will cover the area from the Battery, at the tip of Manhattan Island to the Race at the eastern end of the Sound and will be calibrated in November, 1989. This will be coupled to a hydrodynamic model of the Sound and the linked models will be used to develop a Comprehensive Coastal Management Plan for the Sound by Fall of 1991. The boundary of the Sound water quality at the Battery means it will not cover much of the waters of New York Harbor. The New York Bight Restoration Plan will develop a nutrient model for the waters of the Bight. It is hoped to have a preliminary model in place by the Spring of 1991. The New York/New Jersey Harbor Estuary Program is just underway and an assessment is underway of existing models and modeling needs for that waterbody.

Outstanding needs relative to nutrient modeling in support of water quality management in this region include development of a model covering the waters of the Harbor, the integration of nutrients in the interconnected waters of Long Island Sound, the Harbor, and the New York Bight, and the development of more detailed models in the Bight.

C6. MODEL STUDIES OF NEW YORK HARBOR AND THE NEW YORK BIGHT BY THE WATERWAYS EXPERIMENT STATION

Frank A. Herrmann, Jr.
Waterways Experiment Station
US Army Corps of Engineers
Vicksburg, MS 39180

The Waterways Experiment Station (WES) has conducted numerous studies of the New York Harbor and New York Bight areas over the past 30 years in support of the Corps' New York District. This presentation provides an overview of those studies.

Our previous studies can be sorted by purpose into seven categories: tidal circulation; flood control; salinity intrusion; sedimentation; pollution control; navigation; and coastal processes. Many of the studies involved more than one of these purposes. Most of the studies involved use of a physical model, although several of the more recent studies involved use of a numerical model.

The existing physical model was constructed in 1957 for a study of shoaling in the navigation channel and adjacent pier slips in the harbor area of the Hudson River. The model includes the Hudson River to Hyde Park, the East River, a small portion of Long Island Sound, Upper and Lower Bays, Jamaica Bay, the Kills, Newark Bay, the Hackensack and Passaic Rivers, Raritan Bay and Raritan River, Navesink and Shrewsbury Rivers, and a small portion of the Atlantic Ocean. The model is constructed to geometric scales of 1:1000 horizontally and 1:100 vertically. It covers 25,000 sq. ft., is 500 ft. long, and 100 ft. wide at its widest point. A 12-1/2 hr. tidal cycle is reproduced in the model in about 7-1/2 minutes. The salinity scale is 1:1.

During the 1960's and 1970's, 30 studies were completed, all using the physical model. During the 1980's, 8 studies have been completed with the physical model, including 4 involving numerical models in a hybrid modeling mode, and 5 coastal processes studies involving only numerical models were completed.

The objectives of the LaGuardia Airport runway extension study in the early 1960's were to determine the impacts of the proposed extension on circulation, pollution, and sedimentation. The runway extends almost all the way across Rikers Island Channel, and model tests showed that the planned solid fill extension would dramatically reduce circulation and flushing in the area. The model showed that a pile-supported runway would have little impact. Construction plans were changed based on the model results.

In the mid-1970's, a study was conducted to determine the effectiveness and impacts of a proposed hurricane surge protection barrier to be located at the entrance to Jamaica Bay. It was necessary to construct an undistorted-scale section model to calibrate flow through the tidal openings in the barrier to ensure proper flow characteristics in the distorted-scale model.

A study of the influence of deepening the main navigation channel into the Port of New York to 70 ft on salinity intrusion was conducted in the early 1980's. This was the first application of the hybrid technique to New York Harbor. The numerical model was needed to provide salinity boundary condition data to the physical model, which did not extend far enough offshore to contain the entire length of the deepened channel.

In support of a ship simulator study (at WES) of the Port Jersey Navigation Channel, both physical and numerical models were used in 1988 to generate the detailed depth-averaged velocity fields required to drive the simulator.

Several studies have been conducted to evaluate the dispersion of various contaminants, including thermal wastes. These studies determined the differences between basic conditions, various outfall locations, and proposed projects. Most physical model pollution tests are conducted by tracing the concentration of conservative dyes injected into the model. Dye tests of the proposed Shrewsbury Inlet showed that the inlet resulted in reduced concentrations in areas near the inlet for dyes released in the nearby Shrewsbury and Navesink Rivers.

Over about the past decade, several coastal processes studies have been conducted with numerical models along the Long Island coastline and in the New York Bight. These studies have dealt with circulation patterns, dredged material disposal, and subsequent erosion from the disposal area, shoreline changes, storm-induced beach and dune erosion, stage-frequency analysis, and wave refraction analysis. A numerical model initially developed for a hurricane surge study has subsequently been used to provide many of the frequency data for various phenomena in other coastal processes studies.

Existing physical and numerical models at WES could be used to provide boundary conditions data for the proposed New York Bight models, determine the influence of Harbor pollution on the Bight and visa versa, conduct sensitivity tests of boundary condition changes, etc. Among the advantages of using the WES physical model are that it already exists and has immediate availability, it is fully three-dimensional, it provides a good reproduction of turbulence, and it is the best tool for studying dispersive processes such as salinity intrusion. Among the advantages of using the WES hybrid numerical models are that they already exist and have been verified to both physical model and prototype data, their formulation permits excellent geometric flexibility and the ability to customize detail in problem areas, and they provide efficient boundary condition generation.

C7. CHESAPEAKE BAY THREE-DIMENSIONAL MODEL STUDY

Carl F. Cerco
US Army Engineer Waterways Experiment Station
Mail Stop ES-Q
Vicksburg, MS 39180

A three-component model package is being developed to study eutrophication and associated problems in Chesapeake Bay. Descriptions of the components--a three-dimensional, time-varying hydrodynamic model; a three-dimensional, time-varying water quality model; and a predictive model of sediment-water interactions--are provided.

Chesapeake Bay is the nation's largest, most productive estuary. Pressures of population and industrialization have caused a measurable decline in aesthetic and economic resources of the Bay. Among the identified problems are eutrophication (characterized by excessive nutrient concentrations and anoxic bottom waters), decline in submerged aquatic vegetation, decline in harvest of finfish and shellfish, and toxic substance pollution (USEPA, 1983 a,b).

Numerous water quality studies of the Bay have been conducted to understand causes of the decline and to formulate plans for alleviating the problems. Most recently, a three-dimensional eutrophication model was calibrated to steady-state conditions in the Bay (HydroQual, 1987). The model study identified interactions between bottom sediments and overlying water as key components of the eutrophication process. Calibration of the model to observed conditions in the water column was impossible without the introduction of sediment-water fluxes as boundary conditions. The study also indicated the limitations of the steady-state approach. Extensive "tuning" of dispersion coefficients was required to match observed salinities. No estimate was attained of the time required for the Bay to respond to water quality improvement measures.

Previous model studies indicate several areas in which improvement is necessary to obtain a predictive tool for managing Bay water quality. A time-variable, three-dimensional model of transport and dispersion is required. The ability of the model to resolve vertical density stratification, which leads to bottom water anoxia, is especially important. Processes that determine nutrient recycling and oxygen consumption in the bottom sediments must be modelled explicitly. Model simulations of a time period sufficient to resolve long-term changes in Bay water quality are to be conducted.

