A Research Program for the Hudson River Estuary

Prepared for
'he New York State Department of Environmental Conserva
Pursuant to
The Hudson River Estuary Management Act of 1987

MARINE SCIENCES RESEARCH CENTER
STATE UNIVERSITY OF NEW YORK

A Research Program

for the

Hudson River Estuary

Prepared for
The New York State Department of Environmental Conservation
Pursuant to
The Hudson River Estuary Management Act of 1987

J.R. Schubel
Project Director

Special Report 89

Ref. 89-11

Approved for Distribution

J.R. Schubel

J.R. Schubel, Dean

A Research Program

for the

Hudson River Estuary

Prepared for
The New York State Department of Environmental Conservation
Pursuant to
The Hudson River Estuary Management Act of 1987

J.R. Schubel
Project Director

Sponsored by the

New York State Department of Environmental Conservation

Hudson River Foundation

Marine Sciences Research Center

Project Personnel

Project Director

J.R. Schubel

Project Staff

Cynthia Decker
Trudy Bell
Gina Anzalone
James Rine

Working Group Chairs

Roger Flood
Robert Howarth
Robert Wilson

Table of Contents

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

Thomas C. Jorling
Commissioner

A Research Framework for the Hudson River Estuary

Introduction

The New York State Hudson River Estuary Management Act of 1987 directs the Department of Environmental Conservation (DEC) to prepare and adopt a 15-year management plan for the estuary. The purpose of the plan is to develop a comprehensive approach toward management of the Hudson River ecosystem and to specify the actions that must be taken to preserve, protect and where possible enhance the system's natural resources and their commercial and recreational values. As specified in the Act, the development and implementation of the mangement plan is to be conducted in consultation with an advisory committee composed of scientists, conservationists and resource users (Hudson River Estuary Management Advisory Committee).

An important feature of the Act was its insistence that the Hudson River Estuary be managed as a distinct ecosystem. There was early agreement between the DEC and the Advisory Committee that an ecosystem approach to managing the Hudson required a working knowledge of how the system operates biologically, hydrodynamically, chemically, and geologically. There was also recognition that shaping public policy on issues such as water supply, power plant operation, dredging, filling, pollution abatement, and waterfront development will require difficult decisions, often in the face of considerable uncertainty with respect to their potential ecological consequences. Therefore, a key ingredient of the management program would have to be a concerted effort to conduct research and incorporate research findings on the ecosystem into the day-to-day activities of the numerous managers who must make decisions affecting the estuary.

The DEC and the Advisory Committee agreed to initiate a process of defining a research framework necessary to manage the estuary as a distinct ecosystem. The process would:

(1) define research needs, short and long-term, which are required to develop a working understanding of how the overall ecosystem functions; and

(2) define research needs, short and long-term, which are critical to the management of specific present and future environmental problems in the estuary, focusing on the ways in which research programs can be developed to inform management policy and guide specific practical decisions.

Dr. J.R. Schubel, Provost of the State University of New York at Stony Brook and Director of the Marine Sciences Research Center, was contracted by DEC to develop a research agenda through a process of workshops, interviews with representatives of government agencies, and discussion with the scientific community. This report is the culmination of that process.

The research framework is one of many elements in the development of a management plan for the estuary, providing a focus for future studies to be carried out by the researchers affiliated with DEC, other government agencies, and private institutions. It seeks to broadly address the scientific and research issues associated with the functioning of the Hudson River Estuary as they relate to the management of estuarine resources. Because the Act requires the Management Plan to be updated annually, the research framework can be revised in light of new public policy issues, new information needs of resource managers and new findings by the research community. It is hoped that the framework will foster a new partnership between government and the research community, while providing much needed information to manage the estuary.

Thomas C. Jorling
Commissioner

Dennis J. Suszkowski, Ph.D.
Chairman, Hudson River Estuary
Management Advisory Committee

Preface

This report was prepared at the request of the New York State Department of Environmental Conservation pursuant to the Hudson River Estuary Management Act and with partial funding from the Hudson River Foundation. It is intended to serve as a template to guide the development of a sustained research program for the Hudson River Estuary, a program of fundamental research responsive to the information needs of management. To support such research, we suggest a collaborative effort among a variety of public and private sector institutions.

We have identified a number of priority areas for research, but have neither attempted to identify specific research questions and hypotheses nor to suggest specific research protocols. These activities -- problem selection and formulation and study design -- should be left to the experts, the scientists who will carry out the research.

This report might serve as the basis for a Request for Proposals (RFP). A rigorous external peer review of proposals submitted in response to the RFP should be the primary procedure for selecting which research proposals are funded. The program outlined in this report should be reviewed, reevaluated and revised on a periodic basis, perhaps at a frequency of every two to three years, and new priority areas for research should be identified on the basis of those evaluations. The evaluations should be carried out with the active involvement of the research community, and the initial update might well include a number of the individuals who contributed to this report.

A model program would include research, monitoring and modeling. All three components are essential to a comprehensive environmental program directed at management. We are not proposing or advocating an intensive three, five, or multi-year research effort of relatively short duration. Rather, we are proposing and strongly advocating a sustained commitment to a program of fundamental research to improve our understanding of the natural processes that characterize the Hudson River estuarine system, the ways in which society has affected those processes, the manifestations of society's impacts on the estuary and the uses which society wants to make of it. We also advocate the development of mechanisms to ensure an open, frequent, and continuing exchange of ideas among scientists, managers and the public.

There must be a persistence and a constancy of commitment to the full program if it is to succeed. If the scientific studies outlined in this report are done well, they will answer important questions, they will prove or disprove important hypotheses and aid our understanding of basic processes. In so doing, they will improve our level of understanding, reduce the level of uncertainty and provide information needed to improve the management of this valuable resource. But in such complex systems, there will always be other important questions to be addressed, problems that will need to be solved. There are no quick and complete remediations of the problems of major estuarine systems. The Hudson is no exception. If these systems are important to society, they require our attention.

The Hudson River Estuary program could serve as a paradigm for the nation's other important estuaries. This system has a number of distinct advantages as a natural laboratory over most other major estuarine systems. It serves a large and growing population, one which makes multiple and conflicting demands on it. No estuary in the United States serves so many people with such diverse and demanding needs. The impacts from society on the estuary are clearly evident, but are not irreversible.

The Hudson River estuarine system has a number of attractive features that give it a distinct advantage for research purposes over other major estuaries. It has only one major fresh water input -- the Hudson River. Above New York Harbor, it has a simple geometry with a relatively straight course and few tributary embayments. The suite of distinctive chemical and radioactive tracers introduced into the system from known sources provides an unusual opportunity to study suspended particulate matter and associated particle-bound contaminants -- their sources, routes and rates of transport, residence times within the system and sites and rates of accumulation in the sediments.

The financial settlement which led to the creation of the Hudson River Foundation produced a modest, but stable endowment, which could ensure core support for a sustained, long-term program of fundamental research targeted at important scientific questions -- questions related to scientific themes of management importance. The management analog that should be followed in developing a Hudson River estuarine program might be the "tight-loose coupling" concept advocated by Peters and Waterman (1982): tight in coupling to important broad themes, but loose in the freedom provided investigators in defining problems and in attacking them -- the freedom needed to attract and retain the interest of the very best minds -- a characteristic too often lacking in estuarine research programs.

The desire for quick answers and the pressures to do accountable and relevant research too often have dictated safe, low risk research in the nation's estuaries; programs where chances of success are high, but programs which at best will lead to incremental improvements in understanding and management. It is unlikely that these incremental improvements will significantly advance our ability to formulate cost-effective stategies to conserve, and when necessary, to rehabilitate estuaries. The advances in knowledge may not even allow us to keep pace with increasing stresses and degradation resulting from society's ever increasing demands.

New York and New Jersey are rich in academic institutions, public and private, with strong graduate programs in marine sciences. Several have made important contributions to our understanding of the Hudson River estuarine system and have a continuing commitment to enhancing this understanding. A significant number of students could be encouraged to conduct their M.S. and Ph.D. research on the Hudson River estuarine system. There is perhaps no more cost-effective way of stimulating high quality research than through support of graduate students. Each graduate student project is closely monitored and ultimately judged by a panel of research scientists whose reputations are coupled, in no small measure, to the quality of the students they produce. And, the research is cost effective because much of the costs often are underwritten by the academic institution, particularly in terms of equipment, facilities and infrastructure needed to carry out sophisticated research. There is an added benefit of increasing involvement of involving graduate students: it is clear that many scientists develop long-standing commitments to the environments in which they do their graduate research and continue to study those systems throughout their professional lives.

The New York Sea Grant Institute and the New Jersey Sea Grant Program have demonstrated an interest in supporting high quality research in the system. And, probably no estuarine system has received more attention by private consulting firms than has the Hudson. These groups have made a major contribution to the development of a range of numerical hydrodynamic and water quality models. The primary purpose of these models has been to evaluate different waste management strategies to ensure selection of the strategy, or combination of strategies, for maximum efficacy.

The designation of the Hudson-Raritan estuarine system for inclusion in the National Estuary Program will provide additional opportunities to make major advances in our understanding of this important system and our ability to manage it. But the probability that these opportunities will be exploited in a timely way will be greatly enhanced if appropriate mechanisms are implemented to ensure appropriate levels of coordination and cooperation among scientists, decision makers and the public.

If the Hudson River Estuary Research Program is to serve as a paradigm, it must have several other key features -- features that distinguish it from other estuarine programs. First, there needs to be a system for keeping track of the data that are collected, for assuring their quality, and for ensuring that an up-to-date directory is maintained summarizing where the data are and how they can be obtained.

An up-to-date directory should also be maintained that lists all relevant research project along with principal investigators, objectives and brief abstracts and status; reports and publications, including theses and other relevant sources of information with specific instructions on how to obtain copies.

These are minimum requirements. If the Hudson River Estuary is to serve as a model it must go beyond directories to an environmental data management system. One approach to this would be to develop a comprehensive regional data management facility, but there are other approaches. Modern computer technology offers opportunities for creation of a distributed data network with each of the major research institutions serving as a node in the network. While creation of such a network is possible, it probably is less desirable in solving the regional data problem than creating a single regional data facility.

Next, perhaps, even greater than the need to manage the data is the need to provide for its synthesis and interpretation, and for converting the data into information -- into informational products tailored specifically to the needs of different user groups. As a general rule of thumb, roughly as much support should be earmarked for this set of activities as was provided to collect the data in the first instance. If the primary objectives of the Hudson River estuary research program is to improve the management of the Hudson River estuary, these activities must be an integral part of the program. Data are of little use to decision makers. They need information. Information is derived from data, but the two are different. Information has structure and orderliness. It is configured to convey a meaningful message. Peter Drucker (1988) described the difference between data and information in the following terms: "Information is data endowed with relevance and purpose." The transformation of data into information requires knowledge. New knowledge and understanding come through research. There is beauty in the spectrum of activities from fundamental research and to its application to the solution of society's problems. Pasteur perhaps said it best. "To him who devotes his life to science, nothing can give more happiness than increasing the number of discoveries. But his cup of joy is full when the results of his studies find practical application. There are not two sciences. There is only one science and the applications of science and these two activities are linked as the fruit is to the tree."

In a recent study of monitoring in the marine environment by the National Academy of Science's National Research Council (1990), it became clear that if we are to significantly improve environmental management, mechanisms must be developed to ensure the timely transformation of marine environmental data, particularly monitoring data, into information for decision makers. The information must be carefully tailored to the specific needs of managers and it must be available on a timely and recurrent basis. As a nation, we spend enormous amounts of money on monitoring -- particularly on compliance monitoring -- and too often the data produced are not transformed into information and, therefore, cannot be used in decision making.

The NRC report recommends establishment of a network of regional centers which can serve as foci for transformation of data into information to meet the needs of management and which can synthesize the information on a periodic basis to chronicle the condition of each natural system. There are other potential advantages that would accrue from such a network of centers. Such an effort not only would provide records of changes in the systems, but might provide early warnings of emerging problems which, if attended to early, could be resolved more effectively and at lower cost. Such periodic evaluations might also provide the information needed to assess the efficacy of management actions taken to protect, or to rehabilitate, systems and, in this way, contribute to better management decisions in the future. Such centers should sponsor annual meetings of researchers, managers and public interest groups to ensure a continuing dialogue among the three groups and to ensure that the programs remains responsive to changing needs and opportunities. The Hudson River estuary would make an ideal candidate for one of the first such centers.

Ptolemy once remarked that it is the role of the scientist to "tell the most plausible story that saves the facts." When there are relatively few facts -- data -- more than one story can "save them" -- be consistent with them. As the number of data increases, the number of stories that saves them decreases; eventually, one hopes, only to one.

In our quest to better understand and manage our important coastal systems, it is important that as we continue to add new data to the stock of old data we test to see whether the old stories still "save the facts." Only in this way can we be certain that we are converging on the right story.

In summary, a total environmental program for the Hudson River estuarine system could serve as a model for the rest of the nation's, and indeed the world's estuaries. It should be a coordinated program of research, modeling and monitoring. The three components must be interactive and carefully coordinated. They must be conducted in parallel -- not in series -- with opportunities for coupling. The research program should ensure a sustained program of fundamental research directed at important general themes and a program which provides considerable freedom for investigators to formulate hypotheses and to specify study design, but one which is responsive to management's needs. The program should be an external peer reviewed program and should ensure opportunities for high risk research.

We estimate that an appropriate level of funding for such a program of research, monitoring, modeling and education is about $5 million per year, approximately a five-fold increase over the amount being spent by the Hudson River Foundation. The proposed level of funding does not include any support for remediation. We suggest that the proposed program build on and expand the initial work of the Hudson River Foundation and bring that institution into partnerships with other institutions which share in supporting research on the Hudson and in the need for research information. Partners in this initiative would include, in New York State, the Departments of Environmental Conservation, Health, and State, the Sea Grant Institute and the State and City University systems. In the State of New Jersey, which draws significant benefits from its Hudson estuary waterfront, partners would include the Departments of Environmental Protection and Health, Sea Grant and the New Jersey State University system. The federal governments and local governments should also be included in this partnership. The U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. Department of Commerce (NOAA), the Army Corps of Engineers, the National Science Foundation and the U.S. Coast Guard are important potential contributors to and beneficiaries of a research program, as are the communities along the estuary which depend for their future development on effective estuary management. Private sector institutions should be encouraged to join this partnership, among them foundations such as the Hudson River Foundation; utilities such as Consolidated Edison, Central Hudson, New York Power Authority, Orange and Rockland and Niagara Mohawk which are major users of the Hudson River; and research institutions such as the Marine Sciences Research Center, the Institute for Ecosystem Studies, the Lamont Doherty Geological Observatory and the Institute of Marine and Coastal Science.

How could such an expensive program of research be funded? First, what is needed is a stable, sustained funding source. This is a prerequisite for the type of long-term ecosystem research set forth in this report. Because government cannot be expected to commit to a sustained research budget for a specific geographic area, we recommend the creation of an endowment in the amount of $100 million from which the interest would be drawn to fund an annual research, monitoring, modeling and education program. The endowment could be created with contributions from many of the parties mentioned above.

Creating such an endowment may require the participation of the state legislatures of New York and New Jersey and the U.S. Congress. Such a focused effort would eliminate some of the redundancies in current research efforts and would help to fill the gaps in areas which are not currently receiving the attention needed.

Management means decision making in the face of uncertainty. The question at hand is, how much uncertainty are we willing to accept. Currently vast sums are being expended on public and private capital projects with too little understanding of their environmental consequences. We basically have two choices -- to continue the status quo knowing that many of the most significant impacts on the resources are not well understood, or alternatively to begin to guarantee a steady stream of information on how the Hudson River ecosystem functions, on how our actions impact it and what the consequences will be. This does not mean holding off on development of the region until we have all the answers. That day will never arrive. It does mean adapting management decisions to an evolving and increasingly useful information base and a commitment to transforming new scientific data and information into forms tailored specifically to management needs. It means creating a baseline and a mechanism in the future to evaluate changes as they occur. It means developing and sustaining new partnerships among scientists, managers, industry and the public.

J.R. Schubel
Stony Brook, New York
December 1989

References

Drucker, P.F. 1988. The Coming of the New Organization. Harvard Business Review. 88(1):45-53.

National Research Council (in press). Managing Troubled Waters: The Role of Marine Environmental Monitoring. Committee on a Systems Approach of Marine Environmental Monitoring, Marine Board, Commission on Engineering and Technical Systems. National Research Council. National Academy Press, Washington D.C.

Peters, T.J. and R.H. Waterman, Jr. 1982. In Search of Excellence: Lessons from America's Best-Run Companies. Harper and Row, New York. 245 pp.

Executive Summary of

Research Priorities

for the

Hudson River Estuary

Management Plan

The Scientific Working Groups determined that the following research is essential to developing a better understanding of the processes in the Hudson River Estuary and for providing information for better management of the system.

I. Studies of the factors controlling flora and fauna species diversity and abundance. These studies should incorporate a determination of:

A. Community structure; especially the "key resource species" and other species vital to the functioning of the system;

B. Species' life histories and distributions;

C. Interactions of commercial and recreational fisheries with natural population fluctuations to understand how these interactions may enhance or endanger important fish stocks;

D. Dynamics of nutrient and food cycling;

E. The relative importance of primary production and organic matter input in supporting secondary production.

F. The effects of macrophytes on ecosystem structure and function;

G. The potential for nuisance algal blooms and the factors that determine that potential blooms;

H. The distribution of biomass and its community composition;

I. Factors affecting population variability of important resource species, including those affecting spawning success, such as predatory and competitive links among organisms;

J. Habitat requirements of important species, availability and the effects of habitat alteration and mitigation;

K. The effects of changes in land use and in the environmental quality of bays and tributaries on the structure and function of the ecosystem;

L. The impact of toxic stresses, including assessment of the processes for assimilation and retention by organisms and the lethal and sublethal effects on the organism, population and ecosystem;

M. The abilities and limitations of aquatic microorganisms to detoxify contaminants;

N. Cumulative effects and interactions of multiple stresses and alterations;

O. Interactions between non-consumptive uses of the estuary and ecosystem functioning.

II. Studies of the chemical and physical properties of the system and their effects of the ecosystem. These studies should incorporate determinations of:

A. The dynamics of carbon, oxygen and nutrients within the estuary and how these relate to surrounding watersheds and coastal waters;

B. The effects of river flow variations and variations in water consumption on salinity intrusion;

C. The natural temporal and spatial variability of water circulation and hydrographic properties;

D. The transient responses of the estuary to wind and river forcing as it relates to sediment transport and transport of dissolved and suspended materials;

E. Interactions between the estuary and both the New York Bight and Long Island Sound and the resulting effects on the exchanges of dissolved and suspended materials and the discharge of floatables from the estuary;

F. Nearshore circulation and exchange among shoreline development projects as related to flow modifications and sedimentation;

G. The relationships between circulation and sewage and industrial effluent discharge strategies;

H. The relationships between estuarine transport processes and larval fish distributions as this applies to fisheries management;

I. The effects of channel modification by shoreline development, dredging and sedimentation on tidal response and salinity intrusion;

J. The effects of long-term sea level rise on tidal response and salinity intrusion;

K. The temporal and spatial characteristics of the morphology of the river and estuary bed and its sediment to develop a "picture" of the river bottom;

L. The geochemical cycles and other materials with distinctive signatures so that these can be used as tracers to study river and estuary dynamics;

M. How habitats change and how different animal communities affect sediment and pollutant cycling through integration of sediment and biological studies;

N. The characteristics of suspended sediments to identify factors controlling sediment distribution throughout the river, through direct sampling and tracer studies;

O. The processes controlling sediment resuspension, rates of resuspension and where this occurs to understand the roles and rates of resuspension in reintroducing pollutants to the environment;

P. The processes leading to sediment deposition and the effects of changes in sediment deposition on the sediment cycle, benthic environment and river and estuary chemistry;

Q. Past natural evolution and variations in the system, using the geological record, to predict future responses and to understand past impacts from humans and pollutant and nutrient histories;

R. Sources, speciation and current levels of toxicants associated with sediments and ambient waters;

S. Basic functioning of the tidal, fresh water and salt water portions of the estuary as subecosystems within the ecosystem.

