A COOPERATIVE MONITORING PLAN FOR

THE DELAWARE ESTUARY

DELEP REPORT # 95-02

Report Prepared by
Jonathan H. Sharp
and
Marria O'Malley Walsh

February 28, 1995
Revised August 1, 1995

A COOPERATIVE MONITORING PLAN FOR THE DELAWARE ESTUARY

Monitoring Plan Developed by

Ad Hoc Monitoring Committee of the

Scientific and Technical Advisory Committee

Delaware Estuary Program

Report Prepared by

Jonathan H. Sharp
Graduate College of Marine Studies
University of Delaware
Lewes, DE 19958

and

Marria O'Malley Walsh
U.S. Environmental Protection Agency, Region III
Power Technology Center
201 Defense Highway, Suite 200
Annapolis, MD 21401

February 28, 1995
Revised August 1, 1995

CONTENTS

APPENDICES

INTRODUCTION

The estuary of the Delaware River and Bay is relatively simple in comparison to many other major urbanized estuaries of the United States in terms of hydrodynamics. Since the physics of any aquatic system has a major control on the chemistry and biology of that system, it is critical to design the monitoring plan around the spatial and temporal features of the body of water.

The Delaware Estuary is dominated by a single fresh water input from the Delaware River (58% of the total discharge at the fall line near Trenton, NJ), and has one other significant water input, the Schuylkill River (about 14% of the total discharge). All other subtributary and diffuse inputs contribute less than 5% individually, and only 28% cumulatively, of the total flow at the mouth of the bay. While the drainage basin above the fall line has large agricultural influence, and the tidal river drainage area also has some agricultural influence, the localized urban and industrial inputs in the greater Philadelphia area dwarf other anthropogenic inputs. The lower reach of the River in the greater Philadelphia area near Marcus Hook, PA, is at the beginning of the salinity gradient. From that point, there is a general diminution of pollution inputs, traveling along the salinity gradient to the mouth of the Delaware Bay. In addition to dilution in the Bay, heavy suspended sediment concentrations and extensive adjacent wetlands aid in absorbing pollution inputs downstream from the input sources. There are significant non-point source inputs of some pollutants, but in many cases point sources dominate. Since the flow of the estuary is dominated by the Delaware River, there is a strong seasonal pattern of discharge from spring melt of the mountains in the upper drainage basin. The estuarine flow is almost double the annual average for the three spring months of March-May and the mean flow for the summer-fall period of June-November is about 50% less than the annual average.

The seasonal flow pattern sets up a circulation pattern such that the estuary is strongly stratified in the spring flush period and is essentially well-mixed for the remainder of the year. This physical feature supports almost uniform vertical fields of chemical distributions from June through February. In the stratified spring condition, there is not a strong oxygen gradient since the tidal mixing and cold conditions keep the entire water column close to atmospheric saturation in the lower estuary. The tidal river portion does not show significant density gradients in the spring, so again there is no subsurface oxygen deficit when compared to the surface. As a result, variable depth sampling is not needed to adequately monitor the chemistry.

There is some horizontal variability in the cross-bay axis. However, the circulation of the estuary is such that the majority of the ebb and flood water exchange is channeled toward the center with the flanks having smaller water volume. While some chemical and biological gradients can be seen in a cross-bay axis, the gradients are inconsistent and reversible. It is possible to sample down the spine of the estuary and accurately characterize conditions in the Delaware River and Bay.

Seasonal patterns can be seen in the estuary of biological parameters that fit preconceived winter-summer variations. In addition, the spring flush supports the annually largest phytoplankton biomass, but this occurs at a time of limited activity from the rest of the biosphere.

All of these features have influenced the nature of the proposed monitoring plan. The lack of persistent vertical or cross-bay gradients greatly simplify and reduce the monitoring needs for much of the chemical and microbiological sampling. The uneven seasonal discharge and seasonal variability in biological activity give rise to seasonally irregular monitoring needs which are also reflected in the proposed monitoring plan.

The geography of the lower estuary also influences habitat and land use monitoring. Since the Delaware Bay has such extensive marsh coverage, land runoff with agricultural and suburban influences is less than that experienced in other systems, e.g. the neighboring Chesapeake Bay. However, destruction and alteration of freshwater marshes in the upper estuary has left this region more susceptible to land runoff influences. Therefore, it is critical to be able to map and monitor the vegetation along the periphery of the estuary.

The National Estuary Program requires a monitoring plan in the Comprehensive Conservation and Management Plan (CCMP) of each estuary program. The plan is needed to assess the effectiveness of management action plans. Monitoring can identify environmental problems that require additional management action. For example, recent fish consumption advisories to protect human health resulted from the monitoring of striped bass tissue for PCB contamination. Historically, ambient water quality monitoring in the Delaware Estuary has served partially as an indirect evaluation of regulatory compliance of managing urban and industrial pollution inputs. The goal of the regulatory compliance has been attainment of the federal Clean Water Act's target of "swimmable and fishable" waters. Some living resources monitoring has been done to manage commercial and recreational fisheries.

Comprehensive monitoring of the condition of natural resources of the Delaware Estuary will also be extremely valuable in the case of an unauthorized discharge of a hazardous substance (e.g., chemical or thermal) or creation of a degrading condition (e.g., tributary blockage). Appropriate monitoring will provide up-to-date baselines to be used to accurately assess damages and to support claims for compensation and development of restoration plans. The availability of good monitoring information will make these efforts less costly in time and funds to the agencies involved and support quicker resolutions and restoration actions.

The Delaware Estuary Program established a series of 14 objectives (Table 1) to guide the development of management activities delineated in the CCMP. Taken together these program objectives are significant because they establish a firm link to the

overall objective of the Clean Water Act to "restore and maintain the chemical, physical and biological integrity of the nation's waters." In designing this Monitoring plan specific monitoring goals and objectives were developed to evaluate whether the management actions recommended by the CCMP achieve the desired results as stated in the program's objectives. The cooperative monitoring plan proposed here for the Delaware Estuary has four specific goals:

1. To obtain information on variables that may influence the condition of the Delaware Estuary, and to assess environmental indications of achievement of management goals set by local, state and federal authorities.

2. To measure current status and trends in indicators of the condition of the Delaware Estuary (and surrounding watershed) on a system-wide basis with known confidence.

3. To estimate the areal extent of the critical landscapes of the Delaware Estuary system with known confidence.

4. To evaluate and revise, periodically, the monitoring plan and action plans to address dynamic developments in the Delaware Estuary.

The cooperative monitoring plan for the Delaware Estuary has four subject areas for which different monitoring strategies apply:

1. water quality
2. toxics
3. living resources
4. habitat/land cover/land use

Specific monitoring objectives were developed for each area which defines the types of measurements necessary to evaluate effectiveness of management activities. Central to each is the measurement of status and trends. If existing conditions are considered to be a newly-defined baseline then future conditions can be compared to existing conditions to determine if improvements are being made. The appropriate statistical test for trend will be determined by whether the data are normally distributed and whether the data exhibit seasonality. The first three areas need relatively frequent and extensive sampling while the latter has monitoring needs defined as infrequent "snapshots". In this document, the four monitoring areas are discussed with identification of some ongoing monitoring activities and recommendation of monitoring needs for the future cooperative monitoring program. Monitoring data will be made available through the Regional Information Management Service (RIMS). It is important to recognize that the goals of the monitoring plan can be achieved only if the monitoring strategies for each of the four areas are implemented and the data integrated using RIMS. Two tiers of a monitoring program are suggested, both a minimal one and an expanded monitoring program.

The proposed monitoring plan was developed by the Ad Hoc Monitoring Committee of the Delaware Estuary Program with more than 50 members. It is intended to be a cooperative effort of the three states, federal government, and industry. It is not a new independent monitoring program. Ongoing monitoring efforts are considered, and modifications and augmentation are suggested that will give better cooperative coverage of monitoring needs. It is recognized that some of these activities are currently underfunded. Commitment of resources to fully fund these efforts must be secured to successfully implement the plan.

The following plan is the product of a number of meetings and workshops and a preliminary plan developed by Tetra Tech, Inc. (1994). It presents an outline of the initial activities recommended to be followed to support the effective management of the estuary. It consists of some general guidelines and then more specific guidelines in the four areas. It also includes summaries of documented ongoing monitoring in the estuary that contribute to the overall effort.

Table 1. Delaware Estuary Program Objectives

Objective 1 **Harvested finfish and invertebrate species**	To restore population levels of harvestable species of finfish and invertebrate species to levels that will support recreational and commercial fisheries (e.g., an initial target for oyster population that will support a harvest of 1,000,000 bushels annually).
Objectives 2 **Bird population**	To restore or maintain populations of birds dependent on the Delaware Estuary to levels deemed attainable by comprehensive analysis (e.g., a count of 260,000 black ducks or 250,00 shorebirds).
Objective 3 **Estuary-dependent amphibians, reptiles, mammals**	To restore or maintain populations of estuarine-dependent amphibians, reptiles, and mammals to levels deemed attainable by comprehensive analysis of natural populations.
Objective 4 **Ecological balance for a diverse indigenous biota**	To maintain or restore an assemblage of organisms and their habitat throughout the Delaware Estuary and tidal wetlands that contributes to the ecological diversity, stability, productivity and aesthetic appeal of the region.
Objective 5 **Habitat**	To preserve acreage and enhance quality of shoreline and littoral habitat to sustain a balanced natural system. To restore and maintain the physical and environmental conditions necessary to achieve target levels of estuarine species. (At a minimum, maintain 1990 acreage of habitat and, if necessary, increase acreage of habitat to achieve targeted levels of species such as fish, waterfowl, shorebirds, and horseshoe crabs.)
Objective 6 **Habitat**	To restore habitat diversity (e.g., mixture, array and pattern of wetland types), values and functions of tidal and nontidal wetlands to levels commonly found in the 1920's (prior to parallel grid ditching and large-scale drainage), done in a balanced consideration of today's socioeconomic needs.
Objective 7 **Air quality**	To assess air quality impacts on estuarine resources, and support programs that reduce these impacts.
Objective 8 **Water quality**	To achieve water quality that will maintain and enhance estuarine use designations consistent with the Clean Water Act.
Objective 9 **Water supply**	To ensure an adequate supply of fresh water to the estuary to maintain habitats, distribution of salinity, and human population in 2020.
Objective 10 **Sediments**	To optimize sediment quantity and quality in a manner that maintains or enhances a balanced indigenous estuarine biota and habitat.
Objective 11 **Recreation**	To promote and enhance ample and high-quality water-based and associated terrestrially-based recreational opportunities with sustained availability for public use.
Objective 12 **Commerce**	To develop programs and actions that will be mutually beneficial to both the economy and environment of the estuary, by forging a partnership with industry, commerce and local governments in pursuit of continued economic vitality of the region, while enhancing and preserving its living and natural resources.
Objective 13 **Cultural heritage**	To preserve and enhance cultural resources and traditions in the estuary region, and promote their accessibility to the public.
Objective 14 **Pollution prevention**	To promote pollution prevention technologies and strategies that protect estuarine resources (e.g., from catastrophic spills, point sources, and nonpoint sources).