A model package sufficient to meet these needs is presently being developed (Dortch et al., 1988). The package consists of three interacting models: a time-variable, three-dimensional hydrodynamic model; a time-variable three-dimensional water quality model; and a predictive model of sediment nutrient and oxygen flux. The model package is undergoing calibration through a simulation of tides and currents, dissolved substances, and benthic fluxes observed in the complete year 1985. The models will be verified against similar data bases collected in 1984 and 1986. Once calibrated, the models will be used to simulate a period sufficiently long to attain improvements in Bay water quality. This period is estimated as five to thirty years.

The hydrodynamic model (HDM) is an improved version of the model denoted CH3D (Sheng, 1986). The model operates on an intratidal ($<$ tidal cycle) time scale, employs boundary-fitted coordinates in the longitudinal-lateral plane, employs sigma-stretched coordinates in the vertical direction, and incorporates a higher-order turbulence closure scheme to model vertical eddy transport. The intratidal time scale allows accurate prediction of currents, diffusion, and transport without the need to "tune" dispersion coefficients. Curvilinear and stretched coordinates enhance model resolution in the highly irregular geometry of Chesapeake Bay. The turbulence closure scheme ensures accurate representation of the physical processes that lead to vertical density stratification.

The hydrodynamic and water quality models are operated as separate modules. Output from the HDM is written to an intermediate file that is used as input by the water quality model (WQM). This process is computationally efficient, as numerous WQM runs can be executed without recomputing the hydrodynamics. Indirect linkage of the two models presents several challenges, however. Care is required that water surface levels, flows, and diffusion processes are correctly transferred between the two models. Limits on computation time force operation of the WQM on a longer time scale than the HDM. A series of rigorous tests ensures that transport in the WQM, computed approximately hourly, agrees with transport in the HDM, computed at much shorter intervals. Investigations are underway to develop a deterministic method of converting intratidal HDM transport to intertidal (longer than a tidal cycle) transport for use in the WQM. This method will produce substantial improvement in the computational efficiency of the WQM.

The WQM was developed especially for this project. The model schematizes the Bay into a three-dimensional matrix of interconnected, sequentially numbered boxes. The concept is similar to the WASP model (Ambrose et al., 1986) but with several improvements. Notably, transport equations in the longitudinal and lateral directions are solved using a three-point numerical scheme, QUICKEST (Leonard, 1979), that minimizes numerical dispersion. The vertical transport equation is solved using an implicit numerical scheme that allows employment of longer integration time steps than an explicit scheme.

WQM state variables (Table 10) and processes (Table 11) are incorporated in the model based on recommendations of a workshop attended by Bay scientists and engineers (HydroQual, 1988). The model differs from many conventional water quality models in that algal biomass is represented as carbon rather than chlorophyll "a". Oxygen consumption in the water column is represented by oxidation of organic carbon rather than biochemical oxygen demand. These formulations facilitate comparisons of predictions with observations and optimize interactions of the WQM and sediment model (SDM). Several other features of the model are also necessitated by interactions with the SDM. Algae are sorted into groups differentiated largely by the rates at which they settle to the bottom. Particulate organic matter is separated into labile and refractory fractions so that the time scale of decay in the sediments is correctly represented. Chemical oxygen demand, released by the sediments, is oxidized in the water column.

The WQM and SDM are run interactively rather than linked indirectly as the HDM and WQM. The sediments are schematized as two layers--an aerobic layer in contact with the water column and a deeper anaerobic layer. SDM segments directly underlie WQM segments and the schematization may be viewed as an extension of the box model concept from the water column into the sediments.

The SDM represents three fundamental processes: net settling of particles to the sediment; diagenesis (decay) of organic matter in the sediment; and flux of substances between sediments and water column. SDM kinetics are a development of concepts expressed by DiToro (1986). Fluxes predicted by the model and the processes that induce the fluxes (Table 12) are specified based on recommendations of a workshop convened for that purpose (HydroQual; 1988).

Acknowledgements

The Chesapeake Bay Model package is being developed as part of a program sponsored by the U.S. Army Engineer District, Baltimore, and a state-federal partnership administered by the Chesapeake Bay Liason Office, Region III, U.S. Environmental Protection Agency. Permission was granted by the Chief of Engineers to publish this information.

Table 10. Water Quality Model State Variables

Physical
- temperature
- salinity

Chemical
- dissolved inorganic N & P
- dissolved organic N & P
- particulate N & P (labile and refractory)
- ammonium
- dissolved organic C
- particulate organic C (labile & refractory)
- dissolved oxygen
- chemical oxygen demand
- dissolved silica
- particulate biogenic silica

Phytoplankton
- diatoms
- cyanobacteria (blue-green algae)
- other phytoplankton

Inorganic suspended solids

Table 11. Water Quality Model Processes

- dissolution and settling of particulate organic matter
- mineralization of dissolved organic matter
- nitrification
- exchange of phosphate with inorganic solids
- exertion of chemical oxygen demand
- oxidation of dissolved organic solids
- exertion of chemical oxygen demand
- oxidation of dissolved organic carbon reaeration

Table 12. Sediment Model Fluxes and Processes

Fluxes

- Dissolved Oxygen
- Silica
- Ammonium
- Methane
- Nitrate
- Sulfide
- Dissolved Inorganic Phosphorus

Processes

- Diagenesis of organic matter
- Nitrification and dentrification
- Sulfate reduction and sulfide oxidation

Methane production and oxidation
Partitioning of particulate and dissolved phosphorus
Partitioning of particulate and dissolved silica

References

Ambrose, R., Vandergrift, S., and Wool, T. 1986. "WASP3, A Hydrodynamic and Water Quality Model--Model Theory, User's Manual, and Programmer's Guide." EPA/600/3-86/034. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA.

DiToro, D. 1986. "A Diagenetic Oxygen Equivalents Model of Sediment Oxygen Demand." Sediment Oxygen Demand. K. Hatcher ed. Institute of Natural Resources, University of Georgia, Athens, GA, 171-208.

Dortch, M., Cerco, C., Robey, D., Butler, H., and Johnson, B. 1988. "Work Plan for Three-Dimensional Time-Varying, Hydrodynamic and Water Quality Model of Chesapeake Bay." Miscellaneous Paper EL-88-9. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

HydroQual. 1987. "A Steady-State Coupled Hydrodynamic/Water Quality Model of the Eutrophication and Anoxia Process in Chesapeake Bay." BATL0401/0402. HydroQual Inc., Mahwah, NJ.

HydroQual. 1988. "Workshop Number 1 Water Column State Variables and Aquatic Processes November 12-13, 1987." USCE0010. HydroQual Inc., Mahwah, NJ.

HydroQual. 1988. "Workshop Number 2 Sediment Processes and Sediment Modeling Workshop December 2-3, 1987." USCE0010. HydroQual Inc., Mahwah, NJ.

Leonard, B. 1979. "A Stable and Accurate Convective Modeling Procedure Based on Quadratic Upstream Interpolation." Computer Methods in Applied Mechanics and Engineering. 19:59-98.

Sheng, Y. 1986. "A Three-Dimensional Mathematical Model of Coastal, Estuarine and Lake Currents Using Boundary Fitted Grid." Report No. ARAP Group, Titan Systems New Jersey Inc., Princeton, NJ.

USEPA. 1983. "Chesapeake Bay: A Profile of Environmental Change." U.S. Environmental Protection Agency, Region III, Philadelphia, PA.