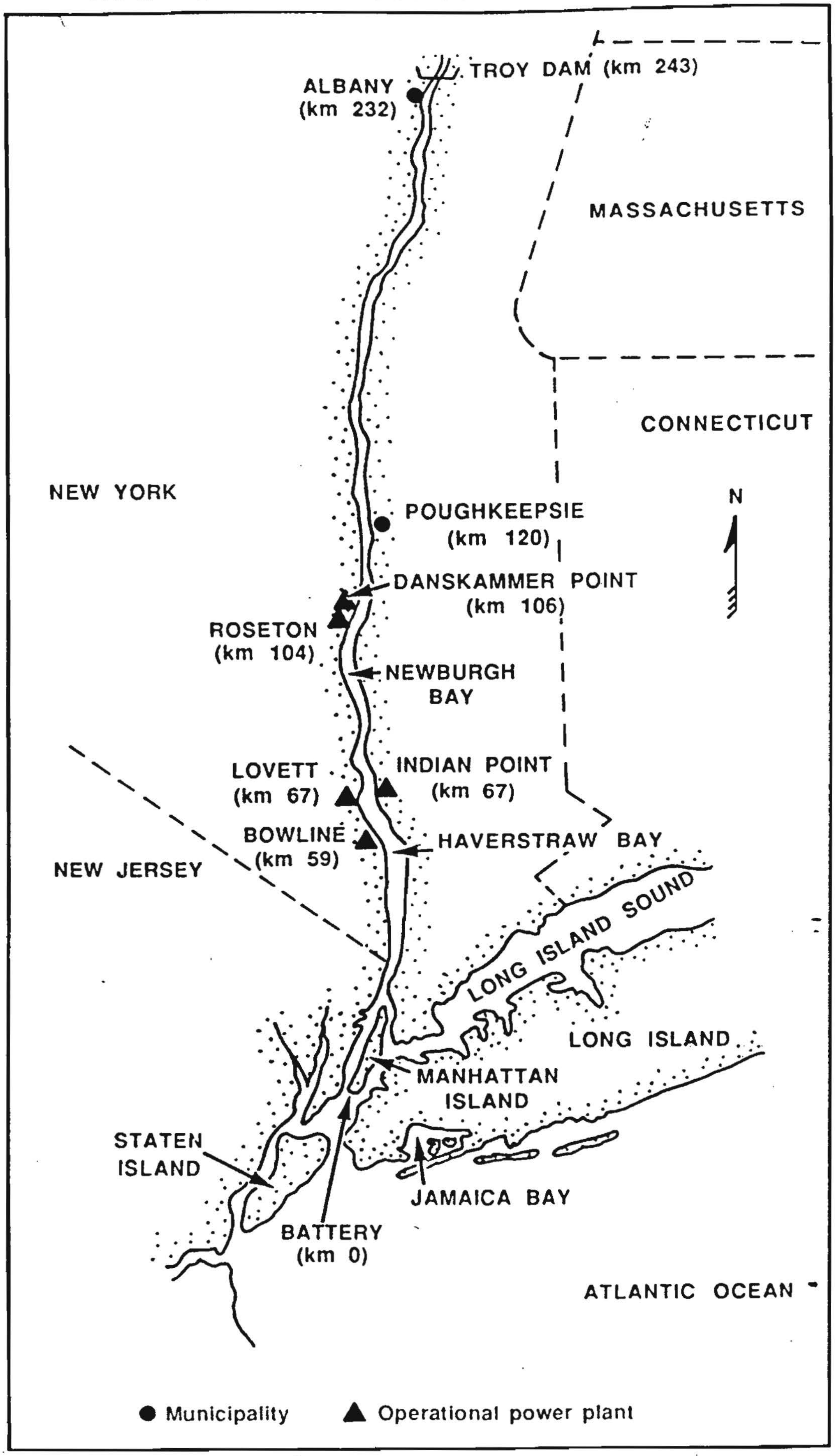
Introduction

From its origin at Lake Tear of the Clouds in the Adirondack Mountains to its juncture with the Atlantic Ocean, the 507 km of the Hudson River offers varied resources of enormous value to millions of people. But along the lower course from the Troy Dam to the Sandy Hook-Rockaway Transect lives the densest population found along any equivalent stretch of water in the country. Within this region, the physical and chemical environment is complex, changing dramatically with tidal influences and salt water intrusion, and supports a diverse flora and fauna. Along this lower stretch, where the surrounding area is mostly densely inhabited, the estuary receives the largest demand by society for use of its resources and the brunt of society's influences. Society's wastes change the biology and chemistry of the water and development encroaches on the margins changing the hydrodynamics and the ecosystem.

The Hudson River Estuary is considered in this report to extend seaward from the Federal Dam at Troy -- the head of tide -- to the Sandy Hook-Rockaway Transect. In other reports, the Hudson River Estuary is defined to extend only to the Battery with the total system described here defined as the Hudson-Raritan estuarine system (Schubel et al. 1982). In both definitions, the Hudson River Estuary is in part a tidal river (fresh water) and in part a true estuary by Pritchard's 1967 definition 1967. The landward limit of intrusion of measurable quantities of sea salt -- the boundary between the tidal river and the estuary proper -- varies with river discharge. In times of low river flow, the boundary may occur as far upriver as Hyde Park, 132 km above the Battery. During times of high river flow, sea water may extend only as far upstream as 3 km below the Tappan Zee Bridge, 40 km above the Battery.

The estuary has enormous commercial and recreational resources that, if rehabilitated, could inject new economic growth into the area. The river also satsifies a more fundamental human need, making perhaps the most compelling case for rehabilitating the estuary. Some communities along the

MAP OF HUDSON RIVER ESTUARY



tidal reaches of the upper estuary depend entirely on the river for drinking water, and soon downstate communities that are running out of safe aquifer waters may need to tap the river for their drinking water, too. The river also provides an important subsistence fishery for low income people inhabiting areas accessible to the river. The broad, shallow expanses of the lower estuary provide nursery grounds for migratory species, as well as indigenous species of fishes. Portions of its shores, once fringed with wetlands, now bear scattered decaying bulkheads from flood control planning of decades ago. These shores could be restored to create new spawning and nursery habitats to offset losses of other natural wetland environments. The contaminant-laden sediment that is dredged from the river's shipping channel is dumped just below the estuary into the apex of the New York Bight. If the river is rehabilitated, the Bight will benefit. The massive nutrient input from the river increases the nutrient load to the northern New Jersey nearshore waters and is a major contributor to the seasonal eutrophication that occurs there. Aquaculture in the estuary might even become a viable possibility; the once-thriving oyster industry could perhaps be reestablished. Rehabilitation might also help reestablish the sturgeon population to the point of supporting an expanded roe industry.

The few lobstermen who still cling to this livelihood set their lobster pots in the lower estuary for the few lobsters they can get. Commercial fishermen continue to fish for what species they can while awaiting resolution of the public health status of preferred species. Water skiing and swimming are virtually nonexistent in much of the estuary; however, countless tourists are still attracted by the Hudson's scenery every year -- just to look. People's strong affinity for water -- to be near it, and better, to be in it -- should provide strong motivation to rehabilitate the estuary. Increasing population density and urban stress have people more urgently than ever seeking places nearby for leisure. The estuary could once again become a prime place to recreate, easing the pressures on Long Island and New Jersey beaches, and providing recreational opportunities for those who can't afford to travel. The economic gain to be realized from a resurgence of tourism for rafting, boating, water skiing, and swimming along the Hudson is also a compelling reason to rehabilitate the estuary.

That the estuary contains one of the most diverse assemblages of fishes in Atlantic coastal waters is another important characteristic of this resource. Within the transition zone -- bounded by fresh water at the upper end of the estuary and by the ocean's salt water at the lower end of the estuary -- is brackish water where anadromous, marine, and freshwater fishes are all able to live, producing a community that is the most abundant and diverse of any river in the country. Within this transition zone, the chemistry and physics of the river change dramatically. The changing salinity and energy of the tides and currents create the diverse nature of this ecosystem.

It is this abundant ecological variety and complexity that sets the Hudson estuary apart from all the rest and that provides the potential for a great variety of uses. It is this abundance and diversity of possible uses -- and needs -- by man that warrants its rehabilitation.

What Data and Information Do Managers Need?

The Managers' Perspective

Cynthia Decker

A number of key managers of the Hudson River estuary were interviewed to determine what data and information they needed and what kinds of research they thought should be carried out to meet these needs. This section summarizes and categorizes the results of those interviews. The list of individuals and their interviews are summarized in Appendix B. Each summary was submitted to the person interviewed for review and comment, and appropriate revisions were made.

Summary of Management Recommendations for the Research Agenda of the Hudson River Estuary Management Plan

The following report is a summary of interviews conducted with representatives of state, federal and interstate management agencies encompassing different of jurisdictions over the Hudson River Estuary. These representatives are responsible, in varying degrees, for making decisions that affect the use and, ultimately, the quality of the Hudson system. The interviewer, therefore, asked them how they would like the proposed Research Agenda for the Hudson River Estuary designed and which questions they would like addressed that are most germane to the decisions they must make. Research directed towards answering these questions would provide the kind of information they need to better make those decisions.

This is not an exhaustive list of every idea that was mentioned but, rather, an outline of the suggestions which were discussed by at least three or more separate inteviewees. The recommendations made by the management personel can be divided into two major categories: environmental issues and administrative issues. Summaries of the individual interviews are included in Appendix B at the end of this document.

ENVIRONMENTAL ISSUES

A. Habitats. There are a number of steps required for a better understanding of Hudson River Estuary habitats.

1. Inventory all habitat types in the harbor, the river and tributaries. This will provide the state with a map of the system and an assessment of the availability of the different types of habitats.

2. Identify the habitats critical to highly mobile aquatic organisms such as finfish (e.g., spawning or nursery areas), particularly for those species that are commercially and recreationally important.

3. Examine the effects of habitat modification such as construction and dredging. What do these activities actually do to a particular habitat, and, thus, to the resident aquatic communities? How can loss or degradation of the habitat be stopped? One recommended solution is to regulate the activities that cause this. A second possibility is to develop a trade-off system whereby these activities are permitted only if critical habitats are created or enhanced elsewhere in the system by those whose activities will cause the original damage or loss.

B. Aquatic Species and Communities. The people interviewed were aware that it would be valuable to know more about any or all species that are found in the Hudson River Estuary. However, certain species of finfish have been deemed more important to study than others based, for the most part, on commercial and recreational interests. More information needs to be collected about their life histories (particularly the early stages), critical habitats (covered in the previous section) and interactions with other species. In this way, the role of these species of finfish in the Hudson system may be able to be assessed. If a value can be estimated for this ecological role and then realistically compared to their economic value, decisions about how to manage these fishes can be made better.

Other organisms which were discussed included those species that are endangered, primary producers (phytoplankton and macrophytes) and some species of shellfish and macrocrustaceans. The latter group is limited to those of commercial and recreational value, particularly those which once had thriving populations in the estuary and for which there is hope of reintroduction.

C. <u>External Stresses</u>. The following are the majority of the concerns important to the management people interviewed:

1. Physical disturbances of the ecosystem each of which has its particular set of impacts. Examples of these disturbances include the resuspension of sediments and habitat alteration from dredging and filling or the shading, piling configuration and materials chemistry related to construction, particularly of platforms and piers.

   The process by which physical activities are reviewed and permitted is currently a case-by-case procedure. It is extremely important that some means of assessing the cumulative impact of structures and waterfront development be undertaken. For example, the effect of one pier may be trivial and the effect of 100 of them may be quite significant, but at what point between one and one hundred is the line drawn? Can a threshold or critical number (of piers, acreage, waterfront feet) be set beyond which no more construction is allowed? What deviation from this critical value is permissible? How would these values vary with habitat? These questions are of immediate concern in the lower estuary but will probably become important farther upriver as development there increases in the near future.

2. Introduction of pollutants into the system -- these pollutants include toxicants such as polychlorinated byphenyls, dioxins and polyaromatic hydrocarbons (PAHs); excessive nutrients, in both agricultural and urban areas; and sewage. Floatables are yet another problem; buoyant items, particularly those made of plastic, are found throughout the Hudson River estuary.

3. Sewage treatment plant effluent -- the sources of pollution to the Hudson River Estuary are land-, air- and water-based. Water-based pollutant sources, which the Plan is most concerned with, can be classified into point and non-point sources. Non-point sources include landfill leachate run-off and all other ground water and sheetflow run-off. One primary point source of pollution is sewage treatment plant effluent, which is a particular problem in the lower estuary because the treatment plants in New York City are at times in violation of state regulations. Sewerage systems in general are costly to monitor and maintain. Many New York City plants are old; poor maintenance and equipment failure have led to leakage and contamination, breakage and shutdowns. Cold weather at times disables the activated sewage sludge process. In addition, if primary sewage treatment plants were not granted exceptions to state regulations, then other problems, such as overcapacitance and a failure to implement the addition of secondary treatment procedures, would put these plants in violation for a much greater percentage of the time.

The greatest sources of pollution in the New York metropolitan area are the combined sanitary and storm sewers which have resulted in combined sewer overflows (CSOs). When a certain level of precipitation occurs, the sewage treatment plants cannot handle the increased volume of water from the storm sewers. Therefore, all the material in both types of sewers is shunted down pipes that empty directly into the river, bypassing the treatment plants. At these times, raw sewage and urban/suburban run-off enter the estuary. Although they enter the river at a point and, thus, can technically be considered point sources, they are, in fact, bringing in material from non-point sources. Such outflow is regulated, but difficult to monitor because of its intermittent nature; it is felt that the pollution in the lower portion of the estuary could be considerably reduced if the CSOs were eliminated, or at least treated.

A number of those interviewed felt that tertiary treatment of sewage treatment plant effluent might also be considered to improve water quality, but so far the expense has been prohibitive.

4. The effects of toxic substances on organisms -- the major concern is what, if any, lethal or sublethal effects exist as a result of these toxicants entering the ecosystem, and, if they do exist, how can lethal effects be differentiated from sublethal effects. Toxicants may affect fecundity of the adults or survivorship of the young or both, leading to slow population declines. These sorts of effects need to be studied on physiological, histological and pathological bases to determine exactly how substances act on individual organisms. The extent of bioaccumulation, or body burden, is another aspect which requires further study particularly, as it can result in a build-up of lethal concentrations of toxicants in the upper trophic levels (e.g. PCBs in birds, finfish, shellfish and macrocrustaceans). Excessive bioaccumulation to levels exceeding food standards could render the resource unusable for human consumption and cause serious economic loss.

   Although standards have been set for a wide variety of toxicants, these vary from agency to agency; there are no standard deviations given within which the levels may vary, and the scientific basis for some standards is questionable. These are all problems that must be addressed either prior to the implementation of the Plan or by the Plan itself.

D. Sea Level Rise. This topic may be of great concern sometime in the future. Although it does not appear to be immediately important, the possibility of global warming from the "greenhouse effect" is something that should not be ignored. Sea level is already rising, but the increased rate of rise that would result from melting of glaciers and expansion of the upper ocean because of warming could have a large impact regionally as well as globally. A further rise of sea level would accelerate shore erosion and flooding and salt water would intrude farther up the Hudson, perhaps threatening freshwater intakes. A rise of sea level of one meter would cause the salt water to move upstream as much as 10 kilometers. Perhaps a general contingency plan could be included in the Management Plan which would outline the initial steps to be taken in planning a for a higher stand of sea level.

In general, regarding the environment, it is understood that the Hudson River Estuary needs to be cleaned up, that some changes must be made and that the system must be improved. The estuary cannot be returned to a pristine condition, but some specific degree of environmental quality must be agreed upon and targeted by this Plan. A clear goal must be set for it to succeed.

MANAGEMENT ISSUES

The Hudson River Estuary Management Plan (HREMP) will be created to preserve and enhance that ecosystem but there are several socio-political issues that must be addressed to accomplish the successful design and implementation of that Plan.

1. Preservation vs. Change from Human Usage. There must be a careful, thoughtful blending of society's uses of the Hudson River and estuary along with the rehabilitation of the system. This will require administrative and legislative balancing of often conflicting interests which the Plan may wish to address, at least in part, from the outset. Most of the environmental issues previously discussed concerned mitigation of the effects of man's activities on the river. It is not the Plan's purpose, however, to prevent people from using and enjoying the estuary in its efforts to preserve it. The Plan cannot deny people the right to use the waterway, either as a commercial resource (for fishing and shipping, as a source of drinking water) or as a recreational resource (fishing, swimming, boating).

2. Coordination Among Agencies. The Hudson River Estuary Management Plan will be administered under the direction of the New York State Department of Environmental Conservation, however. The estuary falls under the jurisdiction of a number of other state and federal agencies, however. These agencies may have different priorities for, or conflicting interests in, the system.

   In addition to operational programs such as monitoring programs, setting standard levels for pollutants, etc. (all discussed in previous sections), there are two comprehensive planning programs which involve parts of the system included in the Plan. The New York Bight Restoration Project and the New York-New Jersey Harbor Estuary Program are ongoing. Coordination of the HREMP with all the agencies from both states that are involved in these projects is very important if duplication of effort and gaps in coverage are to be avoided. Frequent communication among the managers at all necessary levels in these projects is an important first step. A willingness to compromise on priorities, coordinate research and share information and data would enable all of these projects to achieve better results.

3. Public Education. Management decisions can only be made and carried out with the understanding and cooperation of the citizens of New York, especially those who live in the vicinity of the river. These are the people who pay the taxes which provides the funding and elect the legislators -- which supports the Management Plan. If the citizens are not well informed about the importance of the specific issues contained in the Plan, then important projects may not be implemented or even initiated and the Plan may fail.

   In addition, all activities cannot be effectively regulated at the state level. County and local governments must take up some of the regulatory and enforcement responsibility themselves. This would ease the burden on the state and allow more time, money and manpower for other aspects of the Management Plan. None of this will happen, however, if the public is not educated about the intent and importance of the Plan. Although none of the people interviewed felt that public education should be a formal part of the HREMP, this issue was at least mentioned by most of them.

OTHER PROGRAMS

To complete this report, two programs will be discussed, which were brought up by nearly all of the people interviewed. These programs were considered to be vital to the Plan but not the most important in terms of immediate goals or funding.

1. The first program is the creation of a centralized data base and information center. This would fulfill the need which seems to exist for access to all material pertaining to the Hudson River and other similar systems. The data base would be accessible to anyone and periodically updated. It would consist of a collection of all raw data sets known for the Hudson system, available for cross-referencing and statistical analyses. This central repository would also be a library containing all literature concerning the

system, including books, scientific and news articles and technical reports. It could be placed at some "neutral" site such as the Hudson River Foundation, a university, or a scientific computing firm.

2. The second recommendation is to establish a monitoring program. This would ultimately provide managers and researchers with long-term data on the variability of the system which may then be useful in predicting future conditions in the river. This project is meant to continue indefinitely, beyond the proposed 15 years of this management plan.

   Measurements would include basic chemical and physical parameters, levels of toxic substances and numbers of individuals of aquatic species. Appropriate sites would be selected for the taking of samples and would include those areas of particular interest such as critical habitats, combined sewage overflows or development projects. The methods of collection and analysis would be standardized. In addition, the new monitoring program would be incorporated or coordinated with already existing monitoring programs as much as possible.

   There is a realization that monitoring programs are not always perceived as being useful and are often the first item to be cut out of a budget in a fiscal crisis, so this program would require a firm commitment on the part of the Department of Environmental Conservation (DEC). Initiating a central data base, information clearinghouse and a monitoring program would require a large initial outlay of funds but would require a considerably smaller yearly budget to be maintained. These two projects could be established while the rest of the projects recommended by the Plan are developed and carried out. The latter should not wait on the outcome of the former.

SUMMARY

The issues discussed by the management people interviewed can be broken down into two broad categories: environmental and administrative. The environmental category can be divided into four sections: (1) habitat, including an inventory, determination of critical types, modification and regulation of that modification; (2) aquatic species, including finfish (economic vs. ecological value, habitats and interactions), endangered species, primary producers, shellfish and macrocrustaceans; (3) external stresses, including cumulative physical degradation of shoreline and underwater lands and pollution, especially toxic chemicals (the latter includes identification, sources and effects on organisms, both lethal and sublethal); and (4) global warming leading to a rise in sea level. The administrative category can be divided into three sections: (1) balancing environmental preservation and change through human use of the system, (2) cooperation among agencies, and (3) public education.

This outline does not attempt to include every possible issue of concern that may arise in the Hudson River Estuary. It does, however, cover those topics which recurred in interviews with people who are presently making decisions that affect the management of the estuary.

Reports of the

Scientific Working Groups

Report of the Working Group on "Estuarine Dynamics andTransport Processes"

Robert E. Wilson (Chairman)
M. Llewellyn Thatcher
Richard I. Hires

Introduction

The group considered questions of fundamental research on dynamics and kinematics which could also contribute to management objectives within the Hudson River Estuary. We heard a number of specific management objectives during combined working sessions. Some of these relate directly to basic research on dynamics and kinematics, and others relate to more applied numerical modeling. Examples are listed below, and selected fundamental research questions are described in detail. We also discussed research which could lead to flexible numerical modeling capabilities within the estuary for both process oriented and applied modeling.

Examples of Management Objectives Relating to Research on Dynamics and Kinematics in the Estuary

I. An assessment of the effects of long-term sea level rise on
   A. Tidal response;
   B. Salt water intrusion.

II. As assessment of the effects of channel modification by shoreline development, dredging and sedimentation on
   A. Tidal response;
   B. Salt water intrusion.

III. As assessment of the effects of river flow variations and variations of water consumption on salt water intrusion on
   A. Long-term water supply policies;
   B. Water management policies.

IV. As assessment of the natural temporal and spatial variability in circulation and hydrographic properties and implications for

   A. The efficient design of monitoring programs;
   B. The design of field studies;
   C. The design of modeling studies.

V. An assessment of the transient response to wind and river forcing and implications for

   A. Sediment transport;
   B. Transport of dissolved and suspended materials.

VI. Interactions between the estuary and both the New York Bight and Long Island Sound and implications for

   A. Exchange of dissolved and suspended materials;
   B. Management of floatables discharged from the estuary;
   C. An assessment of factors controlling transport processes within the East River.

VII. Nearshore circulation and exchange among shoreline development projects and implications for

   A. Flow modifications;
   B. Sedimentation.

VIII. An assessment of the relationships between circulation and sewage and industrial effluent discharge strategies.

XI. An assessment of the relationship between estuarine transport processes and larval fish distributions -- implications for fisheries management.

Basic Oceanographic Research

In this section, we consider basic oceanographic research on physical transport processes which could contribute to the management objectives outlined above. Within the framework of basic research, we considered both observations and process oriented numerical modeling.

I. Observations of flow structures and turbulence parameters using modern moored and ship-borne instrumentation.

Improved description of the structure of the flow field relates directly to advances in our understanding of estuarine transport processes that contribute to the movement of dissolved and suspended materials. The very limited long-term measurements from sparse moored instruments within the estuary provide little insight into the detailed vertical and lateral flow structure.

Long-term observations are required to improve our description of the natural variability of the estuary. Long-term observations from a moored Acoustic Doppler current meter and an adjacent moored string of temperature and conductivity sensors would provide fundamental insights into the natural variability of the estuary. The lower Hudson should represent an ideal setting for such a mooring because of the lengthy sections of relatively uniform channel. The information of time varying vertical current and salinity structure would provide insight into the dynamic response of the estuary to river forcing and to meteorological forcing, which have, in fact, been previously unavailable for any estuary.

Analyses of these types of observations should represent a fundamental contribution to our understanding of both the Hudson and of partially mixed estuaries in general in the areas of transient response to riverine and meteorological forcing and vertical mixing of mass and momentum.

Preliminary results from moored current meters in the lower estuary suggest that our ideas of increased gravitational circulation during high river flow may be grossly oversimplified. They suggest instead that little of the fresh water may, in fact, mix vertically and that the pulse slips out of the estuary as a thin, high velocity surface flow. The structure of this flow response is controlled by vertical mixing; modern observations are required to describe this important phenomenon.

Classical ideas on estuarine response to wind forcing were developed primarily from an analysis of observations in the Chesapeake Bay and were simply stated as follows: local direct forcing on the estuary produces a depth-dependent, two-layer response, while non-local forcing associated with wind-induced coastal sea level fluctuations produces a more depth-independent, unidirectional current response within the estuary. These ideas are a gross oversimplification of the actual response to wind forcing. Direct local forcing tends to produce vertical mixing, predominately associated with instability of the enhanced internal velocity shear. This instability can lead to very abrupt vertical mixing of almost the entire water column. This abrupt vertical mixing can, in turn, produce a rapid transition from a two-layer response to a depth-independent current response.