GUIDANCE AND COMPATIBILITY

As is suggested by EPA (NEP, 1994), this monitoring plan is a direct outgrowth of the characterization document of the Delaware Estuary Program (Sutton, 1995). Specific problems identified with the Delaware River and Bay system have guided the design of the monitoring plan which is built upon current monitoring activities.

In a draft report, a national intergovernmental task force, led by the US Geological Survey (USGS) and the US Environmental Protection Agency (EPA) has developed guidelines for improving water quality monitoring in the United States (ITFM, 1994). Their document has been valuable in designing our monitoring plan. The task force suggested the following key elements be used to evaluate methods for developing a nationwide integrated monitoring strategy.

1. Goal-oriented monitoring
2. Flexible and comprehensive monitoring
3. Institutional collaboration
4. Methods comparability
5. Information automation, accessibility, and utility
6. Assessment and reporting
7. Evaluation of monitoring activities
8. Research and development
9. Training
10. Funding
11. Incentives
12. Implementation
13. Initial agency actions

The first eight of these elements have been considered and are essential elements in the Delaware Estuary Cooperative Monitoring Plan. Most of the other elements are either automatic in implementation of the monitoring plan or will be covered by cooperating agencies. Quality assurance objectives and quality control procedures for the major federal and state programs are contained in quality assurance project plans. (Dolhancey et al, 1992)

A consultant with prior experience in developing estuarine monitoring plans was contracted by DELEP to develop an overview of ongoing monitoring activities and to facilitate the interactions of agencies and citizens knowledgeable of monitoring and monitoring needs. The resultant report (Tetra Tech, 1994) contains a discussion of measurement parameters, performance criteria and sampling designs and is central to the monitoring plan that is presented here.

WATER QUALITY MONITORING PLAN

Objectives for Water Quality Monitoring Program

1. To determine status and detect trends in water quality in relation to impacts to public health. Specific regulatory criteria will guide evaluation of these status and trends.

2. To determine status and detect trends in water quality in relation to overall ecosystem health. To evaluate areal extent and trends in parameters that define the habitat requirements of important aquatic resources. Specific criteria of success with individual parameters will evolve over time with evaluation of detectable and confirmed trends.

In addition to these two objectives, the monitoring program should use consistent monitoring data to estimate loading to the estuarine system. The loading estimates would start by using head-of-tide input data and effluent point source inputs in modeling efforts to estimate non-point source inputs; but will eventually need actual estimates of non-point source inputs and more information on transport and fate of constituents.

General Water Quality Monitoring Program

The Ad Hoc Monitoring Committee has acknowledged that this category should not be defined solely by the concept of pollutants, but that water quality also pertains to chemical and physical parameters that are neutral or beneficial to living resources. Thus, the plan should address monitoring the quality of the water with measurement of physical, chemical, and biological parameters that characterize the system.

The water quality in the Delaware Estuary has seen very large changes in the past several decades, most pronouncedly as increased concentrations of dissolved oxygen and decreased concentrations of reduced nitrogen compounds in the water. In discussing performance criteria for detecting future changes, it must be recognized that the level of change that has been seen in the past several decades will not be seen again. For most of the estuary, but not near the Philadelphia/Camden area, oxygen concentrations are close enough to the level of atmospheric saturation, and ammonium nitrogen concentrations are close enough to zero, that only very slight changes in these parameters could result from future improvement. It is unlikely that deterioration sufficient to cause a large negative change will occur in the near future. As a result, performance criteria proposed by Tetra Tech (1994) that refer to either 50% or 20% changes are probably both too coarse for these parameters in the tidal river part of the estuary, where most of the problems of the past occurred. However, these criteria can be achieved through the sampling frequency of existing programs.

In the area of the largest urban inputs, it should be possible to document changes of 5 to 10% of some parameters, e.g. nitrate. On the other hand, there are very large natural fluctuations of some parameters, e.g. phosphate concentration, in both the urban and bay regions from tidal, seasonal, and periodic flow changes. Thus, it is critical to not simply use a quantitative criterion for change that does not have adjustment for knowledge of these variations.

The Ad Hoc Committee has proposed a sampling design more "tailor-made" for the present-day situation in the Delaware Estuary. Our plan starts with the Delaware River Basin Commission (DRBC) river-run monitoring and adds ongoing subtributary sampling being done by DRBC, the three states, and the USGS. It also includes some *in-situ* sampling and satellite remote sensing.

For water quality analyses, it is critical to set up both quality assurance procedures and also intercalibration analytical comparisons between various laboratories involved in sample analysis.

Head-of-Tide Sampling

The head-of-tide sampling of USGS in cooperation with the states and local governments (Appendix E) provides essential information on stream flow and water chemistry. The monitoring at the fall line of the Delaware River in Trenton and at the fall line of the Schuylkill has been maintained for many decades. The river discharge data are essential for most hydrodynamical modelling since these two sources represent almost three-quarters of the total flow to the Delaware Estuary system. Discharge data will be continued. Chemical data have been collected as part of the USGS NASQAN network; the data are important for estimating chemical loadings into the area of interest to the DELEP. The present plan from the USGS is to cease funding these two NASQAN stations; it is hoped that local support can be found for continuation.

There are considerable diurnal swings in dissolved oxygen above the Trenton falls apparently caused by upstream weed beds. Monitoring changes in dissolved oxygen due to the turbulent aeration during river passage from the current monitoring point above the falls to head of tide is under consideration by the DRBC.

In addition, fall line stream flow monitoring in most of the subtributaries to the Delaware Estuary is done by USGS in conjunction with states and local governments. These monitoring activities are critical to the overall DELEP monitoring plan and their continuation is important.

River-Run Sampling

The Ad Hoc Committee agrees that the DRBC river-run monitoring (see Appendix A) should continue, and that it should extend to the mouth of the Delaware Bay (with 3 more stations) and up the river further north than Fieldsboro, NJ (one more station). This extension should take place as part of the Minimal Monitoring Program (see Figure 1). The reason for the added station above Fieldsboro is that there are inputs between the head-of-tide and the Fieldsboro station and diel variations are very large in the head-of-tide station. The three stations added in lower estuary will extend the sampling line in the center of the channel to the mouth of the Bay. The additional stations will bring the total number of stations to be sampled routinely to 22. Logistics problems in the sampling may require an additional boat or a two-day sampling regime. These problems are to be worked out along with the budget requirements. The sampling frequency should remain the same as that of the current DRBC sampling (see Appendix A); the twice monthly sampling in the spring is needed to capture the rapid changes in primary production in that period of time and the summer frequent sampling is to better assess BOD influence that might be less effectively sampled with monthly sampling.

The parameters measured in the routine sampling (see Appendix A) should be revised slightly. The river-run sampling has recently added the measurement of silicate while the measurement of chlorophyll allows assessment of Phytoplankton standing stock; silicate is an important plant nutrient that indicates the ability of the water to support diatom flora (important as the base of many aquatic foodchains). An addition needs to be made in the Minimal Monitoring Program for estimating primary productivity on a subset (about 10) of the sampling stations. While chlorophyll measurements will give an estimate of algal biomass and potential primary productivity, research in the Delaware Estuary shows that the productivity (carbon fixation) per unit of chlorophyll varies over a large range (about 30X) over spatial and seasonal scales. Also algal speciation should be made on a subset of about 6-8 stations on the routine sampling runs for evaluation of the ecosystem health and to look for occurrences and increases in nuisance algal species or their spores.

The semi-monthly DRBC sampling from March to November should be expanded with the addition of monthly winter sampling in December, January, and February. The reason for the addition is that during the winter, biological processes are at the annual minimum and river flow is moderately high causing a distribution of chemical constituents distinctly different from that of the spring and summer. At this time of year, the impact of the baseline loading with minimal modification can be best assessed (variable biological influences and extremely high or low river flow in spring and summer confuse the assessment of the distribution of point and non-point inputs). This addition will probably require a larger boat for sampling and is proposed as part of the Expanded Monitoring Program.