USEPA. 1983. "Chesapeake Bay: A Framework for Action." U.S. Environmental Protection Agency, Region III, Philadelphia, PA.

C8. PHYSICAL OCEANOGRAPHIC MODELING IN NEW YORK BIGHT

Alan F. Blumberg
HydroQual, Inc.
1 Lethbridge Plaza
Mahwah, New Jersey

The numerous measurements which have been made in the New York Bight make it among the most extensively investigated waterbodies in the world. Based upon these measurements, it is apparent that the characteristic feature of the circulation is a southwestward mean flow along the shelf of roughly 2 - 10 cm/sec with a mean transport of the order of $2.5 \times 10^5 m^3/s$. The average currents generally increase in magnitude offshore and decrease with depth. This flow is thought to be driven by an alongshore, north-to-south, sea level slope of approximately 2×10^{-7} at the shelf break. Superimposed on these mean currents are fluctuations due to wind stress. Interaction with the deep ocean at the shelf break helps to keep the shelf water on the shelf. Flow off the shelf break exhibits large variability associated with the meanders and warm-core eddies of the Gulf Stream. The major estuarine plume in the New York Bight is the plume emanating from the Hudson-Raritan Estuary. The Hudson plume makes a clockwise turn as it flows from the Estuary. The size of the plume varies depending on discharge rate and wind conditions but the general persistence of the plume appears in all seasons of the year, often out to 30 km from the Rockaway-Sandy Hook transect.

Simulations of the long-term circulation in a region slightly larger than the Bight have shown that the presence of the Gulf Stream is an important component of the circulation along the continental shelf in the New York Bight. Moreover, a series of observations using buoy tracking, intensive hydrography, satellite thermal imagery, and moored current meters has shown that eddy-like features are almost always present along the shelf break. The eddies typically appear as plumes of less saline shelf water that protrude into slope water, curling "backwards" opposite the direction of the mean shelf flow.

This talk reviews the important physical processes thought to be responsible for the observed circulation in the Bight. Ideas on the types and availability of data needed to represent these processes in circulation models will be presented as well. The major features of the summer circulation will be demonstrated with results from the recent three-dimensional hydrodynamic modeling study performed by HydroQual, Inc. as part of the New York Bight Restoration Plan.

C9. MODELING OF SURFACE WINDS AND WAVES

Vincent J. Cardone
Oceanweather, Inc.
Cos Cob, CT 06807

Numerical spectral ocean wave models were introduced in the mid-1950's. Within the last decade, their use has become widespread in applications such as real-time wave analysis and forecasting, specification of the extreme wave climate for the design of coastal and offshore structures, and specification of the long-term wave climate for study of coastal erosion and transport processes. For example, in the New York Bight region spectral models have recently been used to provide detailed forecasts of the two-dimensional spectrum on the continental slope in support of a sensitive drilling program using a dynamically-positioned drillship and in a 20-year hindcast study of the wave climate along the East Coast, carried out by the Army Corps of Engineers, using nested grid systems to provide wave statistics very near the coast. The general area of the Bight is represented in the operational global and North Atlantic wave models operated in real-time at major centers such as NOAA's National Meteorological Center, the European Center for Medium-range Weather Forecasting (ECMWF), the U.K. Meteorological Office, and the Canadian Atmospheric Environment Service. However, the Bight itself is poorly resolved in these models because the grid spacing is at least approximately 100 km and shallow water processes are generally ignored.

The first spectral models introduced used first-generation physics, in which the sources and sinks of energy (source terms in the spectral energy balance equation solved numerically in such models) are mainly empirical expressions. The Corps of Engineer's study mentioned above used a second-generation model, employing tuned parameterizations of sound physical expressions for the source terms representing atmospheric input, nonlinear wave-wave interactions, and wave dissipation. Recently, a third-generation (3G) model has been introduced which includes a more rigorous representation of the nonlinear interaction source term and explicit source terms to represent dissipation due to whitecapping and, in shallow waters, bottom friction. While some first- and second-generation models provide accurate specifications of the surface wave height and period when driven by accurate winds, the 3G model provides comparable specification in modeling the details of the full directional spectrum in complicated wave situations, while employing less arbitrary source terms.

A common feature to all model which might be applied to the New York Bight is the need to model virtually the entire North Atlantic Ocean, or to couple a regional model to an existing model covering this much larger area. A second common feature is the need for accurate wind field data. Fortunately, at least for analysis and hindcasting purposes, several studies have demonstrated that the synoptic scale wind field in the New York Bight may be specified from high quality surface pressure fields to an accuracy of approximately 2.5 m/sec (rms) in speed and 20 degrees in direction through the use of validated marine planetary boundary layer models. Slightly greater accuracy is possible if winds measured by buoys or at exposed coastal stations are incorporated through kinematic analysis or objective assimilation of direct winds observations is necessary to model meso-scale effects such as the sea breeze. Of course, high quality wind and wind stress fields are needed not only to drive a wave model, but also to drive models of ocean circulation and surface drift.

With high quality wind fields, the accuracy achievable with a well-tuned spectral wave model applied on a high-resolution grid to the New York Bight may be expressed in terms of the following errors (rms): 0.5 m in significant wave height; 1.0 s in peak spectral period; and 20 degrees in vector mean wave direction. Spectral models should also skillfully represent multiple peaked spectra associated with the superposition of locally-generated seas and swell generated storms on the open North Atlantic.

With the possible exception of storm situations, the contribution of a wave model to an integrated New York Bight model is unlikely to be the direct specification of surface wave properties. Rather, its significance will be in allowing a proper treatment of the indirect role of surface waves in transfer processes at the air-sea interface, in mixing processes in the upper layers of the water column, and in sediment excitation. Recent studies have tended to confirm that the drag coefficient, relating surface stress to the wind speed, depends heavily on sea state parameters and, therefore, cannot be expressed solely in terms of the wind. Surface waves have been identified (in other presentations at this workshop) as an important element in mixing of, minimally, the upper layers of the water column and, in shallow water, the entire water column. Finally, surface wave action can significantly influence sediment transport processes, as turbulent wave intensities in the bottom boundary layer cause sediment resuspension. This process is sensitive to the relationship between wave-induced bottom stress and sediment properties -- a relationship used in some models to calculate the bottom friction source term.

C10. HYPOXIA AND EUTROPHICATION IN NEW YORK BIGHT

Jay L. Taft
Dept. of Organismic and Evolutionary Biology
Harvard University
26 Oxford Street
Cambridge, MA 02138

The topic I am asked to discuss implies that I know how to model eutrophication in New York Bight, or at least that I know others who know how, as a result of my exposure to modeling efforts in Chesapeake Bay and Long Island Sound. The underlying question is: Does the experience gained in the Chesapeake Bay and Long Island Sound modeling programs apply to modeling the New York Bight? For biological systems, I believe the answer is yes.

To arrive at this conclusion, I considered some of the similarities and differences between the New York Bight, Chesapeake Bay, and Long Island Sound. All have seasonal fresh water inflows, as well as salinity, temperature, and nutrient cycles, and successions of various species. Phytoplankton successions are of primary interest for our purpose. All three systems experience nutrient additions from point and non-point source run-off and from the atmosphere, but only the New York Bight receives significant nutrient input from the deep ocean. All three systems experience bottom water hypoxia in summer to varying degrees. Each region is an important natural and economic resource.