Non-local wind forcing associated with wind-induced coastal sea level fluctuations can also cause vertical mixing: vertically sheared inflow can, for example, cause more saline surface waters from outside the estuary to flow over the waters within the estuary, producing an unstable water column which leads to convection and vertical mixing.

These are but a few examples of the types of dynamic mixing and advection processes that could be described through an analysis of long-term Acoustic Doppler current meter observations from a long-term mooring within the lower estuary. The Hudson would be an excellent place to study some of the interactions because of the strong wind forcing and because of the very strong non-local forcing from the Bight.

Field measurements of fundamental turbulent parameters within the estuary, using a towed device such as that described by Lueck (1987), can be used to infer the vertical diffusivity via the dissipation method (Osborn, 1980). This can provide direct information on vertical turbulent fluxes across the halocline. These types of measurements are planned for the Chesapeake Bay, but such measurements have not yet been made in any estuary. Measurements of the turbulent energy dissipation rates would represent a fundamental contribution to estuarine science.

II. Process-oriented numerical modeling.

One example of process-oriented numerical modeling would be the use of a one-dimensional (in the vertical) mixed layer model to describe the transient response to river and meteorological forcing outlined above. A description of this type of response critically depends on an adequate description of time-dependent vertical mixing processes, which can only be provided by a mixed layer model. Such a model can provide a description of the vertical structure of current, temperature and salinity, as well as turbulence parameters which characterize the intensity of vertical mixing.

A second example of process-oriented numerical modeling could be the use of one-dimensional (longitudinal) and two-dimensional (longitudinal and vertical) models for the evaluation of changes in the tidal response and salinity intrusion characteristics of the estuary. Such changes could arise from changes in river flow and changes in channel cross sectional geometry and friction associated with long-term sea level rise, dredging and shoreline structure development.

Assessment of these changes could first be made using existing theoretical engineering results, some of which have already been applied to the Hudson. Prandle and Rahman (1980) have, for example, presented very practical analytical results for predicting the tidal response in estuaries as a function of channel geometry represented by a simple estuary shape number. They evaluated Hudson estuary tidal response for its present approximate channel geometry in the reach from the Battery in lower Manhattan to Troy, New York. Further analytical work by Prandle (1985) made possible the classification of the tidal response in estuaries on the basis of channel geometry which was also applied to the Hudson. Prandle (1981) examined the characteristics of salinity intrusion in estuaries as a function of channel geometry and freshwater inflow velocity. He applied his results to the Hudson estuary for present channel geometry in the reach from the Battery to Troy. Evaluations of these results could precede more detailed numerical modeling.

A third example of process-oriented modeling would be the adaptation of a model for the tidal hydrodynamics of the East and Harlem Rivers. The model could be used to compare the wave-induced Stokes transport with the transport associated with the residual Eulerian currents through these straits and to determine their relative influence on the transport of dissolved and suspended materials through these straits.

More general modeling considerations for the estuary are discussed in the following section.

Interdisciplinary Research

The interactions among physical transport, mixing processes and larval distributions in the upper Hudson (Borman and Klauda, 1988) potentially one of the most exciting areas of interdisciplinary research. This problem remains to be better defined but should represent a rich area for research. It would have special benefit to fisheries, but the questions raised could motivate research into specific aspects of physical transport processes.

General Considerations for Both Applied and Process-Oriented Numerical Modeling in the Estuary

I. Coupling of models with observations.

The flux of suspended and dissolved material across estuary boundaries is crucial to the management of estuarine water quality. Despite this importance, little is known about the intra-tidal and long-term magnitudes and directions of boundary flux for large estuaries. The lack of knowledge stems from the difficulty in meeting the requirements for obtaining spatially dense and long-term measurements. Costs of such programs for the Hudson are prohibitive, and dense measurements in shipping lanes are not practical. A research program that combines numerical modeling with a skillfully determined program of measurements could provide estimates for fluxes of dissolved and suspended materials. The initial modeling would extend well seaward of locations considered good candidates for sampling stations. By employing the models, the effectiveness of these proposed stations can be evaluated in terms of the cost of information and the usefulness of information for determining boundary fluxes. An optimum selection of stations can thus be determined.

A second step would be the measurement program itself and the subsequent incorporation of measured values in the model for the determination of intra-tidal flux, net flux and long-term flux calculations that will show the response to forcing at episodic time scales.

II. Development of a hydrographic/topographic data base.

The objective would be to make available a hydrographic and topographic data base, complete with computer interface which could generate a geometric scheme of the Hudson for a broad variety of transport models (water, salt, sediment and other water quality parameters). Benefits would include the following:

Reducing the dependence on a few specific models.

Making models more available to both managers and researchers at a much lower installation cost.

Allowing new advances in modeling to be more easily tested and applied.

Possible coordinating with other geographic data bases such as those containing water quality, sediment characteristics and point source data.

NOAA has digitized data bases for hydrography and the U.S. Geological Survey has digitized data bases for topography. These data bases could be accessed to assemble the Hudson Estuary data base, which could then be made available to a variety of users who have access to a personal computer. To enable modelers to quickly generate their required scheme from the data base, techniques would be developed that would calculate the scheme in accordance with the modeler's need. One-dimensional, two-dimensional vertically averaged, two-dimensional laterally averaged, and full three-dimensional models would then be generated of either a finite difference or finite element type.

Report of the Working Group on "Ecosystems and Fisheries"

Robert V. Howarth, Chairman
John Boreman, Rapporteur
Gordon Colvin
Cynthia Decker
Stuart Findlay
Nicholas Fisher
Jeffrey Levinton
Robert Malouf
John Waldman
Peter Woodhead

Introduction

The Hudson River Estuary can be considered as consisting of three major subecosystems for the purposes of research and management: (1) the tidal, freshwater portion stretching from the Troy Dam to the beginning of the salt wedge; (2) the brackish or mesohaline portion with salinities ranging from 2-15 ppt (parts per thousand); and (3) the more saline, or euryhaline portion of the estuary in the vicinity of New York City with salinities greater than 15 ppt.

The group determined that basic research is needed for a better understanding of the functioning of the Hudson River Estuary to effectively manage it. However, the working group also felt that such basic research should have the clear objective of serving management goals because current understanding of the Hudson River Estuary is inadquate to meet these goals. Accordingly, we agreed on a central management goal and on four major scientific objectives to serve this goal.

Central Management Goal

> To restore and maintain adequate ecological diversity and productivity to support a wide array of uses of the living resources of the Hudson River estuary.

Scientific Objectives

1. Ecosystem Function

A better understanding is needed of the dynamics of carbon, oxygen and nutrients within the estuary and how these relate to the surrounding watersheds and coastal waters. Particularly important are the effects of excessive nutrient input to the system. We also need a better understanding of nutrient and food cycling in the estuary and the factors controlling species diversity and abundance. Questions about the effects of changing land use and regulation of tributaries on the ecosystem and fisheries are important, as well as those about the effects of habitat alteration.

Some progress in understanding the basic functioning of the tidal, freshwater portion of the estuary is being made, owing to a variety of projects funded by the Hudson River Foundation. However, our understanding remains primitive. Even less is known about ecosystem functioning in the more saline portions of the River.

2. Toxic Stresses

A better understanding is needed of the impacts of toxic substances on the estuarine ecosystem and subecosystems. Lethal and sublethal effects of toxic substances should be assessed at the organism, population and ecosystem levels.

Although it is well known that large amounts of toxic substances are released into and remain within the Hudson Estuary, little is known about the ecological consequences of these contaminants. In addition to ecological effects, toxic substances often accumulate in organisms having commerical or recreational significance, such as PCBs in striped bass. While the concerns addressed in these objectives should properly involve all aquatic species in the system, it may be necessary for specific research projects to focus on certain species, populations or communities. "Key resource species" is a term which is often used to focus research and usually includes those species of finfish, shellfish, wildlife and any other organisms which are felt to be vital to the functioning of the system. Before decisions can be made as to which species are "key," the roles of all species must be investigated. This work would most properly be done in the context of objective IA. in the Summary.

3. Fisheries

The Hudson River and Estuary are of statewide and national importance as habitat for marine, anadromous, catadromous and freshwater fish species. It may be the only major estuary on the entire east coast to retain strong populations of historical spawning stocks. But a lack of scientific data and information has resulted in recurrent controversies about the movements, life cycles and critical habitats of these species.

A better understanding is needed of the ecology and life-cycles of fish species, including the factors that affect spawning success and other aspects of population abundance of fishes and other important resource species. One needs to be able to describe the diverse and dynamic fish community, its composition and structure spatially and temporally, particularly in relation to the biotic and abiotic characteristics of the estuary; and to be able to describe and quantify the predatory and competitive links among fishes and other organisms.

The sizes of fish populations depend upon the quality of spawning nursery and feeding habitats, water quality and predation and exploitation. A better understanding is needed of the factors that regulate population variation and how fishing interacts with these factors to cause fluctuations in abundance and in the yields of the fisheries.

4. <u>Cumulative Impacts</u>

There is a need to develop a scientific framework for assessing the cumulative effects and interactions of multiple stresses and alterations on the Hudson River ecosystem. The Hudson River and its resources are subject to numerous stresses and alterations. The effect of any single change cannot be fully assessed without considering interactions with other stresses and changes.

Currently, no scientific framework exists to evaluate the cumulative effect of interacting stresses within the Hudson River estuary. The development of such a framework is crucial and should be pursued. However, we recognize that progress in developing this framework will be dependent on a better understanding of the basic functioning of the Hudson River ecosystem and of the impacts of individual stresses. Therefore, we recommend that this objective should be developed further after solid progress is made on the first two objectives.

These scientific objectives are stated in terms of our interest in the biological resources of the estuary. However, a better understanding of the hydrology and sedimentology of the estuary is also necessary if we are to meet these objectives. We strongly feel that an interdisciplinary approach involving linked ecological-geological-hydrological studies is fundamental to future research on the Hudson River Estuary. Some hydrological models already exist that attempt to relate water flow and salinity to biological resources as well. Note that this is the general recommendation of the 1987 workshop on research on the "Land/Sea Interface" sponsored by the National Science Foundation and the American Society of Limnology and Oceanography in Woods Hole.

We believe that research should be guided by conceptual models. Such models maintain a focus for the research, help ensure that the research has some ultimate goal of aiding in the management of the estuary and potentially can assist in developing further conceptual models to be used by the management community. Two examples of such models are used by the research groups at the Institute of Ecosystem Studies (Millbrook, NY) and at Cornell University to guide their research on the dynamics of the lower food web and on carbon and oxygen dynamics in the freshwater, tidal portion of the Hudson estuary.

High quality, basic research is necessary for better management of the Hudson River which is an excellent natural laboratory for addressing certain basic scientific questions. To obtain the best possible research, it will be necessary to let investigators use their creative powers and play a major role in defining research goals from the very beginning. Only in this way will top quality scientists be attracted to a research program.

Several important topics for research were identified within each of the four major scientific objectives. These are briefly discussed below. This list is not intended to be exhaustive but rather illustrative of the types of research that should be supported. It is important to reiterate that individual investigators need to play a major role in defining the actual research agenda: in identifying and formulating the questions and in designing the research to answer them.

Ecosystem Functioning -- Important Topics

1. There is a need to define the effects of changes in land use and changes in bays and tributaries on estuarine ecosystem structure and functioning; and to study the coupling of the subecosystems of the Hudson River Estuary and the New York Bight.

   The present understanding of the coupling of the Hudson River and its estuary to its tributaries and to the New York Bight is still rudimentary, but some interesting preliminary observations highlight its importance. For example, primary production in the tidal river is quite low because of light limitation; the result of extremely high turbidity which, in turn, may be related to erosion in the watershed. As another example, ecosystem respiration greatly exceeds primary production in the tidal, freshwater estuary. This respiration is largely fueled by the input of organic matter from the watershed, probably mainly from agricultural and suburban lands (Fig. 1). Thus, changes in land-use patterns might be expected to change respiration rates, perhaps making hypoxia or anoxia more likely.

2. We need to determine the relative importance of *in situ* primary production and exogenous inputs of organic matter in supporting secondary production.

As stated above, the oxygen dynamics of the tidal river are driven by a high rate of ecosystem respiration and this, in turn, is driven by external inputs of organic carbon from land. However, it is possible that the much smaller net rate of phytoplankton production is more important in supporting the major food webs and that the energy of the external carbon input is used very inefficiently with little transfer up the food web (Fig. 2). The extremely high rate of ecosystem respiration combined with the low rate of primary production offers a "natural laboratory" in which to address the general question of ecological efficiencies in detritus- and algal-based food webs.

Other important questions that need to be answered are as follows: What are the sources, controls and effects of allochthonous organic loadings into the rest of the system? In the estuary near New York City, sewage is probably the major source of particulate and dissolved organic matter. Nutrients from sewage have been shown to cause increased primary production. Is the energy in sewage used more efficiently or less efficiently than that in terrestrially derived organic matter in supporting food webs? Will the composition of the phytoplankton change if primary production decreases? Will secondary production decrease if sewage loading is decreased?

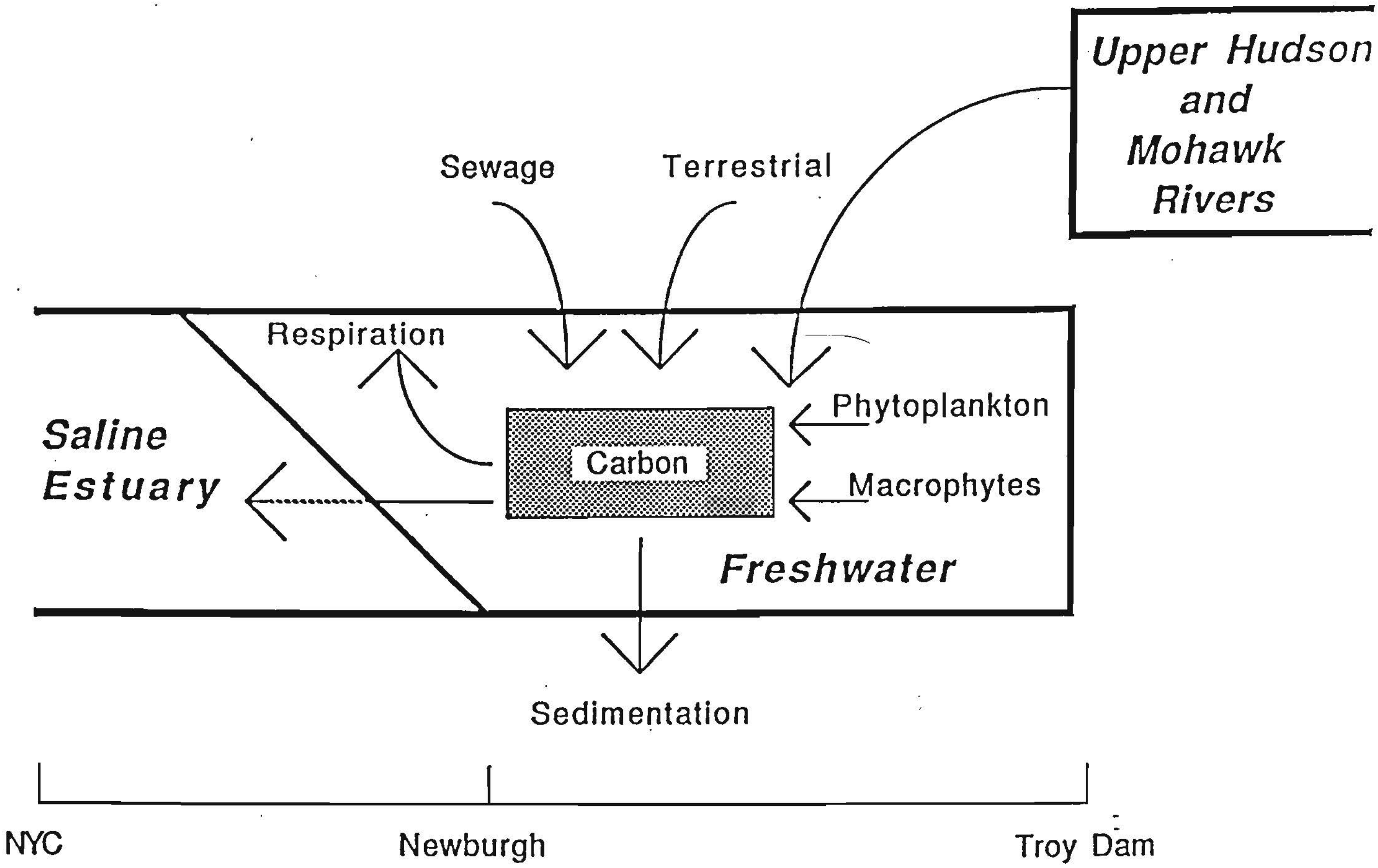


Figure 1 - Conceptual model for carbon cycling in the tidal, freshwater portion of the Hudson River Estuary.

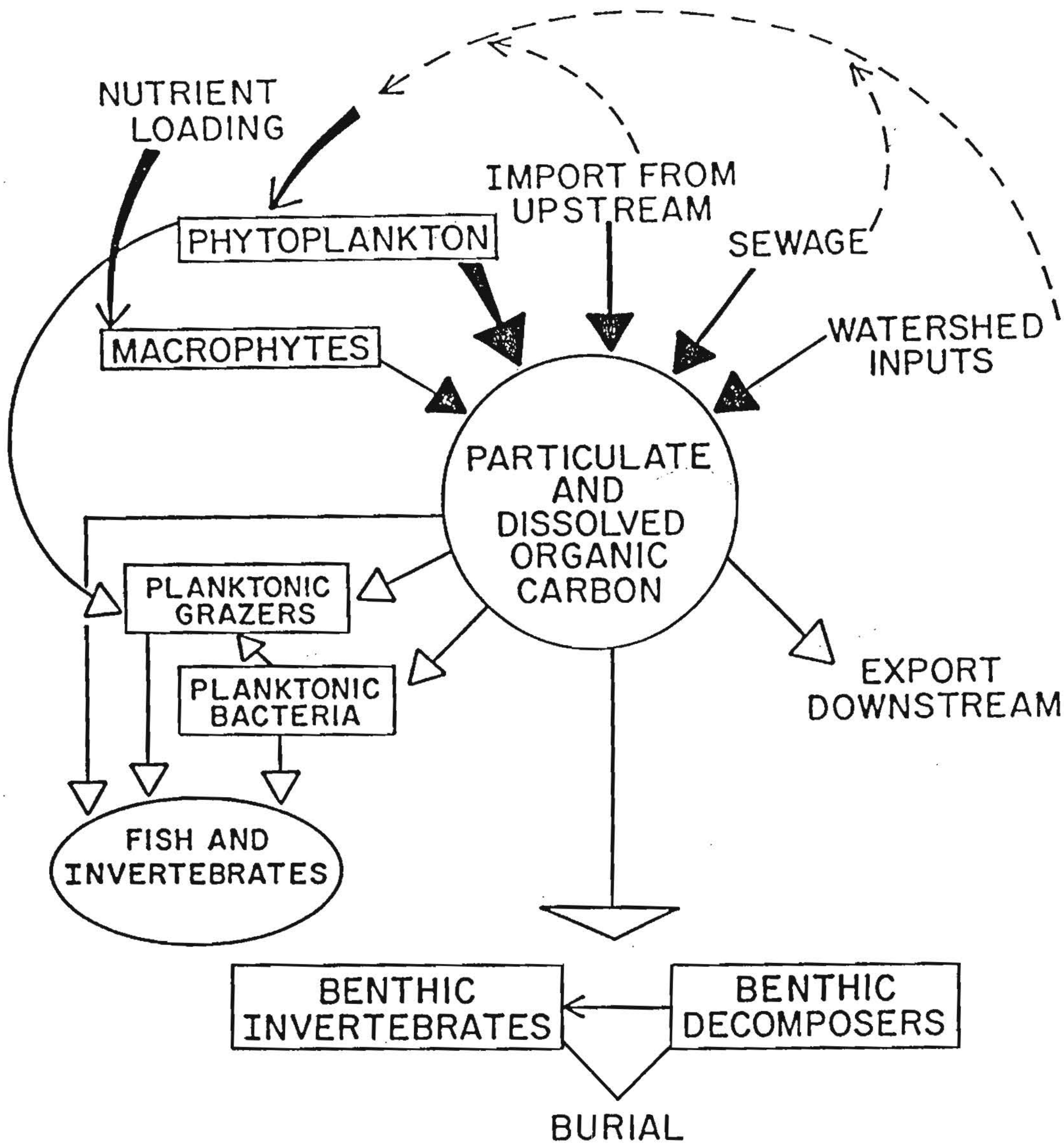


Figure 2 – Conceptual model of componants and interrelationships of the lower food web of the tidal, freshwater portion of the Hudson River Estuary.

3. An assessment is needed of the effects of macrophytes on ecosystem structure and function.

   Aquatic macrophytes appear to have a wide distribution in the tributary embayments of the Hudson River and yet their role in the functioning of the entire system has not been extensively investigated. To understand their importance, it is necessary first to determine the current distribution and community composition of these plants and to evaluate how this distribution has changed in response to human intervention and habitat alteration. How has their community composition changed because of the introduction of exotic species such as the water chestnut? What are the ecological and sociological effects of methods used to control the proliferation of these species? Other issues that should be investigated include the role of macrophytes as a habitat for other species and their role in promoting localized sedimentation through reduced water flow.

4. An assessment is needed of the potential for nuisance algal blooms in the system.

   Algal blooms have been a recurring problem, especially in recent years, in lakes and coastal waters. What is the incidence and distribution in the Hudson of species known to have bloomed in other systems?

5. An assessment is needed of the distribution of biomass and its community composition within the existing continuum of habitat types along the entire corridor of the Hudson River estuary; define and evaluate the contribution of different habitat types to the growth and maintenance of Hudson River aquatic communities.

   Questions about the importance of habitat cannot be answered without first determining the areal extent and distribution of available habitat types within the system. It is important to realize that habitats occur as a continuum yet they can still be mapped on the basis of species diversity and abundance. A habitat map of the Hudson River estuary would be invaluable in assessing the cumulative impact of various activities (e.g. dredging, filling) on the system.