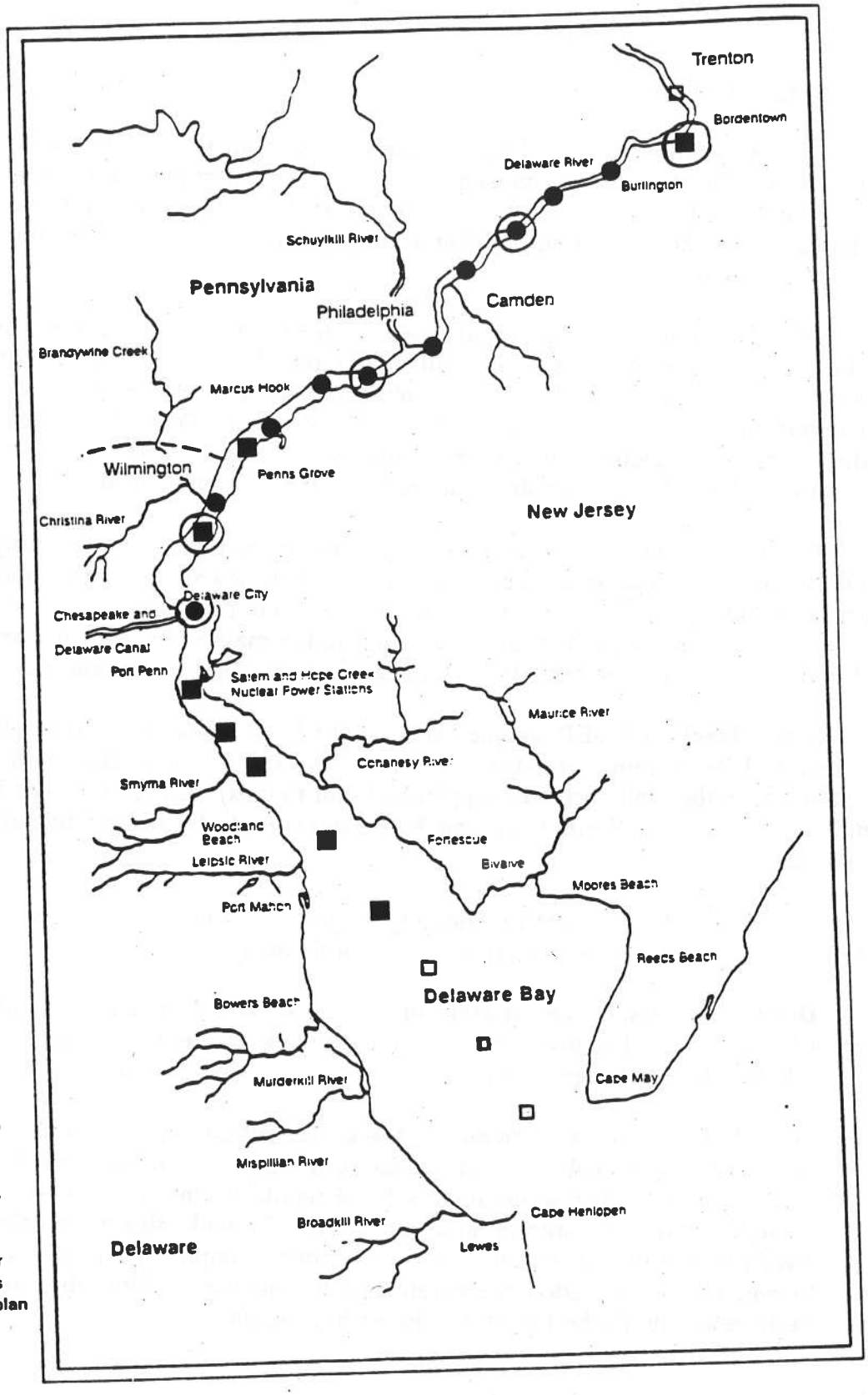


Figure 1. Location of stations for water quality and toxics monitoring. Both currently sampled DRBC stations and four stations proposed for addition are shown.

Subtributary Sampling

Several subtributary sampling programs are ongoing with prospects of continuation. These together represent a very important portion of the water quality monitoring plan of the Delaware Estuary Program. A recommendation is made for extending one of these programs by adding chemical analyses to samples collected in the sampling program.

DRBC: Annual sampling and analyses are funded by DRBC on the main stem at the Trenton falls (see Appendix C), conducted by the New Jersey Department of Environmental Protection (NJDEP). Sampling and analyses on nine Pennsylvania subtributary stations and the Schuylkill River (see Appendix D for details) is conducted by the Pennsylvania Department of Environmental Resources (PADER). These stations are a subset of a larger previously monitored tributary station collection.

Citizens: Monitoring on some of the other streams that were previously supported by DRBC funding could be covered by citizen monitoring activities. An example is the effort by the Delaware River Keeper office which monitors water quality and ambient stream conditions twice each month at 24 sites on the main stem and tributaries. Additional funding will be needed for supplies, training, calibration, and data processing.

Pennsylvania: PADER samples monthly for Water Quality Network (WQN) on the Schuylkill, Neshaminy, Brandywine, White Clay, and Red Clay subtributaries and at two stations on the Delaware (see Appendix D for details). Christina River Basin sampling (Brandywine, White Clay, and Red Clay) is part of a cooperative effort with DEDNREC.

New Jersey: NJDEP has six sampling programs of which three are subtributaries and three are bay networks (see Appendix C for details).

Delaware: Delaware Department of Natural Resources and Environmental Control (DEDNREC) has two bacterial sampling programs and one chemistry program on subtributaries (see Appendix B).

DEDNREC should add chemical analyses (dissolved oxygen and nutrients) on a subset of samples collected for the shellfish sanitation program on the bay. This coupled with NJDEP sampling could add significant information on the lower bay to augment the river run program of DRBC. To make this more compatible to river run monitoring, it is necessary to examine sampling frequency, coordination between states and adequate parameters for analyses. Chlorophyll analyses should be included in all the two state's lower bay sampling.

Remote Sensing

In-situ continuous sampling is also important to understand the overall picture of the estuarine water quality. Tide gauges maintained by the National Oceanic and Atmospheric Administration (NOAA) and USGS should be continued. It is possible to also place some other continuous monitoring equipment at these sites (e.g., for temperature, salinity, dissolved oxygen, light attenuation) and this will be explored.

It is desirable to maintain local meteorological stations with rain gauges and wind measurements in several locations throughout the estuary.

In-situ stations could also be established in two to three locations for water current speed and direction measurements; these would provide valuable information on water circulation necessary to understand transport of chemicals and living resources. NOAA has experimented earlier with a remote current measurement system in the Delaware Bay. These stations could be combined with other expanded monitoring activities mentioned above.

Overflight data from satellites can give very good areal coverage for surface temperature, suspended sediments, chlorophyll, and presence of oil slicks. These images are readily available but funding is needed to support purchase of data from EOSAT and data acquisition and analyses from both EOSAT and NOAA in order to make the images a part of monitoring. The possibility on how to make periodic imagery available will be explored.

Low altitude sensing by private contractors, particularly to detect non-point pollution, is under consideration by the DRBC.

National Weather Service (NWS) rainfall data on the Internet is another available data source that will be explored to be in support of local rain gauge data discussed above. Access and processing again requires a new effort; the data are available without charge and should be acquired and transferred to RIMS.

Minimal Water Quality Monitoring Program

Continue ongoing activity with:

1. Addition of 4 stations to DRBC river run
2. Addition of some primary productivity (10 stations) and algal speciation (6-8 stations) measurements
3. Incorporation of and support for citizen monitoring activities on subtributary streams
4. Addition of chlorophyll measurements to NJDEP routine lower bay sampling and possible increase of sampling frequency
5. Addition of chemistry and chlorophyll analyses to DEDNREC shellfish sanitation sampling program and possible increase in sampling frequency
6. Securing of future of NASQAN head-of-tide sampling

Expanded Water Quality Monitoring Program

Expand DRBC river-run sampling to include three samplings during winter months.

Expand tide gauge stations to also include *in-situ* physical and chemical measurements and current measurements.

Establish meteorological stations at several additional locations in the river and bay drainage system.

Obtain broad area imagery from satellite overflight data and support for interpretation of imagery.

Obtain rainfall data from Internet and transfer to RIMS.

An ability should be developed to have the rapid assessment monitoring capability to respond to infrequent events like major storms. These infrequent events cause major redistribution of water column and sedimentary chemicals and allow better evaluation of impacts of non-point source inputs that can cause major pulses in loadings.

TOXICS MONITORING PLAN

Objectives for Toxics Monitoring Program

The same two status and trends objectives and the future need of the Water Quality Monitoring Program apply to the Toxics Monitoring Program.

General Toxics Monitoring Program

The toxics monitoring includes three separate media groups: water column, bottom sediments, and biotic tissue. In addition, some level of toxicity testing should be done in conjunction with water column and sediment sampling. The main purpose for new toxics monitoring is to assess success of controls at point and non-point sources, and to establish adequate baselines to assess the impacts of accidental discharges or spills.

The water column toxics sampling should be done in conjunction with the water quality sampling, both in the center-of-the-channel sampling by DRBC and in the subtributary sampling by DRBC and the three states. Toxics analyses are proposed on only a small subset of stations (see Figure 1) used for water quality analyses because of the very high cost of sampling and analyses for toxic substances. Reduced numbers of samples are preferable to lower quality analyses. It is recognized that clean techniques for sampling and analyses are essential and that high sensitivity analyses are also important. While recognizing that a sample with below limits of concern (hence no detection) is confirmation of reasonable water quality, lower detection limits will provide data for both status and trends analyses and will provide for estimates of loading.

The sediment toxics sampling must be done in the silty shallow flanks and natural depositional areas of the estuary rather than in the center channel. The shallow areas are more representative of a depositional environment, than in the channel where shipping activity and dredging contribute to turbulence and resuspension of sediments. Since there is regular dredging and some toxics assessment by the U.S. Army Corps of Engineers in the channel, the additional sediment toxics sampling proposed here should only be done in the shallows and in some subtributaries.

The EPA's EMAP sampling of sediment and tissue for toxics was done in 1990-1993. No subsequent regular sampling is planned by EMAP for the Delaware Estuary. Therefore, some regular toxics sediment sampling will be instituted independent of EMAP. NOAA's Status and Trends Program monitoring gives further background on toxics but does not include sediment sampling and also does not have a guaranteed future. The new sediment sampling program should focus on areas already shown to have toxics problems where trends could be followed. A sampling interval of one or even several years may be adequate.

It is desirable to coordinate sampling for benthic invertebrates, sediment characterization, and chemical contaminants in the sediments. Using fish, amphipods, or other taxa, bioassay testing of water and sediment samples from the estuary should be part of monitoring. From these, toxic interactions can be implicated in ecosystem impacts. Rapid bioassay methods to assess stress in benthic organisms hold promise in future monitoring efforts. Although the committee does not see extensive use of these methods at present, their feasibility will be re-evaluated periodically for future use.

On toxics analysis of fish tissue, two separate issues should be considered: advisability of human consumption and health of the ecosystem. Each requires different sampling since the health of the ecosystem can only be evaluated on the basis of residency (resident fish or tissue analysis of migratory fish after time spent in the estuary with reference to concentrations at time of entry into the estuary). For human consumption, edible tissue of both resident and migratory fish could be sampled since both are consumed. Although there is not strong evidence of biomagnification, some of PAH's analyses in biotic tissue should be made since the PAH concentrations are very high and many of the compounds are very toxic. Because bioaccumulation has been associated with certain pathology, species with concentrations of organic compounds should be inspected for pathology.

Testing of raptors is an important way to assess contaminant accumulation, especially organochlorine compounds at higher trophic levels. USFWS has done some shorebird tissue testing. The NJDEP is doing regular testing of feathers, egg shells, and blood of raptors. This includes analysis of blood samples from pre-fledgling raptors collected during banding. These data should be examined as part of the toxics monitoring plan, especially if a toxics-related problem is suspected in bird populations. Some monitoring of predatory marsh mammals would provide valuable information on bioaccumulation of organic toxicants; this would be especially feasible if animals could be sampled from catch of fur trappers.

For an understanding of toxics loadings, wet and dry deposition from atmospheric sources are important. Since several stations of the national precipitation network are maintained by PADER and academic researchers, data on acidity, metals and organics in rainwater should be acquired by RIMS and examined.