The New York Bight has been a focus of oceanographic studies for much of this century. Since the mid-1950's, biologists have been concerned with questions relating to the seasonal plankton succession, nutrient limitation, and nutrient sources and sinks for the Bight. Ketchum and Keen (1955) estimated fresh water flow to the region from Cape Cod to Chesapeake Bay. Their calculations indicated the residence time of river water in that region was about 1.5 years, so that in any given summer the high flows of the previous two springs are present on the continental shelf. They further found a decrease in river water southward along the coast even though new river water was being added. The cross-shelf transport of water was estimated from seasonal salinity changes and horizontal mixing coefficients to be 0.58 - 4.96 x 10^6 cm^2/sec.

A decade later Riley (1967) used this information in a simple mathematical model to estimate the magnitudes of processes affecting dissolved inorganic nitrate and phosphate concentrations in the New York Bight. Using five stations 25 km apart on a transect across the continental shelf perpendicular to the shore and a system with two vertical layers, he assumed the following:

1. Vertical mixing between layers decreased seaward: 10% per day at Station 1; 5% at Station 2; 2% at Station 3; and 1% at the others.

2. Horizontal exchange of 2% between segments, which is equivalent to an eddy coefficient of 2.9 x 106 cm2/sec, near the mean of Ketchum and Keen's (1955) computed values.

3. The system is in steady-state.

4. Phytoplankton production is controlled by nutrient concentrations.

5. Daily nutrient utilization is 20% of the observed concentration.

6. Daily nutrient remineralization by zooplankton and bacteria in the surface layer is 10% of the observed concentration.

7. Net production of the surface layer settles to the bottom layer and is remineralized there.

The model gave reasonable results for a steady-state calculation, thereby confirming the general validity of Riley's assumptions about the biological and physical processes acting in the New York Bight. The model showed that inshore nutrient concentrations in the surface layer may be elevated at high remineralization rates without considering the additional nutrient inputs from the land. Obviously, sewage treatment plants along the coast would contribute both organic and inorganic nutrients to inshore waters. We are concerned about these regions because the inshore bottom along the New Jersey coast typically exhibited hypoxia in data summarized by O'Connor (1979).

During the 1970's, several groups sampled the New York Bight to address questions about the extent of eutrophication resulting from discharges from the Hudson River, the greater New York-New Jersey metropolitan area, and from ocean dumping. Attention was sharply focused on the Bight when it experienced a significant anoxic event in 1976. Several factors interacted to accentuate the regular summer oxygen depletion, but the anoxia was widespread and local nutrient enrichment from the land was not a major causative agent.

Research on the New York Bight indicates that the biological processes operating there are similar, if not identical, to estuarine processes. This should not be surprising because most estuarine organisms either evolved from coastal species since the last glaciation, or are coastal species inhabiting estuaries as extensions of their ranges. Therefore, the biological models which reasonably approximate Chesapeake Bay or Long Island Sound should be adaptable to New York Bight. In fact, a water quality model for Chesapeake Bay was exercised for Long Island Sound without code modifications and yielded sensible results. However, progressing from steady-state to time-variable calculations and coupling the biological model to a circulation model are not trivial tasks.

REFERENCES

Ketchum, B.H. and D.J. Keen. 1955. The accumulation of river water over the continental shelf between Cape Cod and Chesapeake Bay. uppl. to Vol. 3 of Deep-sea Research, pp. 346-357.

O'Connor, J.S. 1979. A perspective on natural and human factors. In R.L. Swanson and C.J. Sindermann (eds), Oxygen Depletion and Associated Benthic Mortalities in New York Bight, 1976. NOAA Professional Paper 11. US Dept. of Commerce.

Riley, G.A. 1967. Mathematical model of nutrient conditions in coastal waters. Bull. Bingham Oceanographic Collection. 19: 72-80.

C11. SEDIMENT TRANSPORT MODELS: A REVIEW OF EXPECTATIONS WITH RESPECT TO THE NEW YORK BIGHT

Henry J. Bokuniewicz
Marine Sciences Research Center
State University of New York at Stony Brook
Stony Brook, NY 11794-5000

Sediment transport models could be used for a number of purposes in the context of water quality and related management decisions in the New York Bight:

*predicting shoreline changes that might occur naturally or as the result of offshore activity;

*selecting containment (or dispersal) sites on the shelf for dredged material disposal;

*predicting substrate changes;

*anticipating the redistribution of sediment particles by storms; and

*identifying the impacts of an activity within the range of natural variability in the system.

At least four types of sediment transport models may be used:

1. Models of shoreline change. These models, like the Corps' GENESIS model, generally require information concerning wave, sediment size, littoral geometry, and coastal bathymetry. They forecast the equilibrium shoreline position and/or profile shape by calculating longshore and/or cross shore transport. Coastal models would use wave information generated by Bight-wide models and could provide estimates of the sand flux beyond the active beach profile for boundary conditions to models of bedload transport in the Bight.

2. Bedload models. Bedload models determine the flux of non-cohesive sediments, usually as a two-dimensional vector field representing the shelf surface. These would be important in the Bight since most of its seafloor is sandy. In general, such models require the bed shear stress to be specified as well as the critical stress needed to initiate sediment motion. The latter value is usually determined from the grain size by standard empirical relationships. The sand flux could be calculated by one of several proposed formulas. These formulas are non-linear and different parameterizations may produce results that differ by orders of magnitude. As a result, the models require site-specific calibration and verification to decide which of the available approaches is best.

   Models of shelf sand transport must include wave-current interactions and a mechanism to differentiate the total drag into a component due to form drag and a component due to skin friction. Skin friction is the relevant stress for sediment transport, but the current profiles are influenced by the total boundary drag. This analysis may involve detailed studies of bedforms. There are uncertainties concerning the best approach for handling mixed grain sizes and models do not typically allow for bathymetric changes.

3. Suspended sediment transport models. These models are generally advection/diffusion models which include particle settling. Many have been developed in two dimensions, but pseudo three-dimensional, three-dimensional, and PIC models have been exercised. These models can incorporate schemes for higher-order, turbulent closure and adjustments can be made to account for differences between the diffusion of momentum and the diffusion of particles. Provision can also be made for interactions between the flow and suspended sediment, which may reduce the drag.

   In practice, suspended sediment transport models are sensitive to extreme events and the determination of appropriate in-situ settling velocities are problematical because of the formation of aggregates or marine snow. Problems in specifying the boundary conditions also arise. The lateral boundaries are unlikely to be simple flux conditions and the treatment of the Hudson River plume will probably require special attention. The bottom boundary condition, however, is most difficult. Resuspension and deposition can only be specified empirically through site-specific, direct measurements, although parameterization based on observed relations determined for the site can be useful.

4. Dredged material disposal operations are perhaps best modeled with the Corps' DIFID, DIFCD, or DIFHD models, although others are available for different specific types of operations. The Corps' models essentially treat the discharged sediment as a dense fluid; the active, dynamic spread of this fluid is followed by passive advection-dispersion with settling. These models

might be strengthened by more extensive verification, especially in deep water. They do not predict the formation of a deposit at the disposal site, for which geotechnical models are required.

In general, sediment transport models are dependent on hydrodynamic models and they are especially sensitive to extreme conditions. It may be that a "smart" model is required to track the hydrodynamic model and initiate detailed calculations of sediment transport only during critical periods.