Different species will use a variety of habitats in different ways. What are the basic habitat requirements of different species in the Hudson? How does the alteration of habitat types affect species either directly or indirectly? How can we identify the impacts caused by loss and alteration of vegetation and by dock and platform construction? How will changes in salinity and hydrology affect aquatic species and the ecosystems supporting them?

Mitigation is increasingly proposed as an approach to environmental management, yet there has been little scientific investigation into this approach. Are restored or newly created habitats ecologically comparable to natural habitats?

Toxic Stresses -- Important Topics

1. A characterization is needed of the sources, concentrations and chemical speciation of pollutants in the Hudson River Estuary ecosystem.

   The sources of the most prominent pollutants need to be identified; point vs. non-point sources for each contaminant should be determined. It is important that at least some attention be paid to the analysis of those organic (e.g. PAHs) and inorganic pollutants (e.g. tin and silver) which are not currently being investigated, in addition to those which are (PCBs, mercury, cadmium, etc.). The concentrations of the "critical" pollutants in water, as suspended particles and as sediments, should be determined for different regions of the Hudson. The chemical and physical speciation of these pollutants will largely dictate their mobility, bioavailability and ultimate toxicity in the system. The speciation may, in large part, be a function of the dissolved organic carbon (DOC) load in the water column, thus DOC should be routinely measured. Sediments can serve as a source (as well as a sink) for certain pollutants. That is, these pollutants can be mobilized from sediments to the overlying water through resuspension, desorption, bioturbation and a variety of human activities such as dredging or construction.

2. An assessment is needed of the processes for assimilation and retention of toxic compounds and their derivatives by organisms.

   Bioaccumulation of persistent contaminants in Hudson River fish and wildlife may directly affect these animals or render them unusable for human consumption. The bioaccumulation of one group of toxic substances, PCBs, in striped bass in the Hudson is one of the consequences of pollution most well known by the public. But more information is needed on the accumulation of other toxicants known to be present in the estuary in other species of the system. Also important would be studies on food chain transfer, retention time of contaminants and sites of accumulation within organisms. Where possible, existing data on the interactions of pollutants with aquatic biota from other systems should be applied to the Hudson River Estuary.

3. An effort is needed to define the abilities and limitations of aquatic species, particularly microorganisms, to detoxify contaminants.

   Many organisms can metabolize some toxic substances in such a way as to reduce, eliminate or sometimes even enhance their toxicity. However, there are limits to these processes, and, while a certain organism may be able to tolerate and detoxify a pollutant up to a certain limit, beyond that limit the abilities of the organism may be overwhelmed. The limit of an organism's ability to metabolize pollutants is not fully known and is species-specific. Micro-organisms may be particularly valuable to the system in this regard as they, more than any other group, may be able to detoxify an area through their abilities to biodegrade organic pollutants.

4. An assessment is needed to establish the toxicity currently associated with ambient waters and sediments.

   The waters and sediments of the Hudson River Estuary contain a large number of potentially toxic substances. Are these substances present in sufficiently high concentrations, and do transfer and uptake mechanisms exist such that they are currently affecting organisms? A representative sample of locations in the Hudson Estuary should be tested with one or more sensitive bioassays to determine if toxic substances are presently biologically active.

Fisheries -- Important Topics

1. There is a need for status assessments of the fish populations, their relative abundances, and their interannual variabilities, especially for those species having documented or potential recreational or commercial value, or that play key roles in the functioning of the estuarine ecosystem.

2. There is a need to characterize the diversity and structure of the fish community of the estuary, including seasonal and yearly changes. Community composition and structure must be related to important abiotic and biological variables in the estuarine system.

3. An important region of environmental changes is in the zone of transition from the estuary proper to the tidal reaches of the river -- in the vicinity of the salt "front." Although the location of this zone ranges widely along the estuary as a function of the freshwater discharge of the Hudson, the response of the fish community to changes in the position of the front are poorly known. We need to have a better understanding if we are to be able to predict the effects of freshwater withdrawal or modifications of the geometry of the estuary.

4. The life histories of fishes in the estuary require further investigation to establish their dependency on different habitats for spawning, for nursery grounds, for feeding areas and for overwintering areas. Size/fecundity relationships need to be established.

5. Documentation is required of the dependency of different life history stages of important species on habitats within the system. The present causes of variability in spawning success and recruitment to adult populations are poorly understood.

6. Information is needed on how commercial and recreational fisheries interact with natural fluctuations in fish populations to enhance/endanger important fish stocks and fisheries.

Cumulative Impacts -- Important Topics

This scientific goal is necessarily elusive at this time. Clearly, we need a far better scientific grasp of the fundamental processes that characterize the Hudson River estuarine system and of how individual human activities affect those processes before we can fully deal with an assessment of cumulative impacts. As we improve our understanding of the Hudson River ecosystem, we suggest that a series of periodic, perhaps annual, workshops be convened to bring scientists and managers together to help develop a scientific basis for integrative management. Such workshops might address issues such as those listed below.

1. Determine the effects and relative contributions of fishing, pollution, habitat alteration and changes in ecosystem structure and function on the production and recruitment of aquatic communities.

2. Define the interactions between non-consumptive uses of the estuary (swimming, boating, shipping, etc.) and ecosystem functioning.

3. Compare the projected commercial and recreational harvest demands in relation to the projected capabilities of the ecosystem to support such demands.

Report of the Working Group on "Geology and Geochemistry"

Roger Flood, Chairman
Henry Bokuniewicz
Kirk Cochran
Nicholas Fisher
Charles Nittrouer
John Sanders
James Simpson

Introduction

Many contaminants (e.g. PCBs, heavy metals and radionuclides) of management concern are associated with sediment particles in the Hudson River. Effective management requires a knowledge of where the particulates are going now, where they have gone in the past and where they are likely to go in the future. Here, we give a summary of a conceptual model for sedimentation and pollutant dynamics in the Hudson River and point out some gaps in our understanding. Several aspects of the Hudson River make it a unique place to undertake the needed basic research. These aspects include the elongated nature of the estuarine/river system combined with distinct inputs at either end of the system and the abundance of substances (tracers) that allow us to follow the movement of particles through the system. Many of the sediment tracers, such as PCBs are, in fact, the very substances that we need to control. Principles developed here would be applicable to other estuaries, but because of the unique aspects of the Hudson River Estuary system, they will best be developed in the Hudson.

The following examples highlight our need to better understand sedimentation and contaminant behavior. Many contaminants in the river system (for example, PCBs) are attached to sediment particles and travel with those particles. However, our understanding of the processes that control the spatial and temporal deposition of sediments and associated contaminants is only rudimentary. Deposition removes contaminants from the water column. Once contaminants have been deposited, chemical, physical and biological processes acting on the sediments can control the recycling of contaminants. Unfortunately, these processes and their spatial and temporal variability are poorly understood. Manmade structures cause enhanced sediment deposition and erosion; however, we cannot predict how specific structures will affect sedimentation. Primary productivity is limited by the amount of light which can enter the river and poor transparency is mostly a result of high suspended sediment concentrations; however, we only partly understand the processes which control how much sediment is in suspension in different parts of the river. Many plants and animals that live in the river spend portions of their lives in contact with the river bottom; however, we only poorly understand the processes which create variability in sediment character or how the biota and the sediment cycle interact. Long-term changes in river depth, primarily due to siltation, affect the distribution and character of the various benthic environments.

The factors that control the long-term evolution of the river are not well known. Dredging of sediment is vital for many uses of the river; however, we only have a general understanding of how sediment removal affects the sediment cycle, where the sediments that fill dredged areas come from, how long dredging activities affect animal/sediment or flow/sediment interactions, or where to dispose of dredge materials. To be able to answer some of these and other questions about the river sediment cycle, we need a substantial increase in our qualitative and quantitative understanding of sedimentation processes in all portions of the river.

<u>Conceptual Model for Sedimentation</u>

Sedimentation in the Hudson River can be broadly described in terms of a conceptual model with the following attributes:

1. The river is both a conduit and a trap for sediment. The river is capable of retaining not only substantial parts of what is delivered to it from upland sources but also from the sea, a possibly surprising but substantial source. Dredging is the major process for removing sediment from the river.

2. Many contaminants become attached to sediment particles soon after the contaminants enter the river. The partitioning of each contaminant between the portion dissolved in the water and the portion attached to particles depends on water column chemistry, for example, dissolved organic carbon (DOC) and contaminant chemistry. To a first approximation, the contaminants appear to be carried in association with the particles as the particulates are transported, deposited, ingested and resuspended. Diagenetic reactions associated with organic matter decomposition in the sediment may lead to the modification or release of some contaminants.

3. Although the wedge of salt water extends a variable distance up the river (between the Tappan Zee Bridge and Poughkeepsie), tidal currents extend throughout the lower Hudson to the Federal Dam at Troy. It seems likely that winds and tides provide energy to keep levels of suspended sediment relatively high and thus reduce the magnitude of seasonal variations in suspended-sediment concentrations.

4. A turbidity maximum probably exists near the upstream limit of the salt water wedge, but the evidence is sparse.

5. Sediment types and sediment organic carbon concentrations vary regionally. These result in part from variations in sediment source along the river and in part through the redistribution of particles by waves and currents. The existence of bedforms (sedimentary features created by water flow) in both coarse-grained and fine-grained sediments demonstrates dramatically that bottom flows are capable of reworking bottom sediments.

6. Particles through the Lower Hudson typically exist as agglomerates with relatively rapid settling speeds. The agglomerates are not limited to the saline estuarine waters, and bioagglomeration, therefore, seems to be an important process.

7. Contaminated sediments accumulate rapidly in dredged channels, hundreds of times more rapidly than in undisturbed areas of the river floor. Large areas of the undisturbed river floor only accumulate sediments slowly, perhaps in response to a slowly rising sea level. As a result, in these areas the veneer of contaminated sediment is quite thin.

Research Goals

To improve our management ability, we need to foster a community of experts who are capable of making forecasts concerning the behavior of the system with a high degree of discrimination among different sites. In addition, to gain this predictive capability, we need to expand our understanding of estuarine processes both empirically (by surveys and monitoring) and through a better understanding of the basic processes (by experimentation and modeling). As new insights are gained into how estuarine processes operate, the processes need to be quantified and introduced into computer models. To help solve management problems, research efforts should include the following goals:

1. Improve our description of river bed and sediment characteristics in the river and estuary and understand the spatial and temporal variability of those characteristics.

   A good description of the estuary floor is essential for understanding many phenomena. Such a description, which should include the development of an accurate picture of what the river bottom looks like, is important for several reasons. First, much of our appreciation of natural systems comes from seeing what an area looks like. Because of the high turbidity, it is virtually impossible to directly inspect the bottom of the Hudson River. Several techniques are now available for imaging the river bottom (e.g. side-scan sonar, remotely-operated vehicles with video capabilities). A better visualization of the river bottom would very quickly bring many aspects of sedimentation, and of animal/sediment interactions and habitats, to our attention.

Second, knowledge of river-bottom characteristics is essential to recognizing animal habitats and the physical processes that affect them. One would not study land-based ecosystems without defining the geography in which they exist, and similar data should be available for studies of Hudson River habitats.

Third, the sediment surface records the effects of man's activities as well as the effects of natural biological and sedimentological processes. For example, a careful interpretation of bedform types and patterns can tell us about sediment characteristics, flow patterns and sediment-transport pathways. Very limited studies have been undertaken in the Hudson, although these studies have proven to be profitable in other estuaries (e.g., Chesapeake Bay and San Francisco Bay).

These descriptions of the river, and indeed all studies of the river, will require good, up-to-date maps. All data collected should be precisely located to be able to compare different kinds of data.

2. Understand the geochemical cycle of contaminants in the river, and use these contaminants and other tracers to understand river dynamics.

   Pollutants in the Hudson River system are both a complicated management issue and a powerful mechanism for understanding river processes. Many of the contaminants have fairly specific sources and moderately well-known release times; they become rapidly associated with sediment particles in the water column; and they are transported, deposited and resuspended with those particulates. By studying these manmade and natural tracers (Table I), we learn about not only the contaminants we are trying to manage, but also about the processes that occur in the system, where they occur and the rates at which they operate. Such information is critical for verifying the predictions of numerical models that describe sediment dispersal.

Table I

Working Group on Geology and Geochemistry

Some Useful Tracers in the Hudson River Estuary

Tracer	*Source*	*Time Scale*	*Potential Applications*
Cobalt-60	Reactor	To Decades	Sediment Dispersal and Accumulation.
Cesium-137	Fallout and Reactor	Since Introduction (Decades)	Sediment Dispersal and Accumulation.
Cesium-134	Reactor	To Years	Sediment Dispersal and Accumulation.
Tritium	Reactor	To Years	Water Transport and Mixing.
Carbon-14	Fallout, Reactor, Fossil-Fuel & Natural	Many, to 40,000 Years	Carbon Cycling. Sediment Dispersal and Accumulation.
Plutonium -239/240	Fallout	Since Introduction (Decades)	Ocean-Estuary-River Mixing. Sediment Dispersal and Accumulation.
Beryllium-7	Natural	To Months	Seasonal Sediment Dispersal and Accumulation.
Lead-210	Natural	To Decades	Ocean-Estuary Mixing. Sediment Dispersal and Accumulation.
PCBs	Manmade (Many Point Sources)	Since Introduction	Sediment Source, Dispersal, and Accumulation . Food Web Studies.
Trace Metals	Manmade (Many Point Sources)	Since Introduction (Decades or Longer)	Sediment Source, Dispersal, Accumulation.

NOTE: Reactor-derived tracers have a point source. Natural tracers generally have a dispersed source. Manmade tracers may have both point sources and distributed sources.

For example, PCBs have both an upriver source and several sources in New York City, but the ratios of the specific PCB compounds (congeners) present in those two sources differ; thus, PCBs can be differentiated within the system. Also, PCBs from upriver sources were mostly introduced to the river downstream of Troy after the dam at Fort Edwards was removed in 1973 following spring floods in 1974 and 1976. Downriver sources of PCBs have apparently been more continuous. By learning how the various PCB congeners change with location and with time, we can learn about the history of sedimentation and the variations in the strength of different pollutant sources. Such studies need to include the proper chemical characterization of sewage inflows and of dredged materials to attempt to characterize the sediment system completely. Radiochemical releases from the nuclear power plants at Indian Point and lead from automobile exhausts also provide powerful potential tools for studying the sediment system.

An improved understanding of contaminant behavior is critical for understanding the impacts, pathways and fates of contaminants in the environment. We need to have a much better understanding of the distribution of various contaminants among dissolved, colloidal and particulate phases and the characteristics of the suspended particles with the greatest affinity for different types of contaminants. We need to know the extent to which contaminant dynamics depends on water chemistry and biological activity. For example, salinity, oxygen content and dissolved organic carbon (DOC) content appear to strongly affect the affinity which different kinds of organic and inorganic contaminants have for particulates of both biological and sedimentary origin.

Our understanding of the long-term evolution of many contaminants is also only poorly known. In particular, studies of PCBs from selected hot spots north of the Thompson Island dam suggest that PCBs are being selectively dechlorinated by anerobic bacteria at depth. However, that effect has not yet been noted for either the fresh or saline portion of the river south of the dam at Troy. We need to know much more about the chemical or biochemical reactions that can occur, the environments where they occur and their reaction rates.

Many natural tracers are also present at trace levels in sediments (Table I). These tracers can be used for studying sedimentation processes and as analogs for studying contaminant behavior. These tracers become attached to particles in the same way as contaminants, but the natural tracers often decay with time to give a time-dependent distribution pattern, which is important for studying rates. Some tracers may be particularly valuable for studying sediment patterns on a time scale of less than a year, whereas others can help to understand long-term water and sediment interchange between the Hudson River and the New York Bight. Numerical models of sediment dispersal will require the insights gained through tracer studies, and the specific tracer distribution patterns observed, to verify the model premises and results.

3. Integrate studies of the sediment and biological studies to better define and map benthic habitats; determine how these habitats change, especially with distance (salinity) along the river; and determine how different animal communities affect sediment and pollutant cycling.

   Biological communities (both plant, especially macrophyte, and animal) are known to influence sediment resuspension and deposition and the fluxes of solutes (e.g. pollutants and nutrients) across the sediment-water interface. We must not only know what the benthic communities are and how closely they are tied to sediment character or other environmental characteristics (e.g., grain size, current strength, salinity, etc.) but also how they affect sediment erosion and deposition and chemical exchange across the sediment-water boundary, especially through bioturbation.

4. Characterize the suspended sediments well enough to recognize the factors that control suspended sediment distributions throughout the river.

Comprehensive information on the suspended sediment system in the Hudson is scarce. To forecast the pathway of particles through the estuary we must know the patterns in the suspended sediment distribution both in time and space. This will require a direct sampling program, carefully planned tracer studies and models whose results are consistent with both sampling and tracer results.

Long-term monitoring of the suspended sediment load at Cohoes on the Mohawk and Waterford on the upper Hudson has shown that much of the sediment that enters the Hudson River does so only for a limited time during runoff events, particularly in the spring. For instance, in 1977, 44% of the yearly sediment load was recorded on only three days. Because many of these sediments have come from the Hudson River above Troy, they may be associated with PCBs. We do not know how such pulses of sediment travel through the system. Similar long-term monitoring of suspended sediment load and associated parameters such as flow velocity and salinity has not been undertaken in much of the rest of the Hudson River. Thus, we cannot characterize the sediment load through the entire river, its relationship to salinity or the evolution of the large input of storm- or runoff-related sediment.

Because many factors combine to create any given distribution of suspended sediment, we need to take advantage of all indicators of sediment transport. Bedforms are one type of indicator and geochemical tracers are another. Many naturally occurring and manmade tracers can be used to study both suspended sediment and sedimentation. These tracers have been described more completely under item 2, page 38 and in Table I. Many tracers have fairly well-defined sources and some decay with time and, when studied during carefully defined research programs, can provide important information about how sediments are being distributed throughout the river system over different time periods and their rates of dispersion. The results of both short- and long-term monitoring of suspended sediment, river flow, water properties and tracers are essential for the testing and verification of models for sediment and contaminant transport. Such data may also allow us to determine how long specific particles remain in contact with the water and, thus, the likelihood that their pollutant loads will be transferred to the biological sphere.

5. Understand better the processes that lead to sediment resuspension, the rates at which they act and where they occur.

   Sediment resuspension is an important factor in controlling suspended sediment distributions and, in conjunction with deposition and biological reworking, in determining how long a particle remains in contact with the water column. Virtually no information exists on the magnitude of resuspension in the Hudson and both direct and indirect measurements of resuspension in different environments in the Hudson need to be attempted. To interpret the role of sediment suspension in the sediment cycle correctly, we will need to investigate the processes important to sediment resuspension and the places in which they operate and rates at which they operate.

   A partial list of mechanisms for sediment resuspension includes the following: shear stresses applied to the bottom by wind-induced or manmade waves and/or currents; animals reworking bottom sediments and affecting how a sediment bed will respond to an applied shear stress; gas generated within the sediments and bubbled through the sediment/water interface; objects such as tree branches, leaves, twigs, cans, tires, etc. bouncing along the bottom; erosion of river banks and shallows (possibly enhanced by ship wakes); scouring by propellers; dragging of anchors; and dredging of shoal areas.

   A first step might be to better characterize the response of natural sediments to an applied shear stress and to couple these studies to *in-situ* measurements of current flow and sediment resuspension. These studies will then need to be expanded to include additional factors that control the resuspension of real sediments. When coupled with appropriate tracer studies and direct observations, this basic research will help us to better determine the role of resuspension in reintroducing pollutants to the environment and the rates at which this occurs.

6. Understand better the processes that cause sediments to be deposited and the effect of changes in sediment deposition on the sediment cycle, benthic environments and river chemistry.

   Sedimentation can have both beneficial and detrimental aspects. Sedimentation removes pollutants from the water column and sedimentation buries both those contaminants and organic carbon. However, sedimentation also fills necessary navigation channels or other marine facilities, and water quality may degrade in areas where sedimentation causes waters to become shallow. An example of the long-term modification of the river by sedimentation is the changing of the river near the Piermont Pier. The Piermont Master Plan[1] (Piermont Planning Commission, Piermont, NY, 1979) summarizes the history of this region.

   > "Until the 1640's, the Hudson River flowed unimpeded along the Piermont shore. Ships were able to enter the Sparkill creek and dock at the old mill's dam. With the agricultural settlement of the land, at the beginning of the 1640's, a fanlike delta began to grow downriver from Piermont. Construction of the mile long Erie Railroad Pier, begun in 1838, has drastically changed the circulation pattern in its vicinity and thus the depositional pattern of the sediment. The marsh south of Piermont has extended itself dramatically, and to the north of the pier heavy siltation has taken place in the bay formed by the pier and the shoreline (Piermont Bay)."

[1]Personal Communication from George Bryan

This marsh is now one of the more important areas biologically on the Hudson River, but the long-term changes in siltation pattern that resulted from changes in land use and construction will probably cause problems in the future.

Short-term and long-term deposition rates need to be measured in all portions of the river system, and the sources for materials deposited in different sections of the river need to be determined and quantified. These determinations will need to be based on careful studies of a suite of both natural and manmade tracers incorporated in the sediments (see item number 2, page 38, and Table I). Although measurements have been made in some areas, sedimentation rates cannot be extrapolated with confidence. We need to know how sediment deposition rates vary in relation to any turbidity maximum and flow/salinity profile. Also, we need to know how sediment deposition averages out over periods of varying lengths, for example, tidal cycles, yearly discharge cycles, decadal time periods and longer. What are the effects of occasional large sediment input events in controlling long-term sediment accumulation patterns? Will a "100-year storm" dominate over 100 years of "average" flow conditions? We need to know where the sediments deposited in various portions of the river are coming from. How do the marine and upland sediment sources combine to give the composite accumulation pattern? In addition to learning where fine-grained sediments are deposited, we need to learn where they are not being deposited and why.

Although direct measurements will allow us to describe the present depositional system, to forecast changes that might be associated with management options, we need to improve our understanding of the basic physics. Deposition rates for fine-grained sediments should theoretically be related to the speed at which particles fall, the concentration of those particles in the water column and the shear stress applied by the flow on the sediment surface. Many of these parameters may change downriver, including suspended-sediment concentration and particle settling velocity, because of the increase in salinity and increased flocculation downstream. However, animals also are important in agglomerating sediments and may control the particle-settling-velocity distribution. We need to know how well the available theory describes sedimentation in the Hudson River.