Minimal Toxics Monitoring Program

Water Column Toxics

Routine DRBC river-run sampling includes analyses of selected total and dissolved metals (Cu, Pb, and Zn) and volatile organic compounds on a subset of 10 of the currently sampled 18 water quality stations. It is suggested that one station be added above the Burlington-Bristol Bridge, one at Port Mahon, while one or two existing stations be dropped. Ni analyses should be added (total and dissolved) and Hg should be added as an analyte using more sensitive techniques than those currently available.

Subtributary sampling by PA and NJ also includes other metals (such as Ni, Hg, As, Cd, Fe, Se) in addition to the three of the DRBC program, as well as analyses of chlorinated pesticides and PCBs. All subtributary sampling should have Ni, Hg, Cu, Pb, and Zn analyses.

Some toxicity testing on samples from 4 stations in the urban region of the river and one each in the transition zone and lower bay should be done on DRBC river-run samples. These tests should be done both during the low flow summer period and at higher flow conditions in the spring.

Fish Tissue Contaminants

Five stations are now sampled once a year as part of the DRBC toxics program (see Figure 1). At each station, composites of filets from five specimens of two species (white perch and catfish) are analyzed for various metals and organics (see Table 6 in Appendix A).

NOAA's Status and Trends Program samples up to six locations in the Delaware Bay for mussels or oysters on alternate years. EPA's EMAP did some tissue sampling of forage fish but future efforts are uncertain. The Food and Drug Administration carries out annual sampling of market fish.

Fish advisory data shows the need for more routine sampling in the future. DEDNREC is planning future sampling to follow up on their fish advisories; but this would not be done on an annual basis. PADER Water Quality Network (WQN) stations do have some fish tissue sampling. The CCMP action plan for establishing standard criteria for fish advisories (T6) should insure that there will be sampling on a continuing basis.

Sediment Toxics

No regular sampling is planned.

Expanded Toxics Monitoring Program

The Expanded Monitoring Program would include water column toxicity testing, sediment sampling of the shallow nearshore areas of the estuary, and sampling of fish and benthic organisms for toxics accumulation. Other organisms including otter, mink, shorebirds, raptors and colonial wading birds should also be sampled for accumulation of toxics. Sediment sampling should include sediment characteristics and sediment bioassays at a number of stations and should utilize aspects of both systematic and randomized sampling design to give meaningful results. Fish tissue should be analyzed for dioxin which DEDNREC and FDA are now considering. Although sampling would not necessarily be a single complete annual survey, the cost on an annual basis for periodic (two to four year intervals) sampling would be about $110,000.

Delaware Valley Regional Planning Commission Mapping

Focus on satellite imagery is good for the mapping activity. However, considerable lower altitude areal photography and on-the-ground activity also needs to be pursued. The Delaware Valley Regional Planning Commission (DVRPC) is doing a land cover inventory with emphasis on human activity (see Appendix G) presently funded by the departments of transportation of PA and NJ. It is desirable to have this program extended into the state of Delaware, but this has not yet occurred. This monitoring plan strongly endorses such extended coverage. This land use approach when extended into Delaware would provide an excellent snap shot today, and should be institutionalized for future continuation.

Citizen Monitoring

Citizen monitoring with inexpensive portable global positioning systems (GPS) for location verification could be a reasonable and inexpensive way to get ground truth input on habitats and land cover. A small grants program from the DELEP could assist local groups in doing such ground truth sampling.

Other Considerations

When habitat/land cover discussions are considered, we should be certain that submerged and subtidal lands are not overlooked. This should include coverage of the full estuary bottom with location of channels and shellfish beds in the lower estuary and of submerged aquatic vegetation in the fresh water region (today, there is essentially no submerged aquatic vegetation in the Delaware Bay). These habitats are essential to many critical aquatic organisms including those fish and invertebrates of commercial importance, those which are endangered species, and organisms of ecological importance.

The CCMP Habitat Chapter contains several actions that build upon work currently getting started by the Nature Conservancy and state Natural Heritage Programs, to consistently classify, map and rank the natural plant communities. By building on the foundation prepared by GAP, and working cooperatively so that the needs of the Delaware Estuary Program and the state Natural Heritage Programs are met, it will be possible for the first time, to evaluate habitat losses and prioritized habitat protection efforts from a regional perspective.

Completion of Baseline Landcover Monitoring

Three different habitat/land cover/land use programs are recommended as the composite baseline for the Delaware Estuary. The first is the local effort of the National GAP Project, which gives a good large scale habitat mapping. This project is expected to be completed by 1997.

The second program is the land use mapping already completed by DVRPC for the critical counties in PA and NJ. This effort is being extended to the 3 remaining NJ counties in 1995 and should be extended into DE as soon as possible. This monitoring plan recommends such extension.

The third program is the detailed GIS mapping being done by NJ. It provides a finer scale grid for both habitat and for human land use activities. Although expensive, similar efforts should be undertaken in Delaware and Pennsylvania. Neither of those states have the hardware development and established GIS efforts of NJ, but both have interests. Although this extension into the other two states may take several years, eventually it should be done. Mapping the land use/land cover will provide an accurate data set that will benefit many agencies involved with land use planning and conservation efforts, at the local, county, and regional level. Because of its value and utility for a wide group of users, the cost can be spread out by establishing partnerships among these users, which will also reduce duplicative costs and efforts. Costs can be further reduced by training citizen monitoring volunteers to conduct the extensive field work required.

Future Monitoring for Land Cover Trends

If the DVRPC effort can be extended into the 3 Delaware counties, the full estuary region would have a good land use baseline. Since DVRPC has already been doing 5-year updates of its current 9 county coverage, the same periodic renewed survey effort is recommended for the extension to the appropriate NJ and DE counties.

The GAP mapping effort for habitat for the appropriate areas of the three states should be updated at 5 - 10 year intervals.

GIS mapping efforts should be started in DE and PA as recommended in the CCMP. Detail should be comparable to the NJ GIS and updates done periodically for trend monitoring.

HABITAT/LAND COVER/LAND USE MONITORING PLAN

Objectives for Habitat/Land Cover/Land Use Monitoring Program

1. To delineate current land use and land cover as a baseline for determining the areal extent of critical habitat for priority species (including fragmentation and connectivity, species composition and substrate characteristics), growth and development and human population and economic trends (including water use & supply).

2. To document changes in land use and land cover and analyze trends in critical habitats for priority species, growth and development and human population and economic trends.

To meet these objectives several technical issues must be considered. Uniform classification schemes should be used for broad areal coverage and appropriate schemes for specific delineation purposes. Minimal information needs must be identified. Delineation should be updated at a frequency of five to ten year intervals. All monitoring data should be in digital or converted to digital format.

General Habitat/Land Cover/Land Use Program

An overview of habitat and land use monitoring needs has been described in the contract monitoring plan report (Tetra Tech, 1994). The plan presented below gives more specifics on how to gather and assess the land cover mapping information. Since the mapping of land cover is the critical mechanism for studying both habitat and land use, it was decided to combine these two areas which were treated separately in the early planning of the monitoring design. With recently completed large area mapping and ongoing activities, a first attempt baseline is available for the entire estuary region. However, this coverage is uneven. Therefore, instead of listing a minimal and expanded program at the end of this habitat/land cover/land use section, we have listed two areas, one of "completion of baseline monitoring" and the second of "future monitoring". For the baseline study to be adequate, more effort is needed in the next few years which will be fairly expensive and this is outlined below. The effort to periodically update a good baseline is considerably less expensive than the first step; this is also discussed below. Decisions must be made in the near future of the actual frequency on which mapping surveys must be redone for accurate trends monitoring.

Significant Habitat Mapping

The USFWS, in cooperation with the DELEP is mapping the significant habitats of the priority species in the estuary. This mapping effort is designed to give a regional picture of long term habitat needs for use by land use decision makers and wildlife managers. The cost of this project (funding from EPA, USFWS and State match) was

approximately $200,000. Due to the nature of these analyses (long term needs and regional scope) it is not anticipated that this will need regularly scheduled revisions. However, as our understanding increases, and/or species are added to the Priority Species List, some additional mapping will need to be undertaken.

State Coastal Zone Efforts

The efforts of the individual states in complying with coastal zone management plans must be better incorporated into the baseline and followup trends monitoring efforts. In the non-point source section of the Tetra Tech report (Tetra Tech, 1994), there are statements about the importance of monitoring, but no real plan is recommended. Currently the three states are doing non-point source inventories as part of their 6217 efforts, and there is interest in better coordination for this as well as possibly more NOAA money to assist the inventories. Our plan should endorse this effort and urge continuation as part of future monitoring.

The participating states of the DELEP have made efforts to share and make compatible their GIS systems and to also integrate their efforts with those of the USFWS and NOAA on habitat and land cover. A great deal of progress has been made in this attempt of compatibility, but more needs to be done and the proposed monitoring plan can hopefully assist in this effort.

National GAP Project

The National GAP Analysis Project (GAP) is now doing extensive mapping of land cover/land use with a focus on plant communities and habitat (see Appendix H). The period of the current mapping is 1992-1993. This effort is being done by USFWS, the National Biological Survey, the states (including MD DNP), the Nature Conservancy, and Johns Hopkins University. EPA is assisting in mapping of urban and agricultural areas. Since this mapping effort covers the entire estuary region, it is considered a good baseline study. While there is a desire to do followup surveys in the future for trend, a strong recommendation from the DELEP will be valuable to justify continued effort. The GAP and other interagency cooperation on thematic mapping can give the large areal coverage that is too expensive to undertake solely by the DELEP.

New Jersey GIS Coverage

The State of New Jersey has produced an extensive land cover inventory of the entire state with coverage of its entire Delaware Estuary coastal region (see Appendix C). This thematic mapping effort is on a larger grid scale than that of the GAP program. It is desirable to have a similar grid scale mapping with compatible GIS system done in Delaware and Pennsylvania. Like the GAP mapping, it will provide a good baseline for future trends analysis of land use and habitat and like the GAP mapping, the periodic update effort will be much less expensive than the original.