These models are heavily empirical. Therefore, they are more or less site- and condition-specific. Since the models are calibrated at the site, if conditions change, the continued reliability of the models is uncertain.

There are many versions for calculating sediment fluxes. No widely-accepted standard method has yet emerged. In practice, several versions are usually tried for each study area to test the appropriateness of each for that area's specific conditions.

Despite these difficulties, many successful and functional sediment transport models have been developed, including a number for the New York Bight.

C12. MODELING THE EXCHANGE OF NUTRIENTS BETWEEN THE WATER COLUMN AND SEDIMENTS

Dominick M. DiToro
HydroQual, Inc.
1 Lethbridge Plaza
Mahwah, NJ 07430

The motives for building a model for the exchange of nutrients between the water column and sediments include: predicting the fluxes of O_2, NH_4, NO_3, PO_4, and Si to and from sediments; to relate these fluxes to the overlying water concentrations and temperature; and to relate these fluxes to the flux of particulate organic matter to the sediment.

The critical connection is between the flux of particulate organic matter (POM) to the sediment and the recycled nutrient fluxes. The sediments act as an additional compartment in which nutrients are recycled and oxygen is consumed. Recent estimates of loadings and fluxes have been made by HydroQual, Inc. (1989). Approximately 45% of the particulate loading of nitrogen to the Bight is recycled from the sediment as inorganic nitrogen fluxes.

The sediment model discussed in this presentation is presently under development as part of a comprehensive model of Chesapeake Bay. The data used for this model is part of a comprehensive sediment data collection program. The model includes three components. The particulate organic matter is delivered to the sediment compartment via settling from the overlying water. The POM decays - a process termed diagenesis - into reactive intermediates. These intermediates undergo further reactions in the aerobic layer of the sediment and are exchanged to the overlying water as nutrient fluxes, and consume oxygen as sediment oxygen demand (SOD). A model of SOD and ammonia fluxes for freshwater sediments that is based on these ideas has been proposed (DiToro et al., 1989).

In the ammonia and nitrate flux model, the critical role of the ratio of SOD to overlying oxygen concentration follows from the equations:

$$SOD = D \frac{dO_2}{dz} \approx D \frac{O_2(0) - 0}{\delta}$$

so that:

$$\frac{SOD}{O_2(0)} = \frac{D}{\delta}$$

which demonstrates that $SOD/O_2(0)$ is the surface mass transfer coefficient.

The SOD model is based on the oxidation of aqueous and solid phase sulfides that are produced by the diagenesis of organic matter:

$$2CH_2O + SO_4^{2-} \rightarrow 2CO_2 + S^{2-}$$

The distribution of solid and aqueous phase sulfide is controlled by partitioning. Mass transfer occurs between the anaerobic and aerobic layer where sulfide is oxidized producing SOD.

The calibration of the model is accomplished using observed relationships between the flux of ammonia and the other fluxes, as influenced by the overlying water oxygen concentration. In the present state of calibration the silica flux model predicts an overlying water dissolved oxygen dependency that is not observed, but other parameters are in reasonable agreement with observations.

The construction of interactive water column - sediment models for eutrophication and hypoxia which include a submodel for sediment fluxes that relate the sediment fluxes to overlying water POM inputs is clearly feasible. In light of this fact, and the fact that this model is being applied to the Long Island Sound hypoxia investigation, it is recommended that the feasibility investigation for the NY Bight be directed at problem frameworks which (1) are clearly of major concern, and (2) for which feasibility has not been demonstrated. For example, the computation of the fate and transport of toxic organic and metal contaminants depends critically on a model of fine grain sediment transport and the associated hydrodynamic model. The feasibility of such a calculation for a comprehensive investigation of the fate and effects of PCB-contaminated sediments that are associated with dredged material disposal, for example, is a question of importance which has yet to be investigated.

C13. SPECIFYING AND MODELING AT THE BIGHT BOUNDARIES

Gregory Han
Han & Associates, Inc.
685 Curtiswood Drive
Key Biscayne
Miami, FL 33149

Major processes affecting the dynamics of water motion on the shelf operate at various time scales: waves (seconds - minutes), tidal/inertial (12 - 24 hours), wind (2 - 15 days) and seasonal/inter-annual (20 - 1000 days)

Tidal time scale processes are well-described and can be reproduced easily throughout the New York Harbor and the adjacent continental shelf. Except within the estuary, they are more important for friction and dispersion than as transport mechanisms.

Wind-driven processes are the most important and most energetic for contaminant transport in the Bight. Successful dynamical frameworks for wind-driven processes have been provided by investigators working over the past 15 years.

Seasonal and inter-annual currents can be modelled using simple dynamics on time-averaged quantities, but these scales are too long for dealing with contaminant transport.

The boundaries defined by these dynamical considerations must be understood. Cross-shelf boundaries should be perpendicular to isobaths; offshore boundaries should be parallel to isobaths. There are definite dynamical regions in the Bight: estuary outflow (Bight Apex), nearshore (< 20 miles), mid-shelf (20 - 100 miles) and shelf break/slope (> 100 miles).

Estimates of the fluxes of heat, momentum, and dissolved and suspended constituents are required across all boundaries. The dynamically-important momentum, heat, and salt fluxes are needed for the hydrodynamic model, which then becomes the framework for the transport model for the other constituents. The most important dynamical boundary conditions are the momentum entering through the horizontal boundaries as current velocity and through the surface boundary as wind stress.

Boundaries for Modeling

Surface Boundary

The wind stress at 3-6 hour intervals can be interpolated from measurements at shore stations and EB. Daily averages of net heat flux can be calculated from bulk formulas using air & sea temperatures, and wind data. Evaporation and precipitation are probably not important processes to consider.

Offshore Boundary

Ocean dynamics makes real time prediction and measurement of transport at the offshore boundary difficult. Transport is mainly along-shore, but deep water depths cause a small cross-isobath transport component to be significant to the small shelf volumes. Extending the deep water boundary offshore only elongates and complicates the cross-shore boundary specification. Using the shelf break as a boundary may allow selection of locations with minimum cross-isobath fluxes.

Cross-shelf Boundary

This is the most important boundary. Temperature, salinity, and velocity measurements are needed along the northeastern and southwestern boundaries. Either cross-shelf sea surface elevations or along- shelf velocity measurements are required. The dynamics of shelf flows is an interrelationship of wind, current, and sea surface elevation (SL). In shallow, frictionally-dominated regions, there is a time-lagged response of SL to the currents and of both SL and currents to the winds. SL quickly comes into geostrophic adjustment with the currents generated by wind forcing. In the deeper mid-shelf region, wind forces the currents and SL adjusts so the SL lags the currents in time. However, in both regions, free shelf waves force currents in the absence of wind and then the currents lag SL in time.

A complexity in modeling the cross-shelf boundary is attributable to the changing dynamics along the cross-shelf boundary as follows: wave zone (turbulent dynamics); nearshore (2-20 m) (frictional dynamics); mid shelf (20-100 m) (Ekman wind dynamics); and shelf break/slope (100-1000 m) (strong topographic control).

The dynamics and forcing also change seasonally with changing stratification and varying weather systems.

The best approach to modeling may be to develop an optimal cross-sectional prediction model from real-time measurements of sea level, wind, and currents. Adequate such data exist to make an optimal prediction model for the Bight boundaries.