Two areas where human activity directly affects sediment deposition, and possibly habitat modification, are sedimentation near structures, and dredging. The placement of structures along the river may affect both sediment accumulation in the vicinity of the structure and, if the structures are extensive, sedimentation patterns within a wider portion of the river. These structures can enhance deposition by reducing flow velocity and bottom shear stress, by increasing particle settling velocity or by creating a habitat where animals which remove sediments from the water column prosper. If sediments that deposit near these structures have enhanced pollutant loadings, then this sedimentation may provide a mechanism for quickly removing polluted sediment from the system. Conversely, sedimentation can be reduced where flow velocities are increased and the bed is scoured.

Dredging usually enhances sedimentation by creating regions of reduced flow velocity, thus an understanding of sedimentation patterns in the river may help to reduce the need for dredging. If structures along the waterfront enhance deposition in shallow water, for example, will the amount of sediment deposited in the navigation channels be reduced? Does dredging in the lower Hudson River enhance the deposition of sediment derived from the shelf or of sediments brought down river? How will sedimentation patterns change in response to a rising sea level? If we can determine how the sedimentation system works, then long-term management questions such as these can be addressed.

The study of sedimentation patterns can take advantage of people's continuing influence on the Hudson River to use the river as a natural laboratory. First, sediments continue to be deposited near piers and other structures constructed both recently and many years ago. By determining how sediments have accumulated near these structures and by comparing actual accumulation patterns to those predicted by models, one can begin to assess the factors which are important in controlling local sediment accumulations. This understanding, supplemented by measurements designed to distinguish between the predictions of several different models, will provide an important capability for predicting the effect of future structures.

Second, dredging occurs regularly in portions of the river. The careful monitoring of post-dredging sediment accumulation would substantially increase our understanding of how dredging affects accumulation patterns. One outcome could be the specification of a shape for the river channel which would minimize post-dredging deposition.

7. Use the geological record to understand past natural variations in, and the long-term evolution of, the Hudson River system. The Hudson River has evolved substantially since the glaciers retreated from this region about 18,000 years ago and since estuarine conditions were established in the Hudson about 12,000 years ago. This evolution has involved the formation of islands, banks, channels, deposits off tributaries, sand spits, marshes, changes in vegetation, etc. Some of the most dramatic evolution has probably occurred since European settlers occupied the valley, and fundamental changes have accompanied the construction of locks and the dredging of the river. The river system responds to man's activities in the same manner as it responds to natural changes, and a better knowledge of how the river has evolved in the past will necessarily help us to understand many of the long-term changes in store for the river system in the future. For example, if we can learn how the river system has responded to past rises in sea level, we may be able to predict how the system will respond to a future rise in sea level.

The analysis of sediments can also help to produce records of environmental data which cannot be obtained by other means. For example, analysis of plant remains from a well-dated sediment sequence may tell us how the river changed when settlers move into the area. Pollutant, or possibly nutrient, histories constructed by similar means are also critically important.

Summary

Our understanding of the Hudson River Estuary is quite advanced as a result of many decades of dedicated research on the part of many scientists and engineers. However, as we seek to get the maximum use and benefit from the Hudson River Estuary, our knowledge and understanding of the system must increase dramatically to provide the kinds of insights and understanding needed to make informed and timely management decisions. Many management issues relate to contaminant and sedimentation in the river system, and these are important areas where additional research and understanding are needed. The Hudson River Estuary is an appropriate place for basic research along these lines to occur because the studies required for basic research are, in many cases, the same studies which are needed to determine the proper management responses.

The studies discussed here are intimately related to both biological studies and investigations of physical oceanography. Our understanding of stress on the river floor, for example, is critical to hydrodynamic modeling as well as to the susceptibility of bottom sediments to resuspension -- modeling distribution of suspended particles, fluxes and ultimate fate of particles in the water column. The geological studies could also be critical to the assessment of habitats and of the potential for ecological impacts due to local sources of pollution in the bottom sediments. The deposition of particles and early diagenesis play a role in the development of budgets for nutrients as well as particle reactive contaminants. Our awareness of the interaction of studies on the Hudson must be heightened.

Fundamentally important scientific studies can also be run in conjunction with ongoing agency activities. Such studies, which require access to facilities or equipment not generally available and which are based on sound scientific principles, can lead to a much better understanding of the Hudson River Estuary. One particularly good candidate for such a study is for the geochemical characterization of sewage outfalls. Many agency studies will occur within the next 10 years to characterize sewage in anticipation of the end of ocean dumping. Through the inclusion of thoughtful scientific studies as part of these massive management and agency programs, the geochemical "fingerprint" of each of the sewage outfalls can be studied in a fashion that is not possible today. The distribution of pollutants in the river and estuary can be compared to the "fingerprints" of the numerous sewage outfalls to determine the transport pathways for the different sources and the magnitude of those sources.

Because management issues are closely tied to many scientific issues in the river and estuary, close cooperation between managers and scientists is essential. In particular, much of our uncertainty in the river/estuarine system is how the system will respond to man's activities. Monitoring of the environment following specific changes to the river (such as dredging, platform construction, etc.) can help us to better understand how these activities impact the environment, and, thus, what modifications of these activities should occur in the future. Such monitoring should be done as part of a scientific study, not as a way to second guess difficult management issues.

Summary of Research Priorities Developed by the Scientific Working Groups

The Scientific Working Groups determined that research in the following areas is essential to developing a better understanding of the processes in the Hudson River Estuary and for providing information for better management of the system. The primary criterion used in selecting all research topics was the extent to which the research would contribute to the knowledge needed for effective management of the system and its living resources. The areas of research have been aggregated into two broad categories: (I) studies of the chemical and physical processes and properties of the system and their effects on the ecosystem and (II) studies of the factors controlling flora and fauna species diversity and abundance.

All of the topics listed below have been given a priority by the full Scientific Working Groups. While projects should be funded on their scientific merits -- on the basis of rigorous, external peer-reviewed proposals -- the program should be flexible enough to exploit opportunistic events such as major storms, floods, droughts, spills. It also should be flexible enough to capitalize on major funding from other sources for a specific class of studies. First order estimates were made of the levels of effort of researchers (in person-years) needed to make significant advances in our understanding of the particular process or problem. We define a significant advance in understanding as one which would lead to new knowledge that could contribute to improved management policies and practices. This may be quite different from the level of understanding and certainty desired by the research community. Successful pursuit of many of the proposed research areas will require support for substantial field and laboratory programs as well as for computing.

The topics indicated might serve as the basis for a request for proposals. We have neither attempted to identify specific questions and hypotheses nor to suggest specific research protocols. These activities -- problem selection and formulation and experimental design -- should be left to the scientists who will carry out the research. Well-crafted and detailed proposals provide the best, most reliable, basis for selecting investigators and projects for funding. The program announcement and request for proposals should be formulated to encourage multidisciplinary studies by teams of investigators which address natural groupings of research topics listed below.

I. **Studies of the chemical and physical processes and properties of the system and their effects on the ecosystem. *These studies should incorporate determinations of:***

	Topic	Effort (In Person Years)
A.	The effects of river flow variations and variations in water consumption on circulation, salinity intrusion, and hydrographic processes;	4
B.	The transient responses of the estuary to wind and river forcing as it relates to sediment transport and transport of dissolved and suspended materials;	5
C.	Interactions between the estuary and both the New York Bight and Long Island Sound and the resulting effects on the exchanges of dissolved and suspended materials and the discharge of floatables from the estuary;	2

D.	The effects of shoreline development projects on riverflow, sedimentation and habitat;	2
E.	The relationships between circulation and sewage and industrial effluent discharge strategies (high priority locally, but lower overall);	2
F.	The relationships between estuarine transport processes and larval fish distributions as this applies to fisheries management;	4
G.	The effects of channel modification by shoreline development, dredging and sedimentation on circulation, salinity intrusion and habitat;	2
H.	The effects of long-term sea level rise on tidal response and salinity intrusion;	1
I.	The temporal and spatial characteristics of the morphology of the river and estuary bed and its sediment to develop a "picture" of the river bottom;	4
J.	The geochemical cycles of natural and signatures which can be used as tracers to study river and estuary dynamics (special emphasis must be put on the fine particle suspended sediment system);	8

K.	How habitats change and how different animal communities affect sediment and pollutant cycling through integration of sediment and biological studies;	5
L.	The processes controlling sediment resuspension, rates of resuspension and where this occurs to understanding the roles and rates of resuspension in reintroducing pollutants to the environment;	4
M.	Past natural evolution and variations in the system, using the geological record, to predict responses and to understand past impacts from humans and pollutant and nutrient histories;	2
N.	Sources, speciation and current levels of toxicants associated with sediments and ambient waters.	6

II. **Studies of the factors controlling flora and fauna species diversity and abundance.** ***<u>These studies should incorporate a determination of:</u>***

Topic	**Effort (In Person Years)**
A. Community structure; especially the "key resource species" and other species vital to the functioning of the system;	2
B. Species' life histories and distributions with emphasis on understanding the factors which regulate population variability;	1
C. Interactions of commercial and recreational fisheries with natural population fluctuations to understand how these interactions may enhance or endanger important fish stocks;	1
D. Dynamics of nutrient and food cycling with emphasis on how these are related to activities and conditions in the surrounding watershed and in contiguous coastal waters;	3
E. The relative importance of primary production and organic matter input in supporting secondary production; the ecological efficiencies of detritus-based and algal-based food webs;	2

F. The effects of macrophytes on ecosystem structure and function; the current distribution and community structure of macrophytes and an assessment of how they have changed in response to human activities; 2

G. The potential for nuisance algal blooms and the factors that determine potential blooms; 1

H. The distribution of biomass, its community composition and its dependency on environmental factors; 1

I. Factors affecting population variability of important resource species, including those affecting spawning success, such as predatory and competitive links among organisms; 5

J. Habitat requirements of important species, at different life history stages, effects of habitat alteration and mitigation; 2

K. The effects of changes in land use and in the environmental quality of bays and tributaries on the structure and function of the ecosystem; 3

L. The impact of toxic stresses, including assessment of the processes for assimilation and retention by organisms and the lethal and sublethal effects on the organism, 4 population and ecosystem;

M. The abilities and limitations of aquatic microorganisms to detoxify contaminants (the main objective is to identify and evaluate those organisms that can metabolize some toxic substances to reduce, eliminate, or even enhance their toxicity);

N. Cumulative effects and interactions of multiple stresses and alterations (the objective is to establish a scientific framework for evaluating the cumulative effects of multiple stresses, including alterations on the ecosystem);

O. Interactions between non-consumptive uses (e.g. swimming, boating, etc.) of the estuary and ecosystem functioning;

P. Basic functioning of the tidal, fresh water and salt water portions of the estuary as subecosystems.

Summary and Recommendations

The Hudson River offers a number of advantages as a natural laboratory for study of estuarine systems and the development of research, monitoring and modeling. No other estuary in the United States serves so many people with such diverse and competing demands. Furthermore, the estuary's physical characteristics lend themselves more easily to scientific study than do most other major estuaries. Finally, as a natural system important to society, it requires our attention.

This report has outlined some of the information needs of managers and identified a number of priority areas for research. We hope it will serve as the basis for requests for proposals (RFPs) as well as the first stage in the development of a model program aimed at the information needed by management.

A model program would include research, monitoring and modeling as its essential elements. To be effective in responding to the information needs of resource managers, a sustained financial commitment will be required and mechanisms must be developed for open, frequent and continuing exchange of ideas among scientists, managers and the public. It will also require processes for the solicitation, peer review and selection of research proposals for funding that have the endorsement of the academic research community.

The following are the elements of a model program which this report recommends:

o Establish a system for keeping track of data that are collected by diverse research institutions and consulting firms. The system must provide for quality assurance and quality control and must ensure that an up-to-date directory is maintained which summarizes where the data are and how they can be obtained.

- Create a centralized data base and information center. This would fulfill the need which exists for reasonable access to all relevant data and information pertaining to the Hudson River system. The data base would be accessible to anyone and periodically updated. It would consist of a collection of all data sets known for the Hudson system which meet appropriate quality standards. This central repository would also be a library -- or at least a computerized card catalog -- containing information, all literature concerning the system, including books, scientific and news articles and technical reports. It could be placed at some "neutral" site such as the Hudson River Foundation, a university, or a public library.

  The Center should also provide a forum and mechanisms for synthesis and interpretation to convert data into information useful to managers and other user groups. The National Academy of Sciences' National Research Council recommends the establishment of a network of regional centers for this purpose (NRC 1990). The Hudson River estuary would make an ideal candidate for one of the first of such centers.

- Fund and implement a program of research, monitoring and modeling. These three components must be interactive, carefully coordinated, and conducted in parallel -- not in series. The research program should be directed at important general themes with freedom for investigators to formulate hypotheses and specify study designs while responding to management's needs.

- Design and implement an environmental monitoring program that would provide managers and researchers with long-term data on the variability of the system. The program may be useful in predicting future conditions in the river; may provide early warnings of incipient environmental problems at a stage when they can be dealt with more effectively and at lower cost than if left unattended to; and will provide modelers with data needed to formulate, adjust and calibrate their models. This project is meant to continue indefinitely, although it should evolve with new knowledge and new technological advances. Measurements made would include basic chemical and physical parameters, levels of toxic substances and numbers of individuals of important aquatic species. Appropriate sampling sites would be selected with advice of researchers and managers and would include those areas of particular interest such as critical habitats and areas influenced by combined sewer overflows or development projects. The methods of collection and analysis would be standardized. In addition, the new monitoring program would be coordinated with already existing monitoring programs to the extent possible and desirable. The program should be on the alert for and be responsive to new advances in sampling and analysis.

On a periodic basis, at least every two years, the data should be analyzed, summarized, interpreted and presented in a variety of formats to meet the needs of different user groups. The Chesapeake Bay Monitoring Program could serve as an example in this respect. Monitoring programs are not always perceived as being useful -- and indeed, many have not been -- and are often the first item to be cut out of a budget in a fiscal crisis. This program would require a firm commitment. Too often funds are made available for data collection, but not for analysis, synthesis and interpretation of the data and for transformation of data into information. As a general rule of thumb, support for the latter set of activities should be roughly equivalent to the funding to collect the data in the first place.

Initating a central data base, information clearinghouse and monitoring program would require a large, initial outlay of funds but would require a considerably smaller yearly budget to be maintained. This could be established while the rest of the projects recommended are developed and carried out.

- Establish a $100 million endowment to fund the above components on a sustained basis, drawing on the interest but not the principal for the annual budget. To establish such an endowment, a partnership should be created involving the states of New York and New Jersey, including the Sea Grant Institutes, state agencies such as Health and Environmental Conservation/Protection; federal agencies including the Environmental Protection Agency, the Fish and Wildlife Service, the Department of Commerce (NOAA), the Army Corps of Engineers, the Coast Guard and the National Science Foundation; private sector and academic research institutions such as the Institute of Ecosystem Studies, Lamont-Doherty Geological Observatory, the Marine Sciences Research Center, and the Institute of Marine and Coastal Science; utilities such as Consolidated Edison, Central Hudson, New York Power Authority, Orange and Rockland, and Niagra Mohawk; and private foundations such as the Hudson River Foundation.

References

Borman, J. and K. J. Klauda. 1988. Distribution of early life history stages of striped bass in the Hudson River estuary, 1974-1979. American Fisheries Society Monograph No. 4, pp. 53-58.

Drucker, P.F. 1988. The Coming of the New Organization. Harvard Business Review. 88(1):45-53.

Lueck, R. G. 1987. Microstructure measurements in a thermohaline staircase. Deep-Sea Research 34:1677-1688.

National Research Council. 1990. Managing Troubled Waters: The Role of Marine Environmental Monitoring. Committee on a Systems Approach of Marine Environmental Monitoring, Marine Board, Commission on Engineering and Technical Systems. National Research Council. National Academy Press, Washington, D.C.

Osborn, T. R. 1980. Estimates of the local rate of vertical diffusion from dissipation measurements. Journal of Physical Oceanography 10:83-89.

Peters, T.J. and R.H. Waterman, Jr. 1982. In Search of Excellence: Lessons from America's Best-Run Companies. Harper and Row, New York. .245 pp.

Prandle, D. 1981. Salinity intrusion in estuaries. Journal of Physical Oceanography 11:1311-1324.

1985. Classification of tidal response in estuaries from channel geometry. Geophysics Journal of the Royal Astronomical Society 80:209-221.

Prandle, D. and M. Rahman. 1980. Tidal response in estuaries. Journal of Physical Oceanography 10:1552-1573.

Pritchard, D.W. 1967. What is an estuary: physical viewpoint. In G.H. Lauff (Ed.), Estuaries, American Association for Advancement of Science, Washington, D.C., pp 3-5.

Schubel, J.R., D.W. Pritchard, K.A. Abood, T.C. Cosper, M.G. Gross, K, Hunkins, T.C. Malone, O.W. Terry and P.K. Weyl. 1982. Influences of the Hudson-Raritan estuary on the New York Bight. Marine Sciences Research Center Working Paper 9, Ref. 82-5, 82 pp.

Appendix A

Summary of a Workshop on the Hudson River Ecosystem Held at Institute of Ecosystem Studies 11-12 October 1988

Basic Ecosystems Processes in the Hudson Estuary

Jonathan J. Cole
Stuart Findlay
Michael L. Pace

Introduction

A meeting of scientists with active interests in basic research on the Hudson River ecosystem was held at the Institute of Ecosystem Studies on 11 and 12 October, 1988. Also attending this meeting were members of the Hudson River Foundation (HRF) and members of the New York State Department of Environmental Conservation (DEC). The major purpose of this meeting was to foster interchange of scientific data and ideas among researchers active in the Hudson. An additional purpose was to provide a forum in which those interested in management of the Hudson could interact with scientists, observe the scientific process first hand and be brought up to date on some of the current scientific concerns with the ecosystem. Because research on fisheries and toxicants in the Hudson usually dominates meetings on Hudson River research, we deliberately excluded these areas from our meeting. Rather, the invited participants were drawn from those with interests in basic research and ecosystem processes.

This meeting was an outgrowth of previous, smaller meetings at the Institute of Ecosystem Studies (IES) in which scientists from IES, Cornell and Lamont Doherty Geological Observatory (LDGO) informally discussed progress and problems with cooperative research on lower food web processes and nutrient cycling. This smaller group felt that a broader group of researchers would benefit from an expanded but similar meeting.

During the first day of the meeting, the activities were structured around a series of 20-minute presentations by scientists and subsequent discussions.

The second day was devoted to a full morning of an overview and synthesis by a three-member panel and to general discussion of this synthesis.

Scientific Presentations

Listed below are the scientific presentations in the order they were given at the meeting. The name of the presenter is underlined. Additionally, we have added a brief description of the information presented.

Freeman, Ward. "Location and movement of the freshwater/saltwater boundary in the Hudson River: A project overview." (U.S. Geological Survey, Albany, New York). Gave an overview of work in progress on models of physical circulation, which will be used to understand the effects of water removal by New York City on the intrusion of salt water upriver.

Bokuniewicz, Henry. "Particulate transport: Questions, answers and guesses." (State University of New York, Stony Brook, New York). Presented data that suggested that the Hudson estuary is a net sink for particles. The burial rate of particles in the estuary is larger than the supply from upstream, suggesting that the estuary must also be a sink for oceanic-derived particles.

Fruci, J. and R.W. Howarth. "Modelling nutrient inputs to the tidal freshwater portion of the Hudson River Estuary." (Section of Ecology and Systematics, Cornell University, Ithaca, New York). Summarized work on estimating the input of organic carbon to the system from sewage, and from watersheds of differing land use configurations. Indicated that contribution from urban and suburban watersheds is poorly characterized.

Fox, L. "Model for the inorganic control of phosphate in river waters." (Harvard University, Cambridge, MA). Presented a geochemical model for control of phosphate by equilibration with mineral iron oxides in the water column of rivers. Included data from several river systems.

Ammerman, J. "Microbial cycling of organic phosphates." (Lamont Doherty Geological Observatory) Showed generalized biochemical scheme for bacterial utilization of organic phosphorous compounds and presented data on this process along whole-river transects in the Hudson. Despite extremely high phosphate concentrations in the river, microbes are utilizing organic-P compounds and producing specific enzymes to accomplish this.

Gilmour, C. and D. Capone. "Microbial metabolism in the sediments of the lower Hudson." (Benedict Estuarine Laboratory, Smithsonian Institution, Washington, D.C. and Chesapeake Biological Laboratory, Univeristy of Maryland) Presented data on anaerobic sediment metabolism (methanogenesis and sulfate reduction) in lower Hudson. Rates are both extremely high and extremely variable. Methanogenesis and sulfate reduction appear to co-occur.

Cole, J.J., N.F. Caraco and B. Peierls. "Primary production and its regulation in the mid-Hudson." (Institute of Ecosystem Studies, Millbrook, New York). Presented overview and conceptual diagram guiding research on "lower food web" components. Gave seasonal and longitudinal patterns of primary production, preliminary estimates of river-wide primary production and compared this to other rivers and estuaries. While algal biomass is maintained at high levels in the Hudson, algal growth rates are slow.

Howarth R.W., R. Garritt, R. Marino and J. Fruci. "Oxygen and carbon metabolism for the tidal freshwater portion of the Hudson Estuary." (Section of Ecology and Systematics, Cornell University, Ithaca, New York). Showed results of whole system metabolism that appears to exceed the total of measured carbon input, suggesting that some input has been grossly underestimated. This was a preliminary attempt at synthesizing some of the lower food web results.

Findlay, S. "Bacterial production in the tidal freshwater Hudson." (Institute of Ecosystem Studies, Millbrook, New York). Showed preliminary data on pelagic bacterial production and respiration. Bacterial carbon demand by photoplankton in the Hudson can exceed supply. Compared bacterial production in Hudson to that in other systems and indicated that bacterial production in Hudson is much greater than expected based on phytoplankton production.

Capriulo, G. "Use of single cell microscopic quantitative fluorescence to measure ingestion rates of ciliates." (State University of New York, Purchase, New York). Presented a method whereby algal cells consumed by ciliates can be quantified within the ciliate. The method may be used to determine ciliate grazing rates, from *in situ* populations, without relying on incubations.

Pace, M. "Zooplankton abundance and dynamics." (Institute of Ecosystem Studies, Millbrook, New York). Showed seasonal and longitudinal variations in zooplankton populations in the Hudson. Data indicate that zooplankton biomass is far lower than expected given the amount of algal biomass in the Hudson. The high suspended load in the river may inhibit zooplankton feeding.