LIVING RESOURCES MONITORING PLAN

Objectives for Living Resources Monitoring Program

The two objectives for the monitoring of living resources are to:

1. Estimate relative abundance and trends of populations of priority species and

2. Estimate overall ecosystem health in terms of production and diversity and trends.

Within the populations of living resources, many of the organisms of interest in the estuary are difficult to monitor without a very large and complex sampling plan and insufficient financial resources are available for such an effort. As a result, two groups (fish and benthic invertebrates) are chosen as those living resources most critical to monitor and for which there are viable sampling plans for detailed monitoring. These two comprise the major proposed monitoring plan which is the subject of the next section and the populations referred to in the minimal and expanded monitoring plans listed below. Monitoring of invertebrates, birds, amphibians, reptiles, mammals are important and should be continued. In most cases, there are ongoing monitoring activities for these groups , but the activities are done as minor periodic efforts by state or federal agencies or private organizations and thus are not as regular nor methodical (but are important) as the current monitoring activities for fish or proposed monitoring activities for benthic invertebrates.

General Living Resources Monitoring Program

Tetra Tech (1994) presents plans for monitoring of benthos and demersal fish after discussion of the broader aspects of living resources. The plan for the demersal fish is an expanded version of that being done by DEDNREC and NJDEP and the plan for the benthic sampling is based on that used by the EPA EMAP program. These two monitoring plans served as partial directions for our plan, however, they were not comprehensive enough and the EMAP monitoring probably will not persist.

Population Abundance and Trends

Fish

Tetra Tech, (1994) concluded that pelagic fish, while important, should not be monitored at this time because "there is currently no agreed-upon and meaningful way to assess the results of such a monitoring effort that can be used to link conditions in the estuary with trends in the pelagic fish community". This is probably not a reasonable conclusion. Trends in the pelagic fish community are very important to follow and those of some species, e.g. striped bass and shad, are one of the main reasons for public interest in the Delaware Estuary. Assessment of pelagic fish populations, although not as complete or thorough as desired, is an integral part of the trawl survey and beach seine survey in the proposed plan. Striped bass, white perch, catfish, summer flounder, and shad are sampled adequately by the trawl and beach seine surveys.

Monitoring for fish in the Delaware Estuary is done as a combination of trawl sampling within the river and bay system and beach seine surveys along the shores of the upper bay and river. It was felt that the existing trawling activity of the two states with minor modification and some planned additional monitoring would give adequate coverage to assess demersal fish populations and would aid in assessing populations of pelagic fish. Beach seine surveys in the river and upper bay gives good coverage of juveniles which can be translated to assessment of both demersal and pelagic fish populations.

The trawl sampling plan is built on a current monitoring activity of DEDNREC, NJDEP (with minor expansion), and additional monitoring by Public Service Electric and Gas Company (PSE&G). Figure 2 shows the location of the current trawl survey sampling stations for DEDNREC and NJDEP. Details of these two sampling schemes are given within appendices B and C. Discussion is underway between DEDNREC and NJDEP to alter the trawl stations slightly for more uniform and comprehensive coverage. In addition, discussions are underway to plan additional trawling by PSE&G that will be compatible with and augment the efforts of the two states. Most of the trawling is done with 16 foot trawls. Less frequent trawling by Delaware with a 33 foot trawl on their side of the bay and NJ sampling with a 100 foot trawl at the mouth of the bay, gives

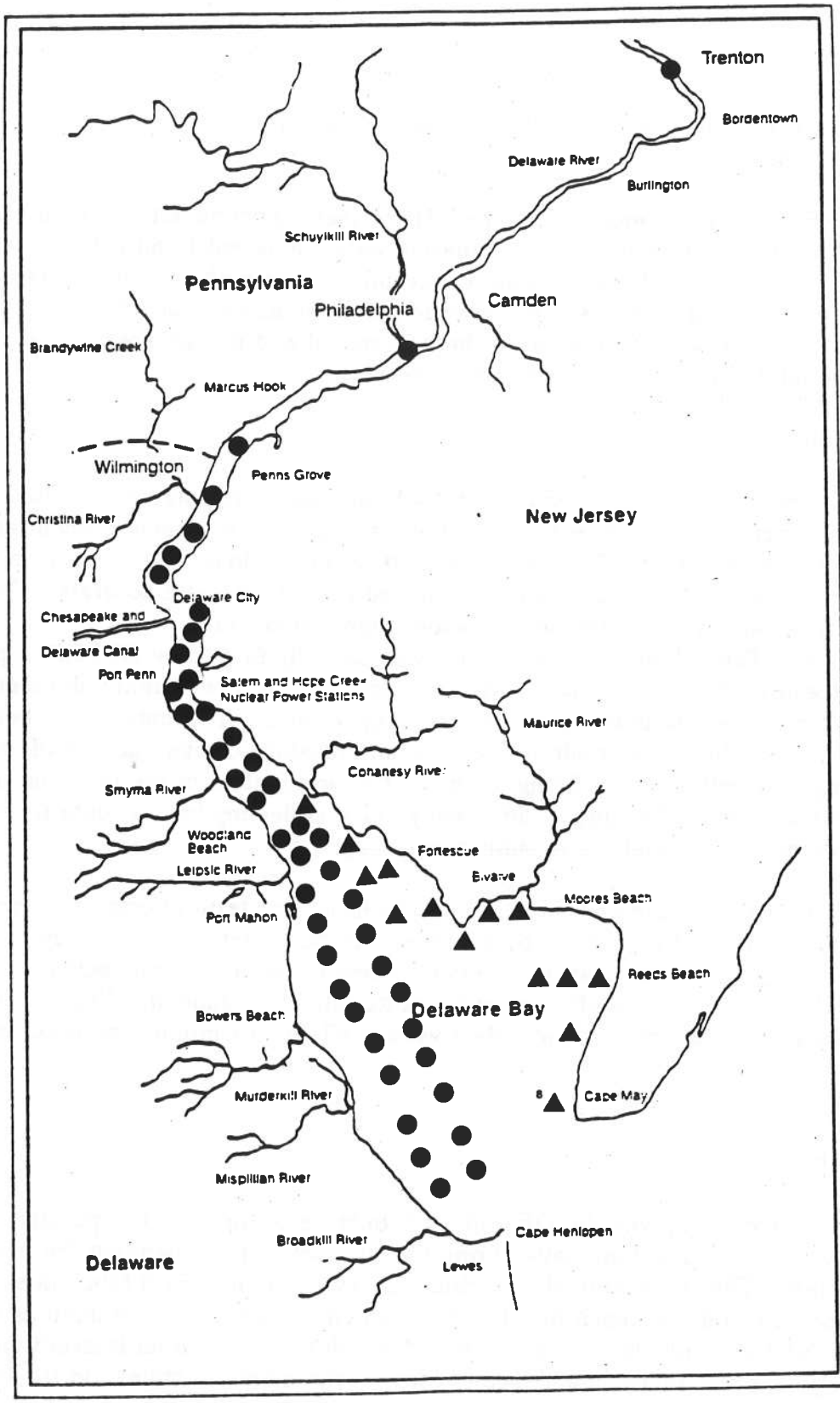


Figure 2. Location of fish trawl stations currently sampled by the states of New Jersey and Delaware.

additional information, especially important for assessing the larger pelagic adult fish populations.

Beach seine sampling done by NJDEP (see Appendix C) covers the upper bay and tidal river sufficiently for the estuarine waters adjacent to all three states. These surveys are designed for assessment of juvenile indices with special emphasis on striped bass and shad and provides data on white perch, menhaden, and bay anchovy and other species. As a result, populations of both demersal and pelagic species and of both residential and migratory species are assessed.

Invertebrates

The trawl surveys provide useful information on populations of blue crabs and horseshoe crabs although inclusion of these two species has been a recent addition to the 33 foot trawl program. The horseshoe crab census as done in the past by a volunteer network beach survey needs to be redesigned to make it more accurate. Data from the state trawl surveys will provide a valuable supplement to the beach survey population estimates. The volunteer survey, which was partially funded by DELEP in past, could be recast and made more accurate. A serious problem has been that volunteer labor necessitates one pre-determined day and large number of volunteers. A better beach survey should be made (multiple days, better statistical design, more professional staffing). A better plan is being discussed by coordinators of the previous surveys (Carl Shuster and Benjie Swann). Additionally, NJ is collecting harvest data from permitting of licensees. DE should have similar reporting.

For oysters, the states of DE and NJ have long term efforts which should be continued. Recent evaluation of the long term NJ oyster survey (Fegley et al, 1994) provides a good assessment of the effectiveness of the monitoring activity. Although the report finds sampling insufficient at times for adequate understanding of the dynamics of the oyster populations, sufficient data were available for monitoring populations.

Birds

Shorebirds

Shorebird surveys by DE and NJ should be continued. Cooperative weekly aerial surveys are conducted annually during the six week period spanning the peak spring migration. The International Shorebird Survey (Manomet Bird Obs.) does annual counts of shorebirds on the beach in NJ. These activities should be continued as the minimal plan. NJ has conducted aerial surveys of marsh transects on an intermittant basis (last three years) that relate abundance of birds in the marsh to counts on the beach. A future expansion should include funded marsh transects (spring through fall) in both states and more frequent overflight surveys or qualification of overflight surveys with estimates of residence time of individuals.

Colonial Nesters

Surveys of colonial nesters (gulls, terns, waders) by NJ are limited to the Atlantic coast and are conducted approximately every four years; least terns are surveyed annually. The Pea Patch Island heronry in the Bay is surveyed by DE but without secure funding. PA surveys the heronry on Tinicum Island. Funding should be secured for surveys of colonial nesters (not necessarily every year) on both sides of the Bay as part of the minimal plan. Surveys could be expanded to provide an indication of toxics accumulation.

Waterfowl

State surveys for Black Ducks although adequate for hunting management are limited in assessing breeding populations. Currently spring and summer surveys are conducted by Delaware Division of Fish and Wildlife and the USFWS. These surveys should be continued and evaluated for their utility in adequately assessing the status of black duck breeding in the Delaware Bay. New Jersey Department of Fish, Game and Wildlife surveys of black ducks are conducted in spring only and are designed to obtain an index for the flyway population, not the local Delaware Bay population. The annual Delaware Bay Mid-Winter Waterfowl Survey (USFWS) covers the entire Delaware Bay and provides information on migratory and wintering waterfowl, in the Delaware Bay Region. Snow geese, which represent a significant management problem, are included in the Mid-Winter Waterfowl Survey. However, there is no systematic survey of migrating waterfowl along the Delaware River. Skilled volunteers such as the birding community in the Philadelphia area, could be utilized to fill gaps in monitoring programs.