The northwestern boundary of the Bight is most important since free waves propagate in that direction. Selection of the region for cross- shelf boundaries is dependent upon the region of interest. The best data are those produced by the MESA Program from 1975-79 because of concurrent velocity and density measurements. Placement of the southern boundary is less important. Suggested northern boundaries are either Montauk or Nantucket Shoals. Nantucket shoals would allow inclusion of Long Island Sound in the model and enough data exist from the Nantucket Shoals Flux Experiment for correlation of the current response. The Montauk transect excludes the more complex Long Island Sound and New England bays, but has the greatest amount of data. Suggested southern boundaries are either the mid-New Jersey coast or Cape May. Since, dynamically, the southern boundary could have a radiation condition, data on this boundary is less important. Modeling south of Cape May introduces Delaware Bay into the region.

Estuary

The Hudson estuary is the most important source of contaminants onto the shelf. This estuarine influence is not important to large scale shelf dynamics except in a minor way as a source of fresh water. The influence of the estuary extends only into the Bight Apex. The fresh water plume of the estuary has two basic modes, either hugging the New Jersey coast in a well-defined jet with a sharp vertically sloping frontal region, or spreading weakly over the surface of the Apex. Early attempts to define a gyre which might trap pollutants along the shore were unsuccessful.

Circulation in the Bight Apex is very complex due to the interaction of topographic, density, and wind-driven influences. For modeling of shelf conditions, the details of the Apex flow may perhaps be ignored and only an estimate of the bulk transport onto the shelf of contaminants may be necessary.

Inclusion of the Hudson-Raritan Estuary and Long Island Sound in the modeling region would be very interesting and would eliminate the estuary boundary specification completely. An attempt at this ambitious model of the whole region requires a better understanding of the individual dynamical shelf regions than presently exists.

C14. MODELING FLOATABLE WASTE TRANSPORT

Malcolm L. Spaulding
Applied Science Associates, Inc.
70 Dean Knauss Drive
Narragansett, RI 02882

The floatable debris trajectory model was employed in a backward mode to calculate the potential source location of medical waste observed beaching along the southern New England shoreline in July 1988. Stranding location data were obtained from the Rhode Island Department of Health and newspaper accounts of the incident. Mean ocean currents and wind conditions used as input to the model were obtained from a synthesis of existing data and meteorological observations from Green Airport in Warwich, Rhode Island. The wind data were scaled, based on the literature, to represent offshore conditions. Model simulations indicate that the probable source of the medical wastes was the New York Bight Apex, with the most probable release time being in mid-June 1988. Forecasted waste stranding locations, assuming selected release times in the New York Bight Apex, confirm the backward mode hindcasts. These calculations also show that a specific set of meteorological conditions was responsible for the observed strandings along the Rhode Island coastline. For release in early June, the waste is calculated to impact the southern Long Island shoreline. The calculations performed were completed within one week using the best available information time frame.

A review of the above simulations and prior work in oil spill trajectory modeling indicates that the principal environmental parameter necessary for high quality forecasting or hindcasting of the trajectories of floatable wastes is an accurate representation of the wind field. The next most important parameter is the mean ocean current. Information on tidal currents is normally of secondary importance in determining long-term transport, unless trajectories are very close to the shoreline. The presence of frontal zones and convergence areas has a significant impact on floatable motion but is poorly represented by most models and data sets used to define the circulation fields.

The basic procedure for modeling the transport of floatables has changed little in the last decade, still relying on the well-known drift factor approach. While this technique is simple and practical, it often has significant errors and only roughly accounts for the wind and wave influences on material transport. It is suggested that an integrated wind-wave hydrodynamic model of the near surface zone be developed to provide improved predictions of floatable material transport. The model needs to incorporate the effects of breaking wave dynamics and near- surface stratification. Development of such a model and its validation against field and laboratory data will result in substantial progress in modeling floatable trajectories.

It is critical in modeling floatable transport to recognize the importance of fronts, convergence zones, intrusions, eddies and rings. These are often sub-grid scale features in hydrodynamic models and, hence, are not adequately described. Available data sets also rarely define the spatial or temporal characteristics of these features, which often are critical to determining floatable transport. As a practical matter, some rudimentary data-model assimilation techniques can be used to address this problem.

Based on a review of the literature there are few, if any, data sets available to allow a detailed comparison between model predictions and observations. This makes model testing and validation a difficult task at best. The use of ARGOS-tracked drifting buoys shaped and weighted to represent floatable waste is one technique to provide the required data sets. This approach has worked well in recent (July, 1989) tracking experiments from an experimental spill of crude oil off the Norwegian coast.

C15. MODELING TOXIC SUBSTANCES: THE LONG-TERM BEHAVIOR OF PCBs IN THE HUDSON ESTUARY**

Robert V. Thomann
Dept. of Environ. Engineering & Science
Manhattan College
Riverdale, NY 10471

Modeling the transport, fate, and accumulation of toxic substances in the New York Bight includes a variety of issues, including estimation of the flux of substances from the Hudson River Estuary to the Bight. Such input loading to the Bight must include a modeling framework extending back to individual point sources of chemicals and to the heads of tide in adjoining river systems to include non-point sources. Without such a framework, management questions relating to the effects of source control on ambient toxicant concentrations cannot be adequately addressed. An example of such a modeling framework, that used to estimate the response of Hudson River Estuary striped bass PCB concentrations to various PCB source control management alternatives, is discussed here.

The particular model is a large space- and long time-scale model of the major components of PCB homolog fate, transport, and bioaccumulation in the Hudson River Estuary and adjacent waters. The model is composed of 150 segments (30 in the water column; 120 in the sediments) and extends from the Troy dam to the New York Bight and Long Island Sound. The physio-chemical model includes mechanisms of partitioning, settling, resuspension, diffusive exchange with the sediment, volatilization, an decay -- all as functions of PCB homolog -- together with flow transport and tidal dispersion/mixing.

The food web homolog model is time- and age-dependent, has the striped bass as its focus, and includes uptake, depuration, accumulation from food consumption, and migration into and out of the study area. The model is driven by the dissolved homolog concentrations calculated by the physio-chemical model.

The time scale of the physio-chemical model is annual with a constant hydrology (interannual hydrology is also analyzed) and calculations begin with zero initial conditions everywhere in 1946. The time scale of the food web model is seasonal with water concentrations constant within a year but variable from year-to-year.

Preparation of the physio-chemical model includes calibration to salinity (for transport & dispersion) and to suspended solids (for net deposition to the sediments). Additional calibration is obtained through use of a preliminary time-variable model of cesium concentration in the Estuary. The PCB homolog model is then calibrated to water column and sediment PCB concentrations using the physio-chemical model and to white perch and striped bass using the food web model.

The PCB load from the Upper Hudson is estimated to have reached an annual average maximum of about 150 lb/d (25 mt/yr) total PCB in the early 1970's, since which time it has been declining at an exponential decay rate of about 0.28 my/yr. The decline may be due to a combination of PCB decay, reduced sediment input and burial in upstream sediments, and reduction in upstream inputs of PCBs from source sites. Estimated total PCB loading in 1987 is about 3.0 lb/d (0.5 my/yr).

The PCB load by homolog group in the 1980's is probably about 40% in the di- and trichlorobiphenyl, about 40% in the terta-homolog, and the remainder in the penta- and hexa-group.