Decker, C. and J.R. Schubel. "Management needs." (State University of New York, Stony Brook, New York). Presented results of a series of interviews in which managers involved with the Hudson were asked about their management problems and how scientists could collaborate with management. A discussion followed this talk on the role of science in environmental management.

Panel Discussion

The panel consisted of Dr. Gene E. Likens, Director of the Institute of Ecosystem Studies; Dr. Robert W. Howarth, Associate Professor, Section of Ecology and Systematics, Cornell University; and Dr. Dennis Suszkowski, Science Director of the Hudson River Foundation, New York City, New York. Each member of the panel was asked to speak for up to 15 minutes to give an overview of his impressions of the program or needs for the future.

Following each member's remarks was an opportunity for questions or comments from the panel. Following the entire panel presentation was a two-hour open forum discussion with the participation of both the audience and the panel. Reported below is a summary of the panel presentations.

<u>Robert W. Howarth</u>

Howarth pointed out that the quality of the scientific presentations was quite high and that there is a growing understanding of basic ecosystem processes in the Hudson, especially in the tidal freshwater region. The scientific knowledge has increased dramatically during the past five years, and is a credit to the Hudson River Foundation for aggressively funding some basic science. Comparatively less is known about the lower Hudson. The focus on the mid-Hudson region is due to several factors:

- The physical components are simpler.

- The Poughkeepsie-Kingston region is close to IES.

- The mid region is less man-perturbed than the lower estuary.

However, both HRF and DEC would welcome more information about the lower estuary and should think of ways to encourage science there. To have scientists work effectively in the lower estuary, there will need to be greater involvement of physical oceanographers, and HRF should realize that the cost of research would therefore be greater and require more complex facilities. Howarth suggested that HRF consider longer and larger grants to encourage this work.

In terms of what we learned scientifically during the meeting, Howarth pointed to the following:

- Phytoplankton primary production is low.

- Zooplankton biomass and production are low.

- System respiration exceeds system production indicating that the system is heterotrophic.

- Heterotrophy is driven by allochthonous C sources and in part by allochthonous sediment load, which maintains the high light extinction that keeps primary production low.

- Less is known about macrophytes than phytoplankton.

Howarth suggested that there may be two food webs in the river: a "normal" pelagic food web leading from phytoplankton to zooplankton and then fish, and a second "dead end" food web in which allochthonous detritus is processed by bacteria.

In terms of management aspects, Howarth was gratified that the concerns of managers (summarized in Decker's presentation) overlapped with those of scientists. However, since the Hudson ecosystem is so poorly understood, we need to focus on a few important concerns which are deemed scientifically tractable. Scientific monitoring would be a good idea only if it addressed some focused questions. Managers need a sound conceptual diagram of their goals. The conceptual diagram used by scientists may not suit managers, but managers need to develop a suitable conceptual framework of their own.

<u>Gene E. Likens</u>

Likens began his remarks by complimenting the success of the meetings in terms of the quality of the science and presentations. He pointed out that the talks had been at least as good as, and possibly better than, a comparable set of presentations at a national meeting like the American Society of Limnology and Oceanography. Further, the small format of the meeting allowed for serious scientific exchange.

Likens said that there is a clear need for management to have a scientific understanding of the Hudson River ecosystem. He said that managers need to understand basic processes and their controls if they are to manage, for example, the construction of docks or piers that will cause shading and other effects and need a conceptual model of how the system works. The conceptual model presented by the "lower food web" group, Likens said, served this purpose well. Such a conceptual model, especially as it begins to be fleshed out with preliminary numbers, helps to fit the pieces together and can be used for validation and quality control of the data. For example, Howarth, summarizing some of the preliminary work from the Cornell and IES groups, showed that respiration exceeds the input of C to the river. This means that either the respiration estimate is too high, or that some input has been underestimated. Likens also criticized the conceptual model in that it ignored the input of dissolved organic carbon (DOC) in precipitation falling directly on the river. This atmospheric input could increase the loading of organic C to the system by about 10g $C \cdot m^{-2} \cdot y^{-1}$, or roughly 10% of the estimate by Cole et al. of planktonic primary production. Likens pointed out that rainfall DOC consists largely of formic and acetic acids, readily metabolizable compounds, which could be fueling a portion of the bacterial production measured by Findlay and Pace.

Likens questioned who will be doing the major synthesis of ecological information on the Hudson River. Will some individual or group be preparing a book to gather together the information and make sense of it? He further pointed out that the boundaries of the Hudson River ecosystem need to be clearly defined. Does it include the entire watershed and airshed of the river or does it not?

What is limiting to research on the Hudson, Likens said, is not only funding for research but the stability of that funding. Longer funding cycles (longer than the one year HRF normally establishes) not only allow more complex questions to be tackled, but also help maintain research teams. Such teams consisting of research assistants and post-doctoral associates in "soft money" positions are difficult to assemble in the first place and evaporate the instant a gap in the funding occurs. Also, longer funding cycles are needed to make sure that environmental extremes in climate are included in the measurement period. Do we know, for example, that zooplankton production is low in the Hudson on the basis of a single year of measurement during a drought year? One needs valid, long-term averages in order to compare the Hudson to other systems.

All of the components in the cycle of monitoring/data storage/management need scientific justification. Likens said that the data must be used to publish scientific articles. Data storage, even in a sophisticated computer retrieval system, is of no use in itself and could potentially waste an enormous amount of money that could be going to research.

Dennis Suszkowski

Suszkowski began his remarks by agreeing with most of Howarth's and Likens' observations but pointed out that he came to this meeting with a different perspective, that of a funding source. He was pleased that HRF was acknowledged in most of the talks and especially pleased that some HRF-funded groups were using their separate funding in joint efforts, especially in the mid-Hudson. He augmented Howarth's observation that the credit for the growth in knowledge of the Hudson belongs to HRF by saying that most of the credit should go to the scientists. Suszkowski wondered what HRF could do to get scientists to commit major parts of their time and effort, and possibly whole careers, to research on the Hudson. As a start in this direction, HRF has introduced two-year funding cycles.

Suszkowski said he also came with the perspective of management for the Hudson River, especially on the question of how to link science with management. Many of the current management problems in the Hudson River (sewage, PCB's, fisheries) are clearly of interest to scientists. Solution of these problems by managers will require input from the scientific community. However, there are problems here because the needs of scientists and managers do not always correspond. Worse, scientists and managers often speak different "languages" and do not understand each other's jargon. This language problem inhibits productive dialogue.

Suszkowski worried about the problem of how to bring scientists and managers into a useful dialogue that would benefit the Hudson ecosystem. One effort to do this is underway. A meeting, jointly sponsored by the New York State Department of Environmental Conservation and the Hudson River Foundation is being held on October 20 and 21 to explore the interactions between science and management for the Hudson. This meeting will lead to a 15-year management plan for the river. An important first step in this effort will be the construction of a conceptual framework. This framework will be developed by a group of scientists assembled under the direction of Dr. Jerry Schubel (SUNY, Stony Brook). Further, the theme of management and science will be the focus of the Hudson River Foundation Annual Symposium on November 7.

Group Discussion

A discussion open to the entire audience and panel followed the panel discussion. A large number of items were mentioned, a few of these repeatedly. We mention here only those items that came up several times during the discussion.

1. Red-yellow-green light system. Likens explained that the United States Forest Service had adopted a management strategy in which input from scientists could cause a project to stop completely (red light); go ahead without further review (green light); or require more information before a decision could be made (yellow light). While this system seems simple, it has been extremely useful and could possibly be applied to the Hudson.

2. Readings in Hudson science. Capriullo suggested that a publication be put together on the Hudson River ecosystem that is made up of existing publications and reports on the system, a sort of collected works. If data on the Hudson were unavailable to cover a particular component, a publication on a similar estuarine/riverine system could be included.

3. Pace suggested that HRF actively encourage scientists working on the Hudson to compare their results to other similar ecosystems. We need to know how the Hudson behaves in comparison to other systems.

Summary of Key Research Points

1. The Hudson River system is heterotrophic, in that metabolism is supported by outside sources of reduced Carbon.

2. The inputs of Carbon from suburban/urban areas are large.

3. Other sources of Carbon must be identified and quantified in order to balance demand for Carbon.

4. Information is needed on amounts and processing rates of large woody debris (logs, etc.) that enter the Hudson.

5. Atmospheric input of Carbon may be as great as 10% of phytoplankton primary production.

6. Planktonic primary production is low compared to many other estuaries.

7. There may be two distinct food webs in the Hudson, one based on algal production, leading to zooplankton and fish, and another based on allochthonous inputs of detritus from the watershed, which is essentially a dead end, culminating in microorganisms (bacteria and fungi).

Appendix B

Summary of Interviews of Some Individuals With Major Management Responsibilities for the Hudson River Estuarine System and Its Living Resources

List of Interviewees

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: Thomas Sperry (Wildlife and Fisheries Specialist)
United States Fish and Wildlife Service
Interviewer: Cynthia Decker

There are a number of goals which the Thomas Sperry would like to see accomplished by the Hudson River Estuary Management Plan, but a necessary first step in the plan should be the organization of a centralized data base. This should be set up to collect, maintain and analyze data about the system so that they would be available to everyone. Once current data have been collected, gaps in information will be identified and it may become obvious how next to proceed in filling in those gaps.

There are several of these gaps which Mr. Sperry has already identified and would like to see addressed by the plan. The first involves contaminants or toxicants in the river. The first step in the resolution of this issue is the identification and location of contaminants. Where do they come from (in the system as a whole)? How do they get in (land-, air- or water-based; point or non-point?) How can these sources be controlled once they have been identified?

The second step involves research on contamination of the aquatic organisms. Population studies of finfish and shellfish, including measurements of mortality (at all stages of the life cycle) and fecundity are important. The physiology, histology and pathology of these organisms are important as well, so that the actual effect of the toxicants can be determined. In addition, studies on bioaccumulation of these substances from bacteria and algae and up the food web into seabirds should be investigated.

Research on the sources and effects of toxicants can be useful only if this information is translated into effective regulations. For example, one major source of contaminants has already been identified -- combined sewage overflows. In addition to these, which are not controlled at all, the sewage treatment plants themselves are at times in violation of the standards and regulations imposed by the federal and state governments. Little enforcement of the regulations and, therefore, even less punishment of violators, coupled with the ability to be granted waivers for being in violation, results in a management system that provides no incentive for the plant to be in regulation.

Regulatory and enforcement policies, as well as basic pollution research cannot be separated in the formation of this plan. For example, a study on dioxins in lobsters demonstrate that very high levels of these substances are detectable in the hepatopancreas of the crustacean. This has led to the conclusion that basically no dioxins in the water is good. New Jersey has passed legislation regulating dioxin levels but New York has not. Perhaps a cooperative effort between the states is needed.

Another issue with which the management plan should be concerned is habitat modification. An update of the existing habitat maps including the National Wetlands Inventory should be done. The extent of usage of various habitats by all species at all life stages should be undertaken. The effects of dredging, sedimentation and other drastic actions on a habitat and the species therein could be investigated.

A final concern of the management plan should be the setting of ultimate goals for the Hudson River Estuary. If a realistic vision of how the river should be after it is cleaned up is not developed, it could lead to over-regulation. The river cannot be returned to the same condition it enjoyed before the industrial revolution, but the "quality of life" can be improved, and the river can be an even more valuable resource if it is taken care of.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: John Tavolaro (Chief, Water Quality Compliance Branch)
Army Corps of Engineers
Interviewer: Cynthia Decker

Mr. Tavalaro felt that for his purposes the issues which should be addressed by a management plan of the Hudson River Estuary are fairly clear cut; however, the means by which they should be addressed are not. When projects or permit applications are given to the Corps of Engineers the major environmental questions they have to face is "What is its impact on the biological resources of the estuary?" Mr. Tavolaro focused on dredging in particular to illustrate this fact.

A major responsibility of the Corps of Engineers is the dredging of waterways to keep them open for navigational purposes. This activity is sometimes limited by the so-called "dredging windows." These are periods of time during the year when states allow dredging because the impact on the system is thought to be minimal. The basis for the timing of the dredging windows, however, appears to be somewhat inconsistent. The resources to be protected are not agreed upon nor are the means to protect them. In addition, the actual effect of dredging on organisms and habitats has not been determined.

The potential results of dredging include turbidity, sedimentation (resulting from the former) and resuspension of contaminants. Although it has been shown that these factors can affect aquatic organisms and their habitats, a direct connection between dredging activities and harm to the biota has yet to be demonstrated. More information is required on particular species and their life histories in order to determine what organisms have the most potential sensitivity to dredging effects.

Studies have been done which demonstrate the effect of turbidity, sedimentation and contaminants on organisms. It is most important, however, to obtain direct evidence of dredging effects on the species of interest. At present, dredging is limited to the winter months when it is colder, more expensive and, at least in the case of ocean dumping, more dangerous. It is possible that if the results of the above-mentioned studies warrant it, the timing of dredging windows may require change, or the restrictions in general may be eased.

In addition to the biological resources, most agencies do not know what the effect of their activities is on the physical and chemical environment. These impacts need to be elucidated as well. More broadly stated, the Hudson River Estuary Management Plan should concentrate not only on the resources in the river but also on the activities of man that take place in and around the river and should consider how all of these can comfortably work together for the best use of the river by all concerned.

One final recommendation from this interview was for the establishment some sort of central information bureau that would contain all existing data on the Hudson River Estuary as well as all literature, including news articles. It was suggested that some state agency, probably the Department of Environmental Conservation, since it will be administering the management plan, should be the repository for this data base. In this way, gaps in information can be identified and acted upon by the state as soon as possible.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: Joseph Seebode (Chief, Regulatory Functions Program)

Army Corps of Engineers

Interviewer: Cynthia Decker

Mr. Seebode felt that the most important thing that he would like to see come out of the Management Plan for his purposes would be an effort to involve the people of the towns along the river and its tributaries in making decisions that would regulate the usage of their part of the system. Because the Army Corps of Engineers, as well as other agencies, spend a significant fraction of their time and money in the permitting and enforcement processes, it would greatly ease the pressure if some of the responsibility were shifted to the towns. Although state or federal legislation could force towns to do some of their own regulating by requiring them, for example, to have waterfront revitalization plans, some type of public education program would be better. A flow of information among the public, the regulatory agencies and the scientific community could lead to a better understanding by the townspeople of the Hudson River system, and thus, foster a desire to perserve and regulate its use. This would transfer some of that regulatory burden to self-regulation by the people who have an actual stake in living on or near the river.

Another effort which Mr. Seebode would like to have organized by the Hudson River Management Plan is the formation of a comprehensive data base. This would include an inventory of endangered aquatic species, commerically-important species, habitats, contaminants, water quality parameters such as dissolved oxygen and nutrients and historic properties along the river. Already existing data would be collected, and where gaps, inconsistencies or noncomparable data in the inventory exist, the plan would provide for data collection to remedy these problems. This information would not just be in the form of a numbers collection but would also take the form of detailed maps done by river mile or township. This information is vital to the Corps of Engineers in assessing areas for selection as part of the Wild and Scenic Rivers system and as Historic Properties.

Summary of Interview Conducted for the
Hudson River Estuary Project

Interviewees: Richard Caspe (Director, Water Management Division)
Mario Del Vicario (Chief, Marine and Wetlands Protection Branch)
Environmental Protection Agency
Interviewer: Cynthia Decker

The EPA representatives identified a number of "political" concerns as well as environmental issues, which the proposed Management Plan must consider if it is to be successful. Environmental questions start with (1) the identification and location of critical habitats, especially those required by finfish and shellfish in the estuary; (2) gaps in the knowledge about life histories of aquatic species and their interactions with each other; (3) the sources of loading (pollutants, excessive nutrients) in the estuary and how to eliminate them (solve the worst first and the rest as money becomes available); (4) and the identification of impairment of such uses of the estuary as swimming and fishing and ways to restore these uses.

Basically, decisions will have to be made about what problem should be targeted first. Additionally, it is important that all pertinent information (both existing and developing) about the river be assembled and contained in one place. This information should be put into appropriate computer data systems that would be accessible and easy for everyone to use. Analyses of these data can then be done to identify the critical gaps; perhaps data from similar studies that used different methodologies could be made compatible so that they can be used to support management decisions.

It is the firm conviction of the EPA, however, that there are two other issues which must be considered before this plan can be implemented successfully. First, it is imperative that all studies in the estuary are well coordinated. This includes the Hudson River Estuary Management Plan, the New York-New Jersey Harbor Estuary Study, the New York Bight Restoration Plan and any other studies that are being conducted in the estuary. This would help reduce any duplication of monitoring efforts, enhance the focus of all these studies and permit the managers of all these programs to effectively manage the estuary.

The second non-research issue with which the interviewees were concerned was that of public education. They believe that any management program will have greatly improved chances of success if the people who will be most affected by that program are well-informed and are consulted about the decisions being made. Receiving funding from the state, getting favorable legislation passed and wasting less time and money on enforcement are advantages to a management plan, all of which can be gained by having a constituency that understands and supports the efforts to solve environmental problems. Furthermore, if the public is aware of good land- and water-use practices, then the local governments might begin regulating land use, sewage and contaminant levels easing a great deal of the regulatory burden of the state and federal government. Therefore, public education should also be a vital part of this management plan.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewees: Christopher Zeppie (Supervisor, Government Liaison)
Bernice Malione (Government Liaison)
Susan Kuenstner (Assistant, Government Liaison)
David Berkovits (Supervisor, Transportation Planning)
Lingard Knutson (Transportation Planner)
Joseph Birgeles (Supervisor, Harbor Planning)
Port Authority of New York and New Jersey
Interviewer: Cynthia Decker

The information which would be most useful to representatives from the New York-New Jersey Port Authority in making decisions about their section of the Hudson River Estuary includes a variety of baseline and practical data. The concensus among the six people interviewed was that the most important issue that should be addressed by the 15-year management plan for the Hudson River Estuary is the identification and mitigation of both point and non-point sources of pollution. This would include input such as industrial outflow, agricultural runoff and that containing toxicants such as PCBs. The most significant source, in their opinion, however, is combined sewage overflows. It was the opinion of those interviewed that the pollution in the New York-New Jersey Harbor could be greatly reduced if untreated overflow occurring during the flooding of storm drains were eliminated. In addition, the Interstate Sanitation Commission has recommended to the NY/NJ congressional delegations that tertiary treatment systems are needed for treatment plants, an assessment with which the interviewees agreed.

The Port Authority is involved in a number of other issues and projects. All of these concern the harbor, but should be of equal interest farther upstream. The first of these involves the identification of all current and proposed development along the waterfront. This has been done for the New Jersey side of the Hudson and should be done for the estuarine shoreline of New York that is impacted by waterfront development to identify different pollution sources and to determine the amount of waterfront space to remain available in any given area.

A second project is the Marine Support Services Study sponsored by the Port Authority, the City of New York and the New Jersey Department of Environmental Protection. This study has identified businesses dependent on waterfront locations, which are important to the function of the Harbor. Examples would include managers to identify the best locations for these businesses and, if necessary, to preserve and zone waterfront property for that purpose. In addition to the marine support services, other location-dependent uses of waterfront property have been identified such as the Downtown Heliport and Pier 34, which is the emergency access for the Holland Tunnel.

A third proposed project about which there was a great deal of concern is the PCB reclamation project which will involve the dredging of PCB-containing sediments upriver. The City of New York has received assurances from the state that there will be adequate protection against resuspended PCB-laden particles entering in the harbor. The interviewees thought perhaps that the possibility of this happening should be investigated more thoroughly first.

The people interviewed were also concerned with issues involving basic ecological research. An inventory and assessment of the economic value of commercially-important aquatic species in the river was recommended. Population studies and water quality monitoring should be included in the study.

In addition, the effects of various sampling programs on fish populations might be investigated. The effect of platforms and piers on aquatic communities would also be very useful. Direct effects (habitat destruction and shading) and indirect effects (sedimentation, low dissolved oxygen and changes in light intensity) should be assessed, and questions about location, configuration and building materials should be resolved.

Other points which were raised included the lack of a comprehensive data base with cross referencing for all available Hudson River Estuary information. Such a data base needs to be accessible and periodically updated. The necessity for seasonal restrictions on dredging was another issue. Scientific data are necessary to determine if a such need exists. The plan should encompass more than the next 15 years and should aim towards the development of an "early warning system" that could identify impending environmental crises.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: Alan Mytelka (Director)
Interstate Sanitation Commission
Interviewer: Cynthia Decker

There are many useful results that could arise from a successful Management Plan for the Hudson River Estuary. Dr. Mytelka felt, however, that some policy decisions must be made at the state level first to ensure that such a plan will be carried out successfully. There must be a very strong commitment to the plan by the state, which will carry it through administrative turnovers. This commitment must be made clear to the public. Within the Department of Environmental Conservation, authority over the Hudson River is fragmented; one person should be put in sole charge of all Hudson River programs as well as the management plan. In addition, decisions arising out of the plan should be strictly enforced by the DEC with no exceptions granted to the regulations.

In general, an outline for the Management Plan could be as follows: first, the cooperation of New Jersey and its Department of Environmental Protection should be secured. If the Hudson is cleaned up in the New York portion, it will mean little if New Jersey has not removed its sources of contamination. Second, find out about the system. This could involve the collection of extant data, inventories of habitats, fisheries, etc. and long-term biogeochemical monitoring. The commitment to these must not be subject to legislative and budgetary whims. At the same time as the second step, future goals must be set.

Dr. Mytelka feels that the general goal of "cleaning up the river" is the most important one for the state. The river will never again be pristine, but reasonable water quality levels can be set. The major source polluting the river is combined sewage overflows (CSOs). Pollutants in the effluent from the combined sewers have never been characterized or quantified by sampling, so that should be the first step in dealing with these sources. Excess nutrients in the water (as measured by biological oxygen demand is considered by some to be the greatest problem and many of these compounds enter the river via CSOs, as well as do many toxins such as PCBs. Therefore, "the most impact for the money" would come through sampling and then eliminating the effects of these combined sewage outfalls.

Summary of Interview Conducted for the Hudson River Project

Interviewee: Frances Dunwell (Special Assistant to the Commissioner for the Hudson River Valley).
Department of Environmental Conservation
Interviewer: Cynthia Decker

As a representative of the New York Department of Environmental Conservation, Fran Dunwell felt that the first step in the formation of a research plan is to bring together the various disciplines in a unified approach to the plan. An ecosystem approach would include relating all components (people's activities as well) to their ability to be managed.