Raptors

State surveys of raptor populations should be continued. NJ monitors bald eagles by surveying each nest weekly or biweekly during the nesting season; osprey and peregrine falcon nesting areas are surveyed one or twice per season. NJ has assessed toxics contamination in both unhatched eggs and feathers of breeding raptors because there are indications of decreased productivity of nesting pairs when compared with Chesapeake Bay and Atlantic coast (NJ) populations. DE monitors eagles and raptors. PA monitors nesting peregrine falcon on the large bridges over the river between PA and NJ. Other groups of raptors, such as migrating birds, may be adequately covered by migration point counts e.g. Cape May Bird Observatory counts at Cape May Point.

Other

Breeding bird survey, Audubon Christmas count, wildlife refuge surveys, and Partners in Flight future monitoring data should be evaluated for utility to overall estuarine evaluation. Breeding bird survey, Partners in Flight (for neotropical migrants), Audubon Christmas counts are all good but do not adequately cover many species.

Recommend states working with Partners in Flight to coordinate breeding bird surveys, neotropical migrants, and Audubon counts into a more secure program. The Audubon Christmas counts are conducted in all three states with noted areas including the Cape May region in NJ, the Bombay Hook sanctuary in DE, and the recent Philadelphia County area. Major changes can be seen in these surveys; e.g. dramatic decline of wintering Ruddy Duck populations in PA.

Estuarine Dependent Amphibians, Reptiles and Mammals

Vernal pools are a vital link between the estuarine and upland environments. Selected species, particularly amphibians, that rely on vernal pools for breeding should be monitored because of their sensitivity to pollution and land use changes and food chain linkage to estuarine waterbirds. The monitoring by the State Natural Heritage Inventory Programs and others should be evaluated for consistency and utility to provide an overall watershed evaluation. Efforts should continue and modified is appropriate.

Mammals, especially muskrats in the marshes are important indicators and are of commercial importance. But, river otters may actually be better indicators because of their position in the food chain. Although there is no current consistent monitoring, future expansion should consider some assessment of estuarine-dependent mammals.

Estuarine-dependent reptiles, such as the diamond back terrapin are also important to monitor. As with the mammals, these should be the subject of consideration for future expansion.

Overall Ecosystem Health

Phytoplankton

Biomass, production and speciation are included in the preceding minimal Water Quality Monitoring program.

Plant Communities

Wetland vegetation is included in habitat monitoring. Considerations should be given to include submerged aquatic vegetation in the freshwater region of the estuary for future expansion.

Benthic Assemblages

It is proposed that a major new monitoring plan be instituted for assessing benthic assemblages. Efforts of PA, NJ, and DE on invertebrates in non-tidal streams give some important information on watershed outside of tidal region. However, there is no

continuing benthic survey activity in the estuary proper. The recommendation by Tetra Tech (Tetra Tech, 1994) has been modified slightly for the plan presented here.

The monitoring should use a stratified random sampling design, modified slightly from prior sampling. The plan should include 12 to 24 sampling stations in the lower bay, 8 to 16 stations in the tidal river and 14 to 28 stations in the subtributaries.

In the past several years, the EPA EMAP study collected extensive benthic samples in the Delaware Estuary and used the sampling to help design needed sampling density for estuaries in general. The results of that investigation (Weisberg et al, 1993) indicates that 24 samples per year in the lower bay are probably sufficient to characterize the benthic invertebrate communities within the precision required (i.e., 80% probability of detecting trends representing twofold to threefold changes over a period of 10 years with 90% confidence). Similarly, 16 samples along the Delaware River associated with 4 zones and 4 samples in each of the subtributaries (28 total) are probably sufficient to meet the performance criteria.

A contract study for DELEP addressed benthic populations in the region from the C&D Canal to the head of tides in the tidal river (Environmental Consulting Services, 1993). That report plus the EMAP study gives a good baseline for future benthic monitoring. The proposed monitoring should have benthic sampling with identification, and some sediment characterization; but with total coverage less frequently than annually, so that complete coverage is made on a 3 to 5 year basis. Figure 3 shows approximate sampling density for the entire estuary for the full coverage.

Evaluations from Population Sampling

Valuable information for assessment of ecosystem health can come from trend analysis for population abundance. Some trend analyses have been made in the past of fisheries using both trawl and beach seine surveys and using landings data. An important role of the Monitoring Coordinator will be systhesis of monitoring data in all categories.

Other Ecologically Important Species

Other ecologically important species will be considered at a future date as management activities dictate. There is an action step relating to the protection of priority species (H9), where necessary, by regulatory means. This will not be possible without knowing status and trends of these species - this requires monitoring. It will be possible to use map products from GAP analysis and significant habitats projects to define sampling universes for monitoring a subset of priority species.

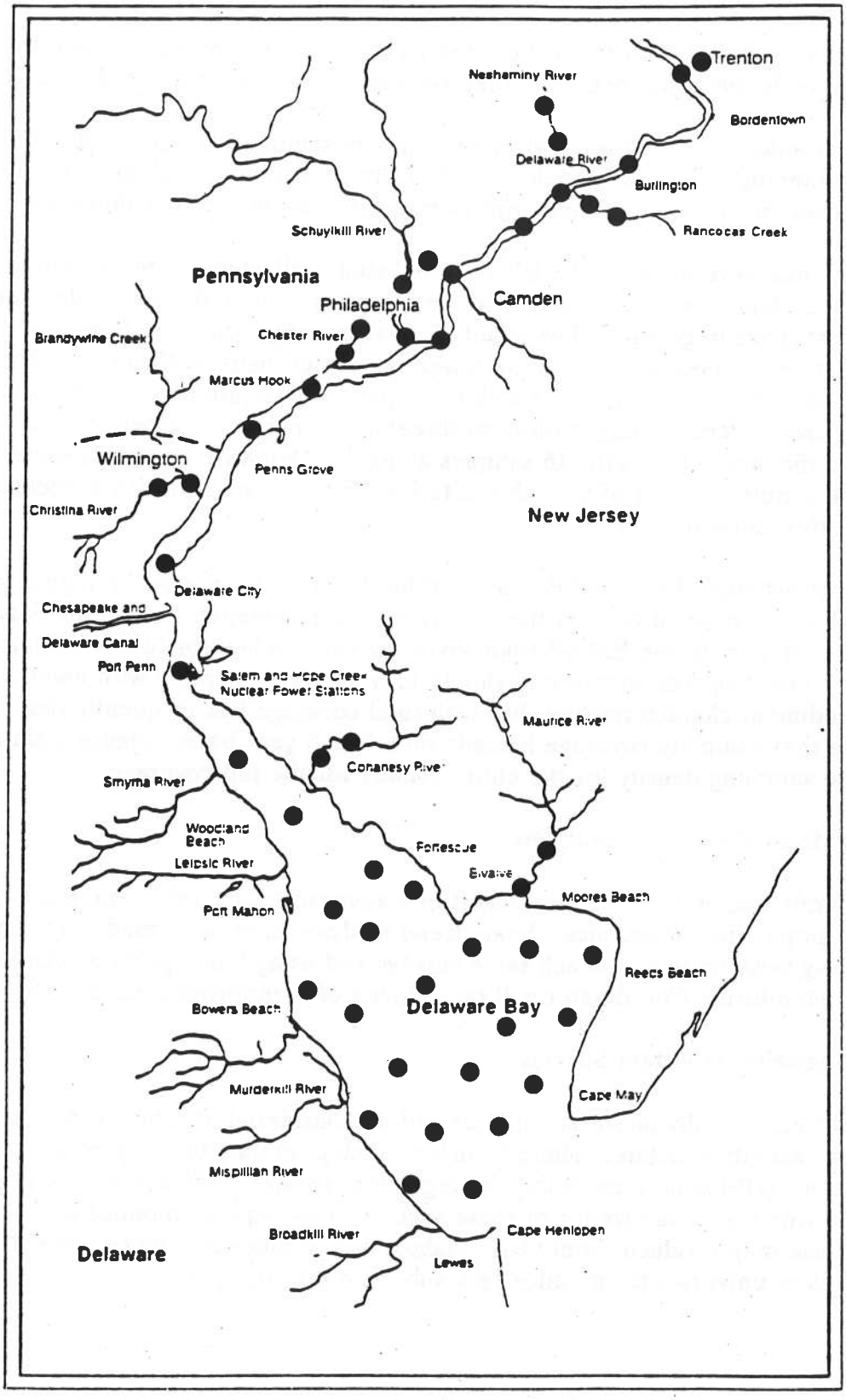


Figure 3. Proposed benthic monitoring stations.

Minimal Living Resources Monitoring Program

Population Abundance and Trends

Fish

The primary item of the minimal monitoring program is the combination of the fish trawl and beach seine fish sampling being done by NJ and DE. As is discussed above, these efforts with minor modification for better overall coverage and with additional trawl sampling being proposed by PSE&G, will give good ongoing monitoring for demersal fish and fair monitoring for pelagic fish. Thus, no new effort is proposed other than those minor modifications already being pursued.

Other priority species monitoring is ongoing, but needs strong endorsement from the Delaware Estuary Program to protect the diffuse small efforts in various state and federal agencies as well as private efforts. These are discussed below.

Invertebrates

Blue Crabs - Continue as part of state fish trawl surveys.

Horseshoe crabs - the volunteer beach survey should be revised and continued with reference to data from state fish trawl surveys.

Oysters - surveys by NJ and DE should be continued

Birds

Shorebirds - DE, NJ, and volunteer activities should continue

Colonial Nesters - PA, DE and NJ survey should continue.

Waterfowl - DE, NJ, and USFWS efforts should be continued with special emphasis on black ducks and snow geese

Raptors - Efforts by all three states on bald eagle, peregrine falcon, and osprey should be continued with both surveys and estimates of toxics influences.

Other

Breeding bird surveys as volunteer effort should continue. Effort by Partners in Flight for surveys of neotropical migrants should be encouraged. The Audubon Christmas bird counts should definitely be encouraged to continue.

Estuarine Dependent Amphibians, Reptiles and Mammals

Vernal pool herptiles - The minimal commitment by state non-game agencies and by the National Heritage Inventory Program is not very strong. There is no other plan for any monitoring of this group.

Estuarine dependent mammals - Although there are several important species such as muskrats and river otters which can give good indications of overall estuarine health, there are only casual state records that could give any trend estimates.

Estuarine dependent reptiles - The ability to track species such as the diamond back terrapin are again relegated to chance by state agencies.

Ecosystem Health

Phytoplankton is included in the Minimal Water Quality Monitoring Program

Plant Communities - Some wetland vegetation monitoring is included in the habitat mapping efforts and the National Heritage program.