Loading of total PCB to the region below the Troy dam from point sources, runoff and atmospheric deposition reached an estimated maximum of 30 lb/d (5 mt/yr) in the early 1970's and declined steadily thereafter. The 1980 estimated downstream load is 46% of the total load to the Estuary. Total loading to the entire study area (Hudson Estuary, New York Bight and Long Island Sound) in 1980 is estimated at about 48 lb/d (8mt/yr) of which only 22% is due to inputs from above the Troy Dam.

Based on an analysis of the downstream striped bass PCB concentration, it is estimated that the inputs of PCBs in the lower Hudson region are declining at an exponential rate of 0.057/yr.

Using appropriate homolog-dependent partitioning, volatilization and zero decay, the PCB homolog model of physical and chemical fate and transport adequately reproduces the observed total PCB water column concentration in the 1977-79 period, which varied from 0.25 ug/L total PCB in the upper end of the Estuary to about 50 ng/L at the Battery.

Surface sediment PCB spatial profiles were adequately reproduced by the model for the years 1975-80 and varied from 1 to 10 ug/g (dry wt) in the Estuary. Homolog distribution in the sediment was reasonable calibrated by the model.

PCB sediment depth data was adequately calibrated in the upper and middle reaches of the Estuary over a sediment residence time of about forty years. Details of observed sediment cores were not reproduced because of the coarseness of the model in the vertical sediment grid and horizontally in the water column. Local regions of deposition and vertical detail were therefore not captured.

With a credible model of the physical and chemical fate and transport of PCB homologs, mass balances of inputs and subsequent deposition of the homologs in the study area can be constructed.

The estimated total mass of PCB discharged to the Hudson River Estuary proper through 1987 is 270 mt (595,000 lb). The calculated fate of this material is distributed by homolog among volatilization (66%0, flux to the New York Bight and the Long Island Sound (17% and 2% , respectively), dredging transport out of the Hudson (9%) and storage (6%).

The annual flux of PCB leaving the Estuary to the New York Bight and Long Island Sound is estimated to be 3.4 mt (7,500 lb) in 1987. This flux is primarily associated with the more highly chlorinated PCB homologs.

Approximately 5 mt (11,000 lb) of PCB were added to the Hudson Estuary sediments in 1973, but it is estimated that, by 1987, these sediments annually released 0.5 mt (1,100 lb) to overlying waters. This represents about 30% of the total load to the water column in the Estuary.

Data on PCB concentration in the Hudson River striped bass indicate an approximate log normal distribution. Average concentrations in 1978 were 1.5-2.0 times the median concentration and were about 5-10 times the current FDA action level of 2 ug/g (wet wt.). Annual coefficients of variation range from 0.6 to 1.0. PCB concentrations in mid and lower Hudson River striped bass have been declining steadily since the early 1980's at an annual exponential rate of about 0.057/yr.

The food web homolog model includes phytoplankton, zooplankton (represented by Gammarus), "small fish", white perch in 7 age classes, and striped bass in 17 age classes. Calibration to white perch in the mid and lower Hudson is good for total PCB. Peak concentrations of almost 50 ug/g (wet wt.) were calculated for the white perch in the mid-1970's. Calibration to the striped bass total PCB concentration in the mid and lower Hudson River for 1978-87 is quite good. Peak concentrations of 45 ug/g (wet wt.) were calculated for the mid 1970's. The downward trend in striped bass concentration is captured through use of a declining downstream loading.

Calibration to the age of striped bass in the mid and lower Hudson River is good for total PCB in 1978. PCB concentrations are calculated to be higher in the younger age classes (< 5 years) because of outward migration to lower PCB concentrations. The model suggests that more than 90% of the concentrations of

PCB in striped bass is due to food web bioaccumulation and less than 10% due to uptake from the water only. Such bioaccumulation is homolog-dependent, ranging from 98% fro the 4-chlorine homolog to 85% for the 2 chlorine homolog.

With a credible model of PCB fate and bioaccumulation, estimates were made of the Hudson River striped bass fishery to two scenarios: a "No Action" alternative and a complete removal of the upstream PCB source at Troy beginning in 1987.

Since the striped bass data are log normally distributed, it is important that a determination be made as to what percent of striped bass will be acceptable below the current action level of 2 ug/g (wet wt.). It is estimated for the weighted average 3-6 year old fish, a mean PCB concentration of 3 ug/g (wet wt.) would result in about 50% of the population below the target level of 2 ug/g (wet wt.). For 95% of the fish to be below the target level, the mean concentration would have to be about 0.9 ug/g (wet wt.).

For the "No Action" alternative, it is estimated that 50% of age 3-6 striped bass would be below 2 ug/g (wet wt.) by about 1992. 95% would be below the target level by 2004. Complete elimination of the upstream PCB load across the Troy dam reduces the time to reach the 50th percentile. The impact of downstream input and sediment releases of PCBs below the Troy Dam are the major determinants affecting the recovery of the striped bass fishery to levels below 2 ug/g PCB (wet wt.).

Local and short-term variability in water column PCB concentrations, variable striped bass migration patterns related to population size, uncertainty in the downstream loading estimates, and parameter specification all contribute to overall model uncertainty. The simulation results should therefore be viewed as indicative of overall trends only.

ACKNOWLEDGEMENTS

This research was supported, in part, by the Hudson River Foundation for Science and Environmental Research to Manhattan College.

**Abstracted from "Mathematical Model of the Long-term Behavior of PCBs in the Hudson River Estuary", Chapter 1, Summary of Conclusions, Thomann, R.V., J.A. Mueller, R.P. Winfield, and C.R. Huang, Hudson River Foundation, 1989.

APPENDIX

NEW YORK BIGHT MODELING WORKSHOP
List of Participants and **Speakers**

Patricia Barnwell
U.S. Army Corps of Engineers, New York District

Laurie Behrman
State University of New York at Stony Brook

Alan Blumberg
HydroQual, Inc.

Henry Bokuniewicz
State University of New York at Stony Brook

Kevin Bricke
U.S. Environmental Protection Agency, Region II

H. Lee Butler
U.S. Army Corps of Engineers, Waterways Experiment Station

Vincent Cardone
Ocean Weather, Inc.

Carl Cerco
U.S. Army Corps of Engineers, Waterways Experiment Station

Ray Chapman
Ray Chapman & Associates

Karen Chytalo
New York State Department of Environmental Conservation

Carol Coch
U.S. Army Corps of Engineers, New York District

Tom Cole
U.S. Army Corps of Engineers, Waterways Experiment Station

Sam Corson
U.S. Army Corps of Engineers, Waterways Experiment Station

Robert Dieterich
U.S. Environmental Protection Agency, Region II

Dominic DiToro
HydroQual, Inc.

Mark Dortch
U.S. Army Corps of Engineers, Waterways Experiment Station

Bruce Ebersoll
U.S. Army Corps of Engineers, Waterways Experiment Station

Doug Evans
Evans-Hamilton, Inc.

Leslie Flanagan
U.S. Army Corps of Engineers, New York District

Eugenia Flatow
Environmental Policy Forum

Debbie Freeman
U.S. Army Corps of Engineers, New York District

Victor Goldsmith
City University of New York

Ross Hall
U.S. Army Corps of Engineers, Waterways Experiment Station

Gregory Han
Han & Associate, Inc.