Species interactions should be studied and must involve not just those organisms which are commercially important, but all those which may be important ecologically, from primary producers on up the food chain. Research involving the effects of chemical, physical and geological parameters on the system should also be undertaken.

The establishment of a long-term environmental monitoring program would ultimately provide an extensive data base and could be used to reconstruct existing problems or predict future ones. However, such a program would have to be targeted to answering specific research questions in order to be meaningful. Agencies which are already doing a certain amount of monitoring could contribute to this effort.

A funding strategy should be developed to foster the cooperative participation of government; foundations, such as the Hudson River Foundation; and research institutions, such as the State University of New York, Cornell University, The Institute of Ecosystem Studies, Lamont-Doherty, etc.

A number of management issues were identified to which research could contribute for more informal decision-making. Water supply and water withdrawals raise concerns relating to biological impacts of salt-front movement. The physical and biological impacts of piers and platforms are poorly understood. Land development in the watershed is producing impacts on the carbon cycle and is introducing a large contribution of home pesticides to the Hudson and its tributaries. These impacts need to be studied and communicated. Management of the Hudson's commercial fisheries would benefit from research into stock sizes and population estimates, as well as the relative contribution of Hudson River stocks to total coastal resources. Predator-prey relationships among species of fish and other wildlife need to be better understood as well as the relationships among population sizes of commercially valuable species and other species. Links among vegetation populations, fish populations and species life cycles need to be better established. The effects of contaminants on organisms in the estuary is not well understood. Compounds other than PCBs should be more extensively studied. Finally, the methods and feasibility of habitat mitigation and restoration should be investigated.

There are a number of other important issues which should be addressed by the management plan, but they were not discussed specifically at this interview. Rather, the interviewer was directed to the Hudson River "Strategy" document, the section on protection and rehabilitation in particular, for a summary of these.

Comments Submitted for the Hudson River Estuary Project

Interviewee: Daniel Barolo (Director, Division of Water)
New York State Department of Environmental Conservation

Question:
What kind of a role should public education and information play?

Answer:
Public information education and involvement play an integral role in the development of the Division of Water's program actions and decisions. Over the past decade, two-way communication with and involvement of affected groups in decision making have resulted in better decisions and more lasting commitments to implementation. Sometimes the benefit is seen in greater public cooperation with the Deparment's programs. Other times, as a result of public participation, a community or constituency develops a sense of ownership and conducts its own environmental programs. In many instances, better decisions are reached as a result of considering the perspectives, values and knowledge of various sectors of the public, and they are more likely to be carried out. This also stimulates other parties to become involved on their own to preserve and protect the state's water resources. Certainly the days of including public participation simply because of federal requirements are past; it has proven its effectiveness and the Division will continue to work with the public in both the planning and implementation phases to deliver water quality programs.

Most of the Division's decisions require both technical and value judgments. Public review of technical factors helps ensure technically sound decisions. Public participation is even more significant in making value judgments: How sure should we be? How much risk is acceptable? How will this decision affect the community? What will the economic or social impacts be? Considering the views of affected publics in making value judgments leads to more workable and acceptable decisions.

The Division of Water seeks public participation in a wide range of activities including development of rules and regulations; formulation of water program policies; initiation of new programs; changes in program direction; permitting processes; and development of support to attain water quality goals.

The Division recognizes that there are many different publics. Division of Water considers all individuals and organizations who are affected, may be affected or believe they could be affected by a decision or program to be "the public" for that program, as well as anyone whose support is needed to achieve water quality goals. The regulated community, regulators, local governments, state and federal decision-makers, industrial, commercial, agricultural, environmental and public interests, individual citizens suffering from contaminated water and taxpayers -- all are examples of publics. Not all publics need to be fully involved in every program. The level, frequency and purpose of public participation vary from project to project, according to the needs of the program and the interests of the publics. Ideals of teamwork and collaboration are balanced with resource and timing constraints of both citizens and governments.

The participatory process, while called by different names at different times, is intended to be a meaningful exchange of ideas, information, concerns or preferences related to decisions about water. To improve delivery of the public participation programs, the Division of Water places special emphasis on the management aspects. Communication activities are professional, planned and tightly integrated into decision-making. An annual planning process identifies communication needs for each bureau. Citizen participation and technical writing staff are then assigned to the projects with the greatest communication need and individual communication plans are developed for these projects or programs. The Division of Water seeks to improve the effectiveness of all levels of public participation, from increased awareness to sustained involvement.

Question:
Do you feel New Jersey should play a substantial role in management of the estuary?

Answer:
Yes. There are existing mechanisms through which New Jeresy can have an active role. New York encourages interstate cooperation as necessary and appropriate when a plan or project is under development in New York State for an area affecting or affected by waters of one or more other states and in the converse situation. New York State has and will continue to cooperate with such other states in the analyses and planning pertinent to such areas.

New York State participates in the following interstate compacts, commissions, and associations with New Jersey:

- Association of State and Interstate Water Pollution Control Administrators.
- Delaware River Basin Commission (compact).
- Interstate Conference on Water Problems.
- Interstate Sanitation Commission (compact).
- New York/New Jersey Harbor Estuary Program.
- Hudson River Estuary Management Program.

Additionally, local governments within the State are authorized and encouraged to establish and carry out contractual and other arrangements when appropriate, with other local governments in New York State and other states for cooperation in the development and implementation of plans. New York State's current laws allow its municipalities to cooperate with each other and with municipalities in other states for the purpose of developing intermunicipal sewage facilities.

Question:
Is there any information on programs that you would like to see included in the HREMP to help better make decisions that affect the estuary?

Answer:
There are several informational and program needs that would enhance program development and assist managers in program delivery.

Hazardous Substances

About 55,000 chemicals are known to be used commercially to a significant extent. Hazardous substances are stored in almost every community in New York with an estimated 10,000 chemical storage tanks (excluding petroleum products) spread across the state for commercial and industrial applications. While there are almost as many opinions as to what is hazardous as there are substances, we generally mean substances that are dangerous to handle and/or are highly and acutely toxic to humans and animals. The widespread storage, transportation, and use of these chemicals provides the opportunity for uncontrolled releases into the environment. The chemical, physical and toxic properties of these compounds are as varied and diverse as are their effects on the environment. Some toxics have persisted in the environment long after the activity that resulted in an insult has ceased. Some, while they remain in the environment, become unavailable for uptake into the ecosystem. We need to continue to identify the "toxicants of concern" (those which do the greatest harm to the ecosystem) and, when enough information is available, develop standards to protect human health, aquatic life, and other living resources.

Additionally, there is a need to fill the program gap that exists on the control of these substances, which are not wastes, through increased attention to good industrial housekeeping, spill prevention, and the institution of industrial and commercial best management practices for materials handling and clean-up.

PCBs in the Hudson River
In 1976, the State discovered that PCBs from General Electric Company plants in Fort Edward and Hudson Falls had entered the river over along period of years. It is estimated that there is a total of 51,000 pounds in 20

PCB "hot spots" along a five-mile section of the river. The continued presence of these pollutants in the river degrades the fishery and quality of the entire river. Contamination of fish that feed on other aquatic life in direct contact with PCB-contaminated sediments has forced the closing or restriction of several important fisheries. This PCB presence in sediments also poses a potential hindrance to navigational dredging because of the problem of sediment disposal.

We need to focus on PCBs as the prime toxic problem in the Hudson and answer these questions:

- How soon will an equilibrium in the lower river be reached from upper river sources? Will this be too long to be acceptable?

- What alternative means of management do we have if dredging and encapsulation are not acceptable?

Nonpoint Sources

The most significant categories of nonpoint source activities in the State are agricultural and urban runoff. Atmospheric deposition may also be significant since the central Catskills and the Hudson Highlands have been designated as major sensitive receptor sites. The impacts of existing agricultural or urban land uses are typically manifesting themselves as identifiable long-term problems in a water body (e.g. cultural eutrophication of a lake or reservoir) which must be prevented or corrected by long-term efforts to install proper management practices on the landscape.

The problems associated with urban runoff are less widespread because they occur only in waters draining major urban centers, but have a more severe affect on local waters. Other types of nonpoint sources are usually more transitory by character (e.g. chemical spills, construction sites) but nevertheless, do occur in many locations with varying degrees of impact.

A comprehensive mass balance would put to rest arguments of the relative contributions of toxics from point and nonpoint sources and point the direction to the best use of resources.

Data Management

A wealth of data has and continues to be generated for use in program management. This data can be broadly classified in two categories. First, for modeling and support for technical decisions, and second, as support for management of various program responsibilities. In addition to data within DEC, other agencies generate data for their program management needs. To effectively use these large systems of data, there needs to be an improved ability to access and manage it. As availability of computer hardward improves, more agency staff are developing data systems to meet specific needs. With these developments, there is a growing need to integrate the data on a statewide basis without compromising the integrity of the individual agency data bases. Mechanisms providing quality assurance and quality control of the data are crucial. Additionally, interagency access or availability of data would broaden the perspective of management decisions.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: Gordon Colvin (Director, Division of Marine Resources)
New York State Department of Environmental Conservation
Interviewer: Cynthia Decker

Mr. Colvin felt that a management plan needs to include strategies for collecting information that is essential to accomplish the plan's long-term goals. There are several topics involving the Hudson River Estuary about which Mr. Colvin would most like to have information collected.

It is most important, he feels, to understand the relations between the availability of different habitats and ability of the river to maintain its resources in diversity and abundance. We need to know what and how activities change or cause loss of habitat so that we can minimize this degradation. Second, it is important to elucidate the relations between the chemical and physical conditions in the estuary and the productivity and diversity of all life history stages of estuarine, freshwater and anadromous fishes. A third concern is the effects of toxicants on the whole trophic web, not just on humans as the top-level consumer. The fourth topic which Mr. Colvin would like to see addressed is the interrelationship among nutrient input and primary producers in the system including phytoplankton communities and macrophytes. They form a large part of the base of the food web and are unmonitored and virtually ignored.

A final consideration which should be in the plan is an examination of very long-term trends in the system and how they might affect it in the future. These would include trends like a rise in global temperature and the concurrent rise in the level of the world ocean. What effects will this have on the Hudson River Estuary and how will we deal with them?

A long-term, comprehensive monitoring program of the system is also very important. Although collection and dissemination of such information should not be the major part of the management plan, it certainly should be included. Such a program would include measuring the physical and chemical parameters and measuring species diversity and abundance of the aquatic communities from the sediment to the surface waters. Current monitoring programs being done by other agencies or companies, as well as those within the DEC, should be coordinated (and perhaps financed) through this management plan, with the DEC filling in gaps where necessary. Merely monitoring the system is not a substitute for basic research into causes and effects, but it provides a background of data which can be useful in many ways.

The DEC's role in the plan will certainly be to write, approve and adopt the Hudson River Estuary Management Plan. If projects are contained in the plan for which they do not have the staff or time, DEC should find the means of accomplishing this work through other institutions. Finally, DEC should coordinate all investigations with other agencies to avoid duplication of effort.

Summary of Interview Conducted for the
Hudson River Estuary Project

Interviewees: Glen Cole (Regional Wildlife Manager, Region 3)
Russell Fieldhouse (Regional Fisheries Manager, Region 4)
James Colquhoun (Chief of the Bureau of Environmental Protection)
Wayne Elliot (Regional Fisheries Manager, Region 3)
Paul Neth (Supervisor of Inland Fisheries of the Bureau of Fisheries)
Eric Fried (Principal Wildlife Biologist)
Division of Fish and Wildlife
New York State Department of Environmental Conservation
Interviewer: Cynthia J. Decker

Although the six people interviewed represent various interests and regions of the Hudson River system, there is a general agreement on what issues concerning the Hudson River estuary are most important in terms of wildlife and fisheries and should be included in a management plan for the estuary. Many of them involve problems which will first require scientific research under the Plan to determine what are the best solutions. The answers to others are already better known and will require decisions included in the Plan on policy and management of the resources involved. Issues requiring scientific research will be discussed first, followed by more management-oriented ones. No issue belongs exclusively to just one of these catagories. Some concerns are very broad in nature and others ask for very specific information. The order and length in which they are discussed does not indicate the priority with which they should be covered in the Plan.

Biological issues with which the fisheries and wildlife personnel were concerned include critical habitats, population dynamics, aquatic vegetation and contaminants.

It is vital that the aquatic habitats which are required by finfish, waterfowl, and fur-bearing carnivores be identified. Examples include the spawning and overwintering grounds for various bass species, resting stops for eagles, osprey and herons and habitat for mustrat. Exactly what is necessary in a habitat for it to be attractive for these purposes needs to be determined. Once these facts are known, the location of such known or suspected critical habitats along the estuary must be mapped and measures for their protection implemented. Fresh and saltwater wetlands may form the crucial habitat for most of these species. Therefore, the protection and acquisition by the state of existing marshes and the creation of new wetlands using, for example, dredged material, is an extremely important issue which should be covered in this Management Plan. Specific measures could include an amendment to the Wetlands Act which provides for an expansion of the protected area adjacent to a freshwater marsh beyond the current 100 feet. In addition, this Act only provides for the protection of wetlands in parcels of greater than 12.4 acres unless a smaller section is of "unusual importance." A commitment of support staff under the Plan could enable these small but sometimes critical parcels to be reviewed under the criteria outlined in the Act.

Although much information has been collected over the years on finfish in the Hudson River estuary, many of these data are limited to only a few commercially important species such as striped bass and shad. It would be very useful to have data on all the finfish species in the river. The ecological role of many of these species needs to be elucidated: fish that are not commercially/recreationally important may have a crucial role in the functioning of the system. In addition, fish species that are not economically important now may be so in the future. Gaps in our knowledge about the population dynamics and life histories of these organisms need to be identified and filled in. These data can then be inserted in models used to predict the consequences of various phenomena on finfish populations. Other species which require similar monitoring and research include blue crabs, oysters and hard clams, all of which used to or still do make up thriving fisheries in the lower, saline portion of the estuary.

Aquatic macrophytes are another major topic of concern discussed by the interviewees. These include subtidal species such as water chestnut and milfoil and marsh plants such as purple loosestrife and phragmites. Many of these plants are not native to the system, thus their spread is relatively unchecked. They impede access to the shoreline; they inhibit boating in many areas; and they clog water intake valves. To control these pests in an environmentally safe manner, it will be necessary to do some basic research on the life histories and population dynamics of these species, including information on the kind of habitats and water quality most favored by each one. The latter will enable their spread to be predicted and checked. It is probably not feasible nor desirable to completely eliminate these plants from the system. Therefore, a practical management plan will involve a survey and mapping of the location of these plant species, an evaluation of their value to the ecosystem and applied research on their removal or preservation. If large-scale elimination is required and cannot be accomplished without resorting to toxic herbicides, then research into the use of these must be done, including an extended Environmental Impact Statement on the use of the most likely candidate in aquatic situations, glyphosate.

There are a variety of contaminants which have been found in the Hudson River estuary. The sources and sinks for these in the system need to be identified and mapped. In addition, the level of toxic substances found in top level consumers such as finfish, mammals and birds should be assessed along with their long-term effects on these populations.

Two large-scale physical disturbances are proposed for the river which may have broad effects on all aspects -- biological, chemical, geological and hydrological -- of the system. Currently, moderate amounts of water are drawn from the river at certain times of the year. In the future, the amount of water withdrawal may be much greater. It is important to understand now what the effects of this removal of fresh water have on the system so that the effects of increased withdrawal can be predicted. Changes can be expected to occur in water quality, habitat availability, flow regime and type and location of solute concentration changes. The adaptations of aquatic communities to these changes must also be predicted. It is equally important that the safest methods for withdrawing water be developed in order to minimize the small scale impact.

A deepening of the main navigation channel in the river has been proposed for the near future. This would be accomplished by dredging. The effects of the channel and the dredging process itself on the hydrology and geological structures and, thus, on the habitats and organisms in the system, need to be assessed. In addition, the disposal method of the dredged material must be agreed upon before the project begins.

Man is an integral part of the Hudson River estuary ecosystem. There are several concerns which will require a certain amount of "social" research along with research into other areas in order to predict the condition of the estuary in the future. In order to accurately assess the status of finfish populations in the river, it will be necessary to obtain information on the commercial and recreational harvesting of some species. The commercial take from the river is well monitored. Very little is known about the impact of recreational fishermen on fish populations, however. It would be most useful to carry out a survey of these people on a regular basis. Information obtained would include the number of fishermen on the river, when and how often they go out, how many fish they catch and of what species. Also important would be their expectations and if these are realized and what attitudes they hold towards particular finfish species, other aquatic species, wetlands protection and access, contaminants and various political issues involving the estuary.

Population growth and associated urban suburban development is a serious problem along the lower stretches of the estuary, around New York City. The consequences of modification and uses of the river in this area are beginning to be studied. It is vital that this research be continued and even extensively expanded. The Hudson River valley and watershed will be one of the fastest growing areas in terms of human population in the next few decades. To predict the effect of growth on the estuary, the impacts of sewage input (excess nutrients, contaminants), water withdrawal and other modifications must be assessed. Studies on cumulative impacts and their mitigation are particularly important. Based on research done in areas already high in human population, models can be constructed and applied to the upper portions of the estuary. The results of these may provide the basis for decisions regarding land and water management. It may be possible to regulate against harmful excesses before they become a problem.

There is one major management issue, in particular, which the interviewees agree needs to be addressed. This is the question of increased public access to the river. This consists of two different types of access. First, they would like to see more access to shoreline areas and wetlands for the purposes of hunting, trapping, birdwatching and fishing. Secondly, there needs to be more parking and launching facilities to enable boat access to the estuary. It is necessary to point out here that this is not exclusively a management issue. Basic research is needed to assess the small-scale, long-term impact of human presence and boats on the ecosystem. Certainly more access, at least within the limits set by this research, can be provided by both the state (perhaps on state-owned land) and private means.

Public education is another issue which could be covered in the Hudson River Estuary Management Plan. It should not be a priority, however some mention of its importance should be made and some low level of funding could be provided for under the Plan, depending on the scope of the programs considered.

One final problem concerns the multiple, overlapping jurisdictions which exist to cover the estuary. Not only does the Department of Environmental Conservation regulate the area in a somewhat fragmented fashion, but other state agencies (e.g. the Department of Transportation) and federal agencies (e.g. the Environmental Protection Agency, U.S. Army Corp of Engineers), not to mention local governments, do as well. In addition, the lower portion of the estuary is bordered by the state of New Jersey which should be consulted regarding policies set for the lower part of the estuary. All of these organizations have a say in how the estuary and its drainage basin are regulated. It is very important that the DEC try to maintain some sort of coordination or at least open communication with these groups if this Management Plan is to succeed.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewees: Carol Ash (Director, Region II)
Barbara Rinaldi (Regional Permit Administrator)
Roberta Weisbrod (Special Assistant to the Commissioner)
New York State Department of Environmental Conservation
Interviewer: Cynthia Decker

The kind of information that would be most useful for making decisions about factors affecting the Hudson River Estuary can be described by a multitiered system in which the different tiers reflect different priorities for the information. The three DEC representatives agreed that at all levels there was need for a greater emphasis on efforts to synthesize and interpret data and to convert data into information.

It was the consensus among the three people interviewed that a top priority for the management of the estuary should be the maintenance and restoration of the aquatic species that utilize the system for all or a portion of their lives. Therefore, the first tier of information needs would include biological information on the population dynamics and interactions among species, information on the effects of changes in the physical-chemical environment (such as current flow, sedimentation and light intensity and chemical data, including levels of dissolved oxygen, nutrients and toxins) on biological communities. Ultimately perhaps, a comprehensive model of the Hudson River estuarine ecosystem should be created, although a practical definition of the specific information required for such a model has not been agreed upon either by the scientists or the managers.

The second tier of information needed would include an assessment of the relative importance and value of aquatic species both to humans (economic) and to the system as a whole (ecological). In addition, the relative values of particular habitats in the system should be evaluated. This evaluation should include an assessment of how different species use the system at different life history stages.

The third level of information required by management is significantly less important than the other two tiers and includes any information that would help managers reduce contamination in the river to levels such that important uses would not be lost or compromised: beaches would not be closed because of sewage, fish could be eaten, etc. In addition, any data that would enable them to make better decisions about allocating the uses of the river such as fishing, shipping, recreation, etc. would be very useful.

They also stressed the need for information to assess the impacts of constructing platforms in the river individually and in the aggregate, on the system. They expressed particular concern about the 16-acre riverwalk platform proposed for the East River. Research is needed to select designs of platforms and their supporting structures which will have the least adverse impact on biological communities because of the loss of light, scouring, siltation etc. Present knowledge is inadequate to predict the consequences of a particular design or to select appropriate mitigation strategies. They suggested that a research project of the North River Treatment Plant platform might provide useful insights.

It was emphasized that an area of the river needing particular attention on all levels is the Upper Harbor (defined as that stretch bounded by the George Washington Bridge to the north and the Verrazano Narrows Bridge to the south). Current information on this area is quite sketchy, derived primarily from studies done on specific areas or species by developers for environmental impact statements. This information is not comprehensive; the data are inconsistent in time and space; synthesis and analysis of these data are incomplete and intended for such specific purposes that information from different studies cannot be compared readily.

Other questions about the Hudson River Estuary which were raised during the course of the discussion included: What effect does construction in coastal areas have on aquatic communities? What would be the cumulative impact of a variety of construction projects on the estuary or segment thereof beyond which there can be no recovery of the system? How much damage has been done and can it be reversed?

All three individuals indicated that integration and interpretation should be a major focus of studies of the Hudson River Estuary Management Plan. They recommended development of a conceptual ecosystem model of the Hudson River and Estuary to guide research and management of the system.

Summary of Interview Conducted for the
Hudson River Estuary Project
Interviewees: Bruce Pyle (Bureau Chief, Freshwater Fisheries)
Bruce Freeman (Administrator, Marine Fisheries)
New Jersey Department of Environmental Protection
Interviewer: Cynthia Decker

Bruce Pyle and Bruce Freeman discussed the Hudson River Fisheries Cooperative which still exists but has been inactive in recent years. They suggested that the issues which were of concern to fisheries at that time are probably still of primary interest today, and perhaps the document which was drawn up by the Cooperative could be used as a source of material for inclusion in New York's Hudson River Estuary Management Plan. In addition, they discussed the fact that New Jersey, along with three other states, participates in the Delaware River Basin Commission, which monitors and manages that system and is responsible for controlling water use therein. This commission could be used as a model upon which to base the Hudson River plan.