<u>Expanded Living Resources Monitoring Program</u>

Benthic Assemblages - The primary item of the expanded monitoring program is the survey of benthic assemblages. It is recommended that this program be started and continued as an integral assessment of the ecosystem health of the estuary.

Plant Communities - Aquatic macrophyte monitoring should be established in the future.

OVERALL MONITORING PLAN

The monitoring plan is to be implemented by 6 action steps; a temporary one for the Year 6 DELEP activities, four permanent ones to establish and coordinate a minimal monitoring program, and an additional one for an expanded monitoring program. This description of the overall plan is consistent with the Monitoring Chapter in the final CCMP.

ACTION M-1: Establish an interim Monitoring Advisory Group.

Starting in February 1995, an interim advisory group will be established by the DELEP to guide implementation of the monitoring plan. Membership of this group should include representatives from state and federal agencies, academic institutions, industry, and the general public. The group will be responsible for developing the final design of the monitoring plan as well as assisting DELEP in obtaining commitments from parties involved in implementing the monitoring plan. Since one of the primary intents of the monitoring plan is for cooperation of ongoing activities, this group will work toward a successful consolidated plan with participation of all parties instead of a new activity or a mandate to agencies in the area. Since the full implementation of the monitoring plan will lag slightly behind the establishment of this interim committee, the interim committee will begin efforts of better quality assurance of measurement methodology between cooperating agencies.

Resource Needs: No new financial resources above that available through the DELEP and the participating agencies to support planning meetings of its members.

Measure of Success: Interim monitoring committee established.

ACTION M-2: Establish a permanent Monitoring Advisory Committee.

By January 1996, a permanent Monitoring Advisory Committee will be established by the Delaware Estuary Foundation with formal appointment of members representing a designated list of agencies and organizations. The list for membership will be suggested by the interim Monitoring Advisory Group. The Monitoring Advisory Committee will guide the Cooperative Monitoring and Mapping program and advise the staff (see Action M-3). The Committee will report to the Estuary Foundation.

Resource Needs: See action plan 3 below.

Measure of Success: Monitoring Advisory Committee established.

ACTION M-3: Establish the Office of Monitoring and Mapping.

By January 1996, a monitoring office will be established with a full time Monitoring Coordinator who will work closely with the Monitoring Advisory Committee. The Coordinator will work with the staff of the Regional Information Management System (RIMS) so that when monitoring data are received they rapidly will be made available to all interested users. In the first two years, the Coordinator will emphasize coordination of monitoring activities within various agencies and quick acquisition of the resulting data from these activities and transfer to the RIMS. A major effort will also be made to insure compatible and consistent analytical quality assurance of measurements made by the various participating agencies and to reduce redundancy and costs. By the third year, the Coordinator's activities will shift more toward evaluation and interpretation of the monitoring information. Both the coordination and evaluation of monitoring will be done in close conjunction with the Monitoring Advisory Committee.

Resource Needs: For salary support of the Monitoring Coordinator and operation of the office for facilitation of input from the Monitoring Advisory Committee, a budget of $100,000 is needed annually with appropriate increases in future years.

Measure of Success: Monitoring coordinator hired, office established and funded.

ACTION M-4: Implement the Minimal Monitoring Program.

The Minimal Monitoring Program will incorporate existing monitoring activities with slight extensions as is defined by the Delaware Estuary Cooperative Monitoring Report. It will be based upon collection and evaluation of data collected by existing agencies and will have no new independent data collection and analyses activities.

Resource Needs: To implement the Minimal Monitoring Program, agencies identified as having current monitoring activity (DRBC, DEDNREC, NJDEP, PADER, USGS, USFWS, NOAA, Audubon Society, Natural Heritage Inventory Program) would need to continue their monitoring; the cost of that continued activity is estimated at about $3 million annually (to be further analyzed). In addition, $375,000 (to be further analyzed) new funding will need to be obtained annually (with appropriate future increases) for the proposed extensions in Minimal Monitoring Program.

Measure of Success: Program funded and implemented.

ACTION M-5: Implement the Expanded Monitoring Program.

The expanded monitoring plan will include the items mentioned in the Delaware Estuary Cooperative Monitoring Report in each of the four monitoring areas.

Resource Needs: New funding of about $900,000 for those items listed in the report to be further analyzed).

Measure of Success: Funding secured and expanded plan implemented.

ACTION M-6: Evaluate and Report Monitoring Information.

For either the Minimal or Expanded Monitoring plan, there will be regular evaluations of the information derived from synthesis of the monitoring data. An annual report will be made of the monitoring summary with identification of the data in the RIMS. Every 3 to 5 years (to correlate with timing of CCMP action plans) a more complete summary of the annual monitoring information will be made with assessment of status and trends and recommendations for modifications, deletions, and additions in the program. New preliminary findings will be distributed in Delaware Estuary newsletters as quickly as possible, even prior to annual reports.

Resource Needs: Support for this reporting is part of the Action M-3 above.

Measure of Success: Completion of annual reports, newsletter information on monitoring data, and data from monitoring plan in the RIMS.

REFERENCES

Bauersfield, W.R., E.W. Moshinsky, and C.E. Gurney. 1994. Water Resources Data: New Jersey, Water Year 1993. Volume 1. Surface Water Data. U.S. Geological Survey Water Data Report NJ-93-1. U.S. Government Printing Office. 503p.

Delaware Valley Regional Planning Commission (DVRPC). 1994a. Land Use in the Delaware Valley, 1970-1990. Analytical Report No. 2. Delaware Valley Regional Planning Commission, Philadelphia, PA. 136p plus appendices.

Delaware Valley Regional Planning Commission (DVRPC). 1994b. Atlas of the Delaware Valley. Report No 14. Delaware Valley Regional Planning Commission, Philadelphia, PA. 27p oversize.

Environmental Consulting Services. 1993. Survey of benthos; Delaware Estuary from the area of the C&D Canal through Philadelphia to Trenton. Delaware Estuary Program. 139pp plus appendix.

Environmental Monitoring and Assessment Program (EMAP). 1994a. Statistical summary, EMAP-Estuaries, Virginia Province-1991. U.S. Environmental Protection Agency. U.S. Government Printing Office (Washington, D.C.). 77p. and appendices.

Environmental Monitoring and Assessment Program (EMAP). 1994b. Statistical summary, EMAP-Estuaries, Virginia Province-1992. U.S. Environmental Protection Agency. U.S. Government Printing Office (Washington, D.C.). 63p. and appendices.

Fegley, S.R., S.E. Ford, J.N. Kraeuter, and D.R. Jones. 1994. Relative effects of harvest pressure and disease mortality on the population dynamics of the eastern oyster (*Crassostrea virginica*) in Delaware Bay. Rutgers University (Port Norris, NJ). 36p. plus tables and figures.

Intergovernmental Task Force on Monitoring Water Quality (IGTF). 1994. The strategy for improving water-quality monitoring in the United States: Final Report of the Intergovernmental Task Force on Monitoring Water Quality. Draft, September 1994.

James, R.W., R.H. Simmons, and B.F. Strain. 1993. Water Resources Data: Maryland and Delaware: Water Year 1993. Volume 1. Surface Water Data. U.S. Geological Survey Water Data Report MD-DE-93-1. U.S. Government Printing Office. 364p.

National Estuary Program (NEP). 1994. Technical Characterization in the National Estuary Program. U.S. Government Printing Office (Washington, DC). 46p.

Sutton, Clay. 1995. Characterization of the Delaware Estuary. Draft document prepared for the Delaware Estuary Program.

Tetra Tech, Inc. 1994. Delaware Estuary Program Regional Monitoring Plan. Volumes 1 and 2. Delaware Estuary Program (Philadelphia, PA).

Weisberg, S.B., J.B. Frithsen, A.F. Holland, J.F. Paul, K.J. Scott, J.K. Summers, H.T. Wilson, R. Valente, D.G. Heimbruch, J. Gerritsen, S.C. Schimmel, and R. W. Lattimer. 1993. EMAP-Estuaries Virginian Province 1990 demonstration project report. EPA 600-R-93/006. U.S. EPA, Environmental Research Laboratory (Narragansett, RI).

White, K.E., T.E. White, R.L. Druther, and P. Moleski. 1993. Water Resources Data: Pennsylvania, Water Year 1992. Volume 1. Delaware River Basin. U.S. Geological Survey Water Data Report PA-92-1. U.S. Government Printing office. 340p.

Appendix A - Current DRBC Monitoring Activities

DEDNREC, under annual contract with the DRBC, conducts a boat run, center channel monitoring of the estuary. The locations of sampling are shown in Table A1. Samples are collected at a depth of three feet below the water surface at low or high water slack. Parameters analyzed and frequency of sampling, conducted March through November, are shown in Table A2.

PADER, under annual contract with the DRBC, monitors water quality of tributaries to the Delaware. Streams are annually sampled six times at each of the locations shown in Table A3. Sampling is three times in the June through October period and once each in the fall, winter, and spring. Tidal streams are sampled at head of tide during low water slack. Parameters analyzed are shown in Table A4. VOC analyses are done for three of the six samples for each tributary.

NJDEP, under annual contract with the DRBC, monitors the Delaware River above the falls at Trenton. Sampling is seven times per year for the parameters shown in Table A5. NJDEP, under annual contract with the DRBC, also monitors fish tissue for toxics. Fish are collected from the Delaware River in the vicinity of each of the following locations:

1. C&D Canal
2. Deepwater
3. Paulsboro
4. Tacony-Palmyra Bridge
5. Crosswicks Creek

Two species, channel catfish and white perch, are collected at each location. A minimum of five fish of similar size and age class for each species are collected at each sampling location. Two samples consisting of standard fillets of the five specimens are prepared for analysis, one for each species at each sampling location. Each sample of the fillets are analyzed for the parameters listed in Table A6.

TABLE A1. DELAWARE ESTUARY BOAT RUN MONITORING LOCATIONS OF SAMPLING

Station	River Mile
Mahon River	31.0
Ship John Light	36.6
Smyrna River	44.0
Liston Point--Buoy 8L	48.2
Reedy Island	54.9
*Pea Patch Island	60.6
New Castle	66.0
*Cherry Island	71.0
Oldmans Point	74.9
*Marcus Hook	78.1
*Eddystone, PA	84.0
*Paulsboro, NJ	87.9
*Navy Yard	93.2
*Benjamin Franklin Bridge	100.2
*Betsy Ross Bridge	104.75
*Torresdale	110.7
*Burlington Bristol Bridge	117.8
Fieldsboro	127.5

*See Table A2 for significance of stations with asterisk.

TABLE A2. DELAWARE ESTUARY BOAT RUN MONITORING
PARAMETERS AND FREQUENCY OF ANALYSIS

CATEGORY OF PARAMETERS	PARAMETER	STATIONS	FREQUENCY
CONVENTIONAL	ACIDITY	ALL	TWICE MONTHLY
	ALKALINITY		
	CHLORIDE		
	DISSOLVED OXYGEN		
	HARDNESS		
	pH		
	PHOSPHOROUS: DISSOLVED ORTHOPHOSPHATE		
	PHOSPHOROUS: TOTAL		
	SILICA (REACTIVE)	SEE FOOTNOTE 1	
	SODIUM	ABOVE R.M. 78	TWICE MONTHLY
	SPECIFIC CONDUCTANCE	ALL	
	TEMPERATURE, AIR		
	TEMPERATURE, WATER		
	TOTAL SUSPENDED SOLIDS		
	TURBIDITY		
BACTERIAL	E. COLI		
	ENTEROCOCCUS		
	FECAL COLIFORM (MTEC)		
ALGAL	CHLOROPHYLL A		
	PHEOTOPHYTIN A		
NITROGEN SERIES	NH3-N		
	NO2-N		
	NO3-N		
	TOTAL KJELDAHL-N		
METALS	COPPER, DISSOLVED	STATIONS MARKED * ON TABLE 1	MONTHLY
	COPPER, TOTAL		
	LEAD, DISSOLVED		
	LEAD, TOTAL		
	ZINC, DISSOLVED		
	ZINC, TOTAL		
RADIOACTIVITY	ALPHA EMITTERS	ALL	ANNUALLY
	BETA EMITTERS		
	TRITIUM		
VOC	FOR STATIONS MARKED * ON TABLE 1		MONTHLY

Footnote 1: Silica to be determined initially at several locations and times. Further delineation of silica monitoring to be based on initial results of 1994-95 program.

TABLE A3. LOCATIONS AND CODES OF PENNSYLVANIA TRIBUTARY SAMPLING SITES

STREAM	SITE	ESTABLISHMENT CODE
CHESTER CREEK	ROUTE 291 (SECOND STREET)	422094
CRUM CREEK	ROUTE 291	422115
DARBY CREEK	ROUTE 291 (INDUSTRIAL HIGHWAY)	422088
FRANKFORD CREEK	ARAMINGO AVENUE	422091
NESHAMINY CREEK	ROUTE 13	422103
PENNYPACK CREEK	STATE ROAD	422097
POQUESSING CREEK	STATE ROAD	422100
RIDLEY CREEK	ROUTE 291 (FOURTH STREET)	422120
SCHUYLKILL RIVER	CALUMET STREET	422110
SCHUYLKILL RIVER	CHESTNUT STREET	422111

TABLE A4. PARAMETERS FOR ANALYSES
PENNSYLVANIA TRIBUTARY SAMPLING SITES

CATEGORY OF PARAMETERS	PARAMETERS
CONVENTIONAL	ALKALINITY
	BOD5 (INHIBITED)
	BOD5 (UNINHIBITED)
	CL
	CONDUCTIVITY
	D.O.
	FECAL COLIFORM
	Ph
	TDS
	TEMPERATURE
	TOTAL PO4
	TSS
NITROGEN SERIES	NH3
	NO2
	NO3
	ORGANIC N
	TKN
METALS	TOTAL AS
	TOTAL CD
	TOTAL CU
	TOTAL FE
	TOTAL HG
	TOTAL NI
	TOTAL PB
	TOTAL SE
	TOTAL ZN
VOC	

TABLE A5. DELAWARE RIVER ABOVE TRENTON FALLS
PARAMETERS FOR ANALYSES

CATEGORY OF PARAMETERS	PARAMETERS
CONVENTIONAL	ALKALINITY
	CL
	CONDUCTIVITY
	D.O.
	ENTEROCOCCUS
	FECAL COLIFORM
	Ph
	TDS
	TEMPERATURE
	TOTAL P
	TSS
	TURBIDITY
NITROGEN SERIES	NH3
	NO2
	NO3
	TKN
METALS	TOTAL CU
	TOTAL NI
	TOTAL HG
	TOTAL PB
	TOTAL ZN
VOC(QUARTERLY)	
PESTICIDES/PCBs, METHOD 608 (QUARTERLY)	

TABLE A6. FISH TISSUE ANALYSES

PESTICIDES/PCBs	METALS
Aldrin	Arsenic
α-BHC	Zinc
ß-BHC	Cadmium
δ-BHC	Copper
Chlordane	Lead
DDD	Mercury
DDE	Nickel
DDT	Selenium
Dieldrin	
Endosulfan I	
Endosulfan II	
Endosulfan sulfate	
Endrin	
Endrin aldehyde	
Heptachlor	
Heptachlor epoxide	
Toxaphene	
PCB Congeners (62)	

Appendix B - Current Delaware Monitoring Activities

Water Quality and Toxics Monitoring

Surface water monitoring by the State of Delaware includes general assessment, priority basin (Christiana, Appoquinimink), toxics in biota, and specials (biological monitoring in nontidal perennial streams - see Figure B1). The estimate for the 1995 cost of these activities is $385,000.

1. DEDNREC general assessment monitoring is performed on an annual or semi-annual basis in 15 subtributary basins and Delaware Bay for nutrients, carbon, metals. (Tables B1 and B2)

2. Intensive survey for toxic contaminants in fish/shellfish have been conducted on the Christiana River and within the Delaware Estuary since 1992. An intensive survey is scheduled for the Appoquinimink Basin in FY 95.

The shellfish monitoring program includes approximately 70 stations in the Delaware Bay - see Figure B2. The estimated annual cost of this program is $105,000.

1. A coliform sampling program that is similar to that of NJDEP. Approximately 72 stations on river, bay, and subtributaries for shellfish sanitation are sampled six times a year.

2. Recreational water quality sampling, using enterococcus, includes two stations on Lewes Beach (part of a larger lake and ocean beach water quality monitoring program).

Fish Trawl Sampling

The DEDNREC trawl survey primarily targets juvenile bottom-associated species. Sampling from 1980 to present covers from the C&D Canal south in Delaware waters (map shown in Figure 2, following p. 22). The sampling uses a 16 ft trawl and is done monthly from April to October. From 1989 on, sampling has also been done from Reedy Island up to the Wilmington area.

DEDNREC also does trawling with 33 foot trawls; this gets better sampling of larger fish. The program has been continuous from 1989 and discontinuous from 1966 (5 year intervals). Sampling is done monthly except in winter.

In all trawl samples, all fish are sized and counted. The analyses also includes horseshoe crabs.

Hardcopy maps, geology, USGS topoquads, paper prints of 1986, 1991/92 photobasemaps - Contact Map Sales, NJDEP, (609)777-1039

Fish Trawl Sampling

Since 1991, NJDEP has been using the 16 foot trawl for sampling, primarily nearshore (stations shown in Figure 2, following p. 22). Sampling is done monthly from April to October. There had been some previous sampling with this program, but not continuous.

In addition, the NJDEP ocean survey with 100 ft trawl includes 3 or 4 stations that are at the mouth of the bay. They have been sampled 5 times a year since 1988.

In all trawl samples, all fish are counted and sized; the inventory includes horseshoe crabs.

Beach Seine Sampling

NJDEP performs beach seine sampling from about Artificial Island to Trenton. The sampling is done in DE, NJ, and PA waters. Since 1980, sampling has been done 3 months annually in August, September, October. A total of over 200 samples are collected at 16 fixed sites and more random stations.

This beach seine collection covers juveniles of pelagic as well as demersal fish, and of residential as well as migratory species. Analyses of the data uses juvenile indices. Species that are emphasized in evaluation include striped bass, shad, white perch, menhaden, and anchovy. The program shows increases in the number of species since 1980 in the lower and middle regions; this indicates primarily increased abundance, most of the species were there or nearby, now they are more abundant and ubiquitous.

TABLE B1

General Assessment Stations For Delaware Estuary Drainage Basins

BASIN	STATION AND STORET NO.
Army Creek	114031 Railroad Br. below Landfill 114021 Rt. 13 Bridge Rt. 9
Blackbird Creek	110041 Rt. 9 Taylors Br. 110021 Rt. 13 Bridge
Broadkill River	303331 Rt. 1 Bridge (mainstem) 307171 Beaverdam Cr. Rd. 88 303031 Broadkill River Rt. 5 Br. 303011 Ingram Br. Rd. 246 303051 Red Mill Pond Rt. 1 303351 Waggamons Pond Outlet
C & D Canal	108021 St. Georges Bridge 108031 Summit Bridge 108051 Lums Pond Rt. 71
Cedar Creek	301031 Rt. 1 Bridge
Dragon Run	111011 Rt. 9 Bridge 111031 Rt. 13 Bridge
Naamans Creek	101011 Behind Steel Plant
Delaware Bay	401011 Roosevelt Inlet 401021 Primehook Beach 401031 Fowlers Beach 401061 Big Stone Beach 401081 Murderkill Jetty 401101 Little River
Leipsic River	202031 Rt. 9 Bridge 202041 Rt. 42 202021 Rt. 13 Bridge 202011 Rd. 42 Bridge
Little River	204031 Rt. 9 Bridge 204041 Rt. Rt. 8 Bridge 204011 Horse Pond Rd., DAFB
Red Lion Creek	107031 Rt. 9 Bridge
Shellpot Creek	102041 Cherry Island Rd. 501 Bridge 102011 Rt. 13 Bridge

TABLE B1 (continued)

General Assessment Stations For Delaware Estuary Drainage Basins

BASIN	STATION AND STORET NO.
St.Jones River	205041 Barkers Landing
	205091 Rt. 10 Bridge
	205241 Rt. 13 North Moores Lake
	205151 Rd. 69 State College
	205181 Rt. 13 Alt Moores Lake
	205191 Silver Lake Spillway
	205211 Derby Pond Rt. 13A
Smyrna River	201041 Rt. 9 Fleming Landing
	201021 Rt. 137 Bridge
	Rt. 485 Bridge
Mispillion River	208021 Rt. 1 Bridge
	208211 Rt. 36 Silver Lake
Murderkill River	206131 Rt. 121 Webb Landing
	206191 Rt. 12 Bridge (Frederica Bridge)
	206361 Rt. 15 McCauley Pond
	206451 Rt. 15 Coursey Pond

TABLE B2

Water Quality Parameters for General Assessment Monitoring

Parameter