Donald Harleman (co-moderator)
Massachusetts Institute of Technology

Tom Hart
U.S. Army Corps of Engineers, Waterways Experiment Station

Larry Hauck
U.S. Army Corps of Engineers, Waterways Experiment Station

Paul Hauge
New Jersey Department of Environmental Protection

Frank Harmann
U.S. Army Corps of Engineers, Waterways Experiment Station

James Irish
University of New Hampshire

John Kuo
Columbia University

Joseph Letter
U.S. Army Corps of Engineers, New York District

Betty Little
American Association of University Women

Thomas Meeks
City University of New York

JoAnn Moisedes
New York State Department of Environmental Conservation

Tom Morrissy
Connecticut Department of Environmental Protection

Joseph O'Connor
New York University

Mario Paula
U.S. Army Corps of Engineers, New York District

Jack Pullen
U.S. Army Corps of Engineers, Waterways Experiment Station

Robert Reid
National Marine Fisheries Service, NOAA

Donald Robey
U.S. Army Corps of Engineers, Waterways Experiment Station

John St. John
HydroQual, Inc.

Chris Schubert
State University of New York at Stony Brook

Malcolm Spaulding
Applied Science Associates, Inc.

Eric Stern
U.S. Army Corps of Engineers, New York District

Andrew Stoddard
Creative Enterprises of Northern Virginia, Inc.

R. Lawrence Swanson
State University of New York at Stony Brook

Jay Taft
Harvard University

Billy Tam
U.S. Army Corps of Engineers, New York District

John Tavalaro
U.S. Army Corps of Engineers, New York District

Barbara Tempalski
City University of New York

Robert Thomann (co-moderator)
Manhattan College

Rao Vemulakonda
U.S. Army Corps of Engineers, Waterways Experiment Station

Roberta Weisbrod
New York Sate Department of Environmental Conservation

Joannes Westerink
Texas A&M University

Randall Young
State University of New York

Lenore Zethen
New York State Department of Environmental Conservation

Cheng Zeming
City University of New York

NEW YORK BIGHT HYDRO-ENVIRONMENTAL MONITORING WORKSHOP
List of Participants and **Speakers**

Robert Alpern
New York Bight Coalition

Kenneth Baldwin
University of New Hampshire

Patricia Barnwell
U.S. Army Corps of Engineers, New York District

Robert Beardsley
Woods Hole Oceanographic Institution

Laurie Behrman
State University of New York at Stony Brook

David Berkovitz
Port Authority of New York & New Jersey

William Boicourt (co-moderator)
University of Maryland

Henry Bokuniewicz
State University of New York at Stony Brook

Marcia Bowen
Normandeau Associates

Jim Brannon
U.S. Army Corps of Engineers, Waterways Experiment Station

Thomas Brosnan
New York City Department of Environmental Protection

H. Lee Butler
U.S. Army Corps of Engineers, Waterways Experiment Station

Ray Canada
national Data Buoy Center, NOAA

Cindy Carusone
New York State Department of Environmental Conservation

Carl Cerco
U.S. Army Corps of Engineers, Waterways Experiment Station

Karen Chytalo
New York State Department of Environmental Conservation

Douglas Clark
New Jersey Department of Environmental Protection

Keith Clarke
City University of New York

Carol Coch
U.S. Army Corps of Engineers, New York District

Carol Coomes
Evans & Hamilton, Inc.

Sam Corson
U.S. Army Corps of Engineers, Waterways Experiment Station

Mario Del Vicario
U.S. Environmental Protection Agency, Region II

Roy Denmark
U.S. Army Corps of Engineers

Robert Dietrich
U.S. Environmental Protection Agency, Region II

Mark Dortch
U.S. Army Corps of Engineers, Waterways Experiment Station

Iver Duedall
Florida Institute of Technology

Bruce Ebersoll
U.S. Army Corps of Engineers, Waterways Experiment Station

Curt Ebbesmeyer
Evans & Hamilton, Inc.

Larry Enoch
New York State Coastal Management Program

Nick Fisher
State University of New York at Stony Brook

Eugenia Flatow
Environmental Policy Forum

Debbie Freeman
U.S. Army Corps of Engineers, New York District

Daniel Frye
Woods Hole Oceanographic Institution

Joe Germano
Science Applications Internation Corporation

Victor Goldsmith
City University of New York

Stan Gorski
National Marine Fisheries Service, NOAA

Paul Hauge
New Jersey Department of Environmental Protection

Ross Hall
U.S. Army Corps of Engineers, Waterways Experiment Station

William Hanson
City University of New York

Thomas Hart
U.S. Army Corps of Engineers, Waterways Experiment Station

Larry Hauck
U.S. Army Corps of Engineers, Waterways Experiment Station

Carelton Hunt
Battelle Labs

James Irish
University of New Hampshire

Victor Klemas
University of Delaware

Lingard Knutson
Port Authority of New York & New Jersey

Amor Lane
National Marine Pollution Program Office, NOAA

Steve Lieberman
Naval Ocean Systems

Edward Murchelana
national Data Buoy Center, NOAA

Thomas Meeks
City University of New York

Stanley Michaelowski
U.S. Army Corps of Engineers, New York District

JoAnn Moisedes
New York State Department of Environmental Conservation

David Nelson
U.S. Army Corps of Engineers, Waterways Experiment Station

Donald O'Connor
HydroQual, Inc.

Joel O'Connor
U.S. Environmental Protection Agency, Region II

Francis Padar
Nassau County Department of Health

John Paul
U.S. Environmental Protection Agency, Narragansett ERL

Mario Paula
U.S. Army Corps of Engineers, New York District

John Pearce
National Marine Fisheries Service, NOAA

Robert Pikanowsky
National Marine Fisheries Service, NOAA

William Preslan
U.S. Army Corps of Engineers, Waterways Experiment Station

Jack Pullen
U.S. Army Corps of Engineers, Waterways Experiment Station

Charles De Quillfeldt
New York State Department of Environmental Conservation

Donald Robey
U.S. Army Corps of Engineers, Waterways Experiment Station

David Rosenblatt
New Jersey Department of Environmental Protection

Lloyd Saunders
U.S. Army Corps of Engineers, Waterways Experiment Station

Jerry Schubel (co-moderator)
State University of New York at Stony Brook

Harold Stanford
Office of Marine Assessment, NOAA

Eric Stern
U.S. Army Corps of Engineers, New York District

Andrew Stoddard
Creative Enterprises of Northern Virginia, Inc.

R. Lawrence Swanson
State University of New York at Stony Brook

Billy Tam
U.S. Army Corps of Engineers, New York District

John Tavolaro
U.S. Army Corps of Engineers, New York District

Barbara Tempalski
City University of New York

Dave Timpy
U.S. Army Corps of Engineers, Philadelphia District

Rao Vemulakonda
U.S. Army Corps of Engineers, Waterways Experiment Station

Henry Walker
U.S. Environmental Protection Agency

Michael Waring
U.S. Army Corps of Engineers, Waterways Experiment Station

Roberta Weisbrod
New York State Department of Environmental Conservation

Stuart Wilk
National Marine Fisheries Service, NOAA

William Wise
State University of New York at Stony Brook

Randall Young
State University of New York at Stony Brook

Cheng Zeming
City University of New York