The interviewees then individually discussed a number of ecological issues that they felt should be covered by the plan. It was felt that a description of the estuary is needed: an inventory of the aquatic species, their abundances and recruitment, as well as of the habitats in the river, particularly those most important to fish populations as spawning and nursery areas. The physical characteristics of the system are also very important. Where is the salt line and how does it fluctuate? How are fish populations affected by the movement of that line and what are the effects of the tidal fluctuations on aquatic species?

People's impact on the system needs to be evaluated as well. Impingement and entrainment data need to be verified and updated. Water quality should be assessed, including factors such as fluctuations in temperature, dissolved oxygen and salinity, as well as pollutants and excess nutrients. Pollutants in particular are the major factor affecting the health of the Hudson River resources. Types of pollutants in the system and their sources must be identified. Then their impact on aquatic life must be examined, particularly sublethal effects, which alter reproduction and recruitment, and body burden, which may accumulate up through the food web into species that are consumed by humans.

A broader discussion of man's impacts would go beyond studying just those substances which are put directly into the river and would include the use of the tributaries and the land surrounding the system and how this leads to degradation of the estuary. It is vital that these be included in the management plan. These broader impacts must be studied so that decisions can be made about growth and development in (human) communities within the system. Although development will certainly increase pollutant loads into the system, it may also increase the amount of water drawn from the river for comsumption. This will mean that less water will be available to dilute these pollutants and, thus, their relative impacts will be greater.

If the management plan is successful in improving water quality and thus aquatic habitats and species populations, this success will spur the demand for more development along the river and its tributaries. At the very least, recreational use of the river will increase. This increased use (swimming, fishing and boating along with the required access to the water) can also have a detrimental effect on the river. It is important to foresee these effects and try to plan for them in advance. The lesson from the Delaware River Basin Commission is to control growth. Development of the Hudson Valley must be monitored carefully and restricted where necessary so that the system does not risk being degraded beyond the point of no return.

In summary, the management plan should describe and monitor the Hudson River Estuary. It should outline and provide the means for accomplishing the most important research needs and should have the power to control the use and development of the estuary, its tributaries and the land surrounding them. The latter function should not be kept waiting, pending the completion of the other two, and the research should not wait for the completion of the description and monitoring. All of these things must proceed together; modifications can be made as more information becomes available. Finally, it would be wise to include New Jersey in the plan as it realizes considerable value from the Hudson and discharges into the lower portion of the estuary.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: Larry Schmidt (Director, Planning Group)
New Jersey Department of Environmental Protection
Interviewer: Cynthia Decker

There were a number of concerns which Mr. Schmidt felt should be addressed by a management plan of this type. First and foremost among these is the issue of development along the waterfront. This is already a major problem in the lower portion of the system and could be an issue upriver very soon. Questions about infrastructure capacity (transportation, wastewater, etc.) air quality and platforming must be addressed now to reduce problems in New York Harbor and to prevent them from occurring in the upper portion of the estuary in the future.

Non-point source pollution is one of the major impacts on the system right now. It is entirely a land-use problem, and as such, is tied in with development issues. Garbage and, as a subset of this, medical waste are other problems; the expense of putting this material into local landfills or shipping it out of the area may lead to illegal dumping directly into the river or into sewers.

Related concerns are the disposal of sewage sludge and dredged material. Both are currently dumped offshore but, in the case of sewage sludge, this will probably not continue for long. Alternatives to this are incineration and land application for the sludge. Unfortunately, in the case of New York City sludge, the upstate agricultural interests may not accept it for use on their fields and the city can't agree on the criteria for incinerators. One viable method of dealing with the most contaminated class of dredged material is to create a containment island within the harbor.

Aside from suspended particle concerns, dredged material wouldn't necessarily be a problem if it weren't for the raw sewage and contaminants in runoff that enter the system and wind up in bottom sediments. The source of much of this is from the combined sewage overflows (CSOs) the shunting of material that would ordinarily go to sewage treatment plants directly into the river during times of heavy precipitation. The solution to these, short of replumbing New York City, will not be a simple one. Sewerage systems themselves require a great deal of maintenance and monitoring. Even without CSOs, it may be necessary to spend a great deal of money taking care of the rest of the system. In addition to all the problems mentioned above, one long-term concern which should be considered is a future acceleration in the rise in sea level that is already occurring. All management programs should include a contingency plan for this.

In summary, the most important issue of concern for the plan should be waterfront development -- its impacts on the natural system and public access to the water's edge. Subsets of this would be land use and growth control. Of secondary importance would be the impact of development in the water or on the water's edge on fishery communities. The third topic covered by this plan should be the control of non-point source pollution, including their sources and effects on the aquatic communities.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: Thomas Belton (Research Scientist)
New Jersey Department of Environmental Protection
Interviewer: Cynthia Decker

Mr. Belton felt that there are information gaps in two main areas: technical and management. In addition, public relations must not be neglected.

Many of the gaps in the technical area relate to monitoring. Agencies in both New York and New Jersey collect water samples, but they may do different (non-comparable) assays on them or they duplicate effort by monitoring exactly the same areas. The assays need to be standardized, and both states need to go beyond minimal data collecting and do more careful, thorough studies to answer important unresolved questions. In addition, a better characterization of the entire Hudson system is needed so that the monitoring data can be placed in a proper perspective in relation to the functioning of the ecosystem. This would include sediment and habitat mapping and inventories of the aquatic species. Such information would provide a baseline from which to make decisions about the system as a whole rather than on a permit-by-permit basis.

Federal and state standards on pollutants are often not consistent, and this needs to be remedied by coordination among agencies and perhaps by using standardized statistical analyses of data to set the limits within standard deviation values. Another problem is the novel test in bioassays. Standard species are used in the lab for toxicity testing, but perhaps more appropriate or local species should be used for the purpose.

Disposal of dredged material and sewage sludge is also an issue of concern. Are current methods simply sending the material back into the system? Non-point sources of pollution such as runoff, combined sewage overflows and airshed impacts (such as polynuclear aromatic hydrocarbons) are extremely important and much more work should be done to assess their impacts.

The major management problem is the large number of agencies and the lack of coordination among them. Often they cannot agree on how to carry out regulations or which should be the lead agency. These conflicts may result in resentment and adversarial relations among the agencies in the future. The primary reason for this on the federal level seems to be that the laws are often written with wording that is too vague. The laws need to be more specific about how to regulate a situation and who is responsible for what aspect.

Community and public relations are also very important to the success of the plan. Since the public is responsible for commerical and recreational use of the estuary as well as residential and retail use of waterfront property, they naturally have a great interest in the condition of the system, access to it, the effects of such activities as dredging and the regulations which control these things. For the most part, they wish to be helpful and participate. Perhaps the management plan could encourage such participation by recruiting local citizens to disseminate information and help formulate regulations.

The most important questions which this plan should address, however, are both point and non-point contaminant source reduction, sewage pre-treatment upgrading and elimination of combined sewage overflows. If these things can be accomplished, then the river might be able to recover.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: John Weingart (Director, Coastal Resources Division)
New Jersey Department of Environmental Protection
Interviewer: Cynthia Decker

The most critical issue that this management plan will have to deal with is that of land use and development. The decisions that will be made regarding these will have great impact on the Hudson River Estuary. The questions of decking (or cantilevering) and filling, in particular, are in need of immediate resolution since there are a large number of proposals submitted for these activities and which are presumed to have detrimental effects on aquatic communities through habitat alteration or loss. Small, isolated platforms or piers, however, should not be subject to the same strictures as very large ones or groups of them, since the former will probably have very little environmental impact and, in the case of public parks and marinas, may have a great deal of social value. The cumulative impact of these structures needs to be studied so that regulations can be made that consider what the system as a whole is able to withstand. Public access to the waterfront is extremely important, as is space for marine-dependent businesses such as tugboat repair facilities.

Several other issues were mentioned by Mr. Weingart. He felt that long-term monitoring of the system could be useful but must be geared towards a specific goal. Public education is important and, with increased public access to the waterfront, the constituency that cares about issues affecting the Hudson River estuary will increase as well. Although the management plan is being prepared for the State of New York, New Jersey could be consulted on the issues addressed by the plan, but its actual involvement need only be minimal as its shoreline on the estuary is small compared to New York's.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: Eric Evenson (Deputy Director, Division of Water Resources)
New Jersey Department of Environmental Protection
Interviewer: Cynthia J. Decker

Mr. Evenson discussed two major technical issues and several important non-technical ones that he felt should be addressed by the Management Plan. A thorough investigation of these issues could provide information vital for making technically sound decisions involving major capital expenditures. Both of these issues focus on water quality.

First, he would like to see the establishment of a human-specific pathogen indicator. The current standard organism used to indicate possible pathogenic contamination is the fecal coliform bacteria. These microbes are present in the feces of all warm-blooded organisms. As a result, samples from areas which receive large inputs from birds or livestock, to name two examples, may show high numbers of fecal coliform bacteria even though pathogens dangerous to humans are not actually present. In other words, a "false positive" reading may result from the culturing of water samples from these areas.

Alternative tests have used various viruses. These organisms are human-specific and, because they live longer in the environment than fecal coliforms, they may provide a more accurate assessment of the duration of contamination in the areas tested. The viral cultures do have some disadvantages: the require a longer incubation period and are much more expensive to do because they require more technologically advanced lab facilities. The viruses currently being tested may not be the best organisms to use as pathogen indicators but at least they provide an alternative to the fecal coliform as an indicator.

The second issue discussed by the interviewee concerned toxic compounds.

The 1987 amendment to the Clean Water Act requires states to develop water quality criteria by 1991 for priority pollutants (as defined by a list maintained by the Environmental Protection Agency). Additional research and information are needed on human health risk and aquatic life criteria to be applied for these substances.

Finally, Mr. Evenson would like to see more effort applied to monitoring and data collection for pathogens, toxicants and nutrients. The first step in achieving this is establishing a better ambient surface water quality monitoring network -- not just larger and more frequent numbers of samples taken, but also using better methods of sampling. Unfortunately, funding for monitoring has been steadily decreasing over the last decade. As a result, decisions requiring the use of water quality data are based on a fairly small and quite old data set. Most data are from the 1970s or early 1980s.

The interactions between bottom sediments and overlying water are also important to understand. As regards toxic substances, in particular, what is the contribution of the sediment to surface waters? If the contribution is substantial, how can contaminated sediments be cleaned up? One example is the upriver dredging of PCB-laden sediments. This may be the best solution to this particular problem, but there may be better solutions in other situations.

Although a large portion of the Hudson River Estuary is within New York State boundaries, the lower part of the system is bordered by New Jersey as well. The waters around New York City receive approximately equal input from both states. Therefore, coordination between state agencies is very important from the decision-making process to the regulatory process.

Public education is another issue which the interviewee felt should be addressed by the Management Plan. Point source discharges, however, can be controlled only with the cooperation and coordination of the citizens of New York and New Jersey.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewees: George Lutzic (Chief, Division of Operations Control)
Angelika Forndran (Chief, Water Quality Section)
Thomas Stokes (Project Scientist)
New York City Department of Environmental Protection
Water Quality Section
Interviewer: Cynthia Decker

It was the consensus of the three representatives of the New York City Departmen of Environmental Protection that the first step in implementing a management plan for the Hudson River Estuary should be to set up a centralized data base for all the existing information about the river. This clearinghouse should collect data and make them available to managers and scientists. The collection could be located at a university or comparable institution such as the Hudson River Foundation or perhaps at a scientific computing firm. A second step in setting up the plan would be to coordinate water quality monitoring in the waters of New York Harbor, particularly those in the vicinity of New York City's sewage treatment plants. If their efforts were coordinated with others in timing and methodology at other points in the estuary, a good set of data could be established. Along with the monitoring, the interviewees would like to see the water quality standards established by the state re-examined to determine if these standards are appropriate to actual or potential species of the Hudson River Estuary.

Beyond the establishment of these two long-term programs. there are several concerns that these three people would most like to see addressed by the management plan. The first and foremost among these is a toxic substances modeling program. Some of the sources of toxicants are known -- New York City sewage treatments plants, specifically -- and are being controlled, but the levels of toxicants in the receiving waters are much higher than can be accounted for by these sources. Possible sources they would like to see investigated include sediment sorption and desorption; effects of dredging and storms on sediment resuspension and metals desorption and other suggested (but unmonitored) point sources. Related to the issue of toxicant standards is the question of whether or not resident aquatic species have acclimated to current levels. Toxicity testing is done with standard sensitive species in the lab, but if native species currently residing in the estuary show acclimation, then state and federal standards could be relaxed until other sources can be located and cleaned up. In addition, the validity of using coliform bacteria as an indicator organism for sewage vs. pathogenic bacteria and viruses should be investigated.

A second topic of interest to the interviewees is the effect of toxicants on the Hudson River biota. These include tissue metal concentrations in finfish and shellfish (standards for the animal's survival vs. edibility for man), tissue metal concentrations in lower trophic organisms; and an economic analysis of the value of potential fisheries and tourism resources vs. the cost of cleaning up the pollution.

An effort should also be made to develop comparable standards and data collection with the State of New Jersey, or all of New York's efforts could be negated by non-regulation of pollution on the New Jersey side.

Summary of Interview Conducted for the Hudson River Estuary Project

Interviewee: Barry Seymour (Acting Director, New York City Waterfront Revitalization Program)
New York City Department of Planning
Interviewer: Cynthia Decker

The New York City Department of Planning WRP office, as a local component of the State Coastal Management Program, must review almost all development proposals along the New York City waterfront that are subject to discretionary permit actions. The more information that can be obtained on the ecology of the Hudson and effects of man's activities on it, the better able they will be to make the best decisions.

Mr. Seymour outlined several specific steps that he would like to see taken by the plan, which he feels would achieve the above goal. The first step would be the creation of a consensus policy encouraging or requiring active resource habitat enhancement in conjunction with development proposals. Basically, there are two types of habitats around New York City -- heavily disturbed and less disturbed. This step would define a target habitat condition that could be used as a guideline for planning. Target conditions could vary by area based on existing conditions, and the target could be expected to be raised over time. The second step, building on the first one, would establish a uniform set of information needs that would be required from a developer before a proposal would even be considered. As it is now, an increasing number and type of questions are asked at each stage of approval because the regulatory agencies do not really know what issues are important. This process wastes everybody's time.

To implement these two steps, a habitat inventory as well as the establishment of a long-term monitoring program are necessary. In addition to the development of uniform information needs, the precise methodology for collecting and analyzing these data should also be set so that all studies could be compared to one another. If the proposed development is approved, the owner should also have to have the site monitored afterwards so that these data would be available to aid in making future decisions about similar projects.

The final step in this plan would be to develop a resource enhancement program. The current attitude is that any development is a negative disturbance. With adequate information, however, development could be done in such a way as to not just minimize disturbance but to actually enhance an area. If this is to be accomplished, more research into the effects of structures (materials, configuration, etc.) needs to be done. Another way of enhancing the waterfront would be to require a developer to trade permission for construction in one area for the creation of a park, wetland or wildlife refuge in another area. It is not possible to stop development completely, so perhaps it is best to try to work with developers to improve the quality of the habitat that exists. At the moment, however, there are no ground rules to aid developers in the creation of their projects. It would accomplish much more, in terms of the protection of the environment, to establish a cooperative system with well-defined, evenly applied standards and regulations to lead to active resource enhancement.

Appendix C

List of Participants and Additional Individuals Who Contributed to this Report

Carol Ash
New York State Department of Environmental Conservation
Region II
Hunter's Point Plaza
47-40 21st Street
Long Island City, New York 11101

Daniel Barolo
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233-0001

Nancy Beard
New York State Department of Environmental Conservation
21 South Putt Corners Road
New Paltz, New York 12561

Thomas Belton
Kaselan D'Angelo Association, Inc.
515 Gore Street
Haddon Heights, New Jersey 08035

David Berkovits
Port Authority of New York and New Jersey
One World Trade Center
Room 64 South
New York, New York 10048

Joseph Birgeles
Port Authority of New York and New Jersey
One World Trade Center
Room 64 South
New York, New York 10048

Betsy Blair
New York State Department of Environmental Conservation
Hudson River Research Reserve
c/o Bard College Field Station
Annandale, New York 12504

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

John Boreman
NOAA-NMFS
Northeast Fisheries Center
11 Water Street
Woods Hole, Massachusetts 02543

Robert Brandt
Hudson River Fisheries Specialist
New York State Department of Environmental Conservation
21 South Putt Corners Road
New Paltz, New York 12561

James Calquhoun
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233-0001

Richard Caspe
U.S. Environmental Protection Agency
26 Federal Plaza
New York, New York 10278

Kirk Cochran
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

Glen Cole
New York State Department of Environmental Conservation
21 South Putt Corners Road
New Paltz, New York 12561

Jonathan Cole
The New York Botanical Garden
Institute of Ecosystem Studies
Mary Flager Cary Arboretum
Box AB
Millbrook, New York 12545-0129

Gordon Colvin
New York State Department of Environmental Conservation
Region I
State University of New York
Building 40
Stony Brook, New York 11794-2356

Cynthia Decker
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

Mario Del Vicario
U.S. Environmental Protection Agency
26 Federal Plaza
New York, New York 10278

Herbert E. Doig
Assistant Commissioner
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233

Cathy Drew
The River Project
67 Vestry Street
New York, New York 10013

Fran Dunwell
New York State Department of Environmental Conservation
21 South Putt Corners Road
New Paltz, New York 12561

Lynn Edgarton
NRCC
122 East 42nd Street
45th Floor
New York, New York 10168

Wayne Elliot
New York State Department of Environmental Conservation
21 South Putt Corners Road
New Paltz, New York 12561

Tom Engler
LMS Engineers
1 Blue Hill Plaza
Pearl River, New York 10965

Russell Fieldhouse
New York State Department of Environmental Conservation
Region IV
Route 10
Stamford, New York 12167

Stuart Findlay
The New York Botanical Garden
Institute of Ecosystem Studies
Mary Flager Cary Arboretum
Box AB
Millbrook, New York 12545-0129

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

Roger Flood
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

Angelika Forndran
New York City Department of Environmental Protection
Bureau of Waste Water
Wards Island, New York 10035

Bruce Freeman
New Jersey Department of Environmental Protection
CN-400
Trenton, New Jersey 08625

Eric Fried
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233-0001

Mary Downes Gastrich
Bureau of Water Quality Standards and Analysis
New Jersey Department of Environmental Protection
CN-029
Trenton, New Jersey 08625

Monte Greges
New York District, Operations Division
U.S. Army Corps. of Engineers
26 Federal Plaza
New York, New York 10278

Clay Hiles
Hudson River Foundation
40 West 20th Street
New York, New York 10011

Richard Hires
Department of Coastal and Ocean Engineering
Stevens Institute of Technology
Hoboken, New Jersey 07030

Robert Howarth
E309A Vorson Hall
Cornell University
Ithaca, New York 14853

William Kirk
Consolidated Edison
4 Irving Place
New York, New York 10003

Lingard Knutsen
Port Authority of New York and New Jersey
Room 64 South
One World Trade Center
New York, New York 10048

Susan Kuenstner
New England Fish. Development Association, Inc.
280 Northern Avenue
Boston, Massachusetts 02210

Jeffrey Levinton
Department of Ecology and Evolution
State University of New York
Stony Brook, New York 11794-5245

Dennis Logan
New Jersey Department of Environmental Protection
401 East State Street
CN-029
Trenton, New Jersey 08652

George Lutzic
New York City Department of Environmental Protection
Bureau of Waste Water
Wards Island, New York 10035

Bernice Malione
Port Authority of New York and New Jersey
One World Trade Center
Room 64 South
New York, New York 10028

Robert Malouf
New York Sea Grant Institute
State University of New York
Stony Brook, New York 11794-5001

Alan Mytelka
Interstate Sanitation Commission
311 West 43rd Street, Room 201
New York, New York 10036

Paul Neth
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233-0001

Charles Nittrouer
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

Joel O'Connor
U.S. Environmental Protection Agency
Region II, Water Division
26 Federal Plaza
New York, New York 10278

Michael Oppenheimer
Environmental Defense Fund
257 Park Avenue South
New York, New York 10010

Michael Pace
The New York Botanical Garden
Institute of Ecosystem Studies
Mary Flager Cary Arboretum
Box AB
Millbrook, New York 12545-0129

Bruce Pyle
New Jersey Department of Environmental Protection
CN-400
Trenton, New Jersey 08625

Barbara Rinaldi
New York State Department of Environmental Conservation
Region II
Hunter's Point Plaza
47-40 21st Street
Long Island City, New York 11101

John Sanders
Department of Geology
Barnard College
Columbia University
New York, New York 10027-6598

Larry Schmidt
New Jersey Department of Environmental Protection
CN-402
Trenton, New Jersey 08625

J.R. Schubel
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

Joseph Seebode
U.S. Army Corps of Engineers
26 Federal Plaza
New York, New York 10278

Barry Seymour
New York City Department of Planning
22 Reed Street
New York, New York 10007

James Simpson
Geochemistry Department
Lamont-Doherty Geological Observatory
Palisades, New York 10964

Thomas Sperry
U.S. Fish and Wildlife Service
Post Office Box 369
Islip, New York 11751

Thomas Stokes
New York City Department of Environmental Protection
Bureau of Waste Water
Wards Island, New York 10035

Dennis Suszkowski
Hudson River Foundation
40 West 20th Street
New York, New York 10011

John Tavalaro
U.S. Army Corps of Engineers
26 Federal Plaza
New York, New York 10278

M. Llewellyn Thatcher
Department of Civil Engineering and Engineering Mechanics
Columbia University
S.W. Mudd, Room 610
New York, New York 10027

John Weingart
New Jersey Department of Environmental Protection
CN-401
Trenton, New Jersey 08625

Roberta Weisbrod
New York State Department of Environmental Conservation
Region II
47-40 21st Street
Long Island City, New York 11101

John Waldman
Hudson River Foundation
40 West 20th Street
New York, New York 10011

Kenneth Wich
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233-0001

Robert Wilson
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

Peter Woodhead
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

Christopher Zeppie
Port Authority of New York and New Jersey
One World Trade Center
Room 64 South
New York, New York 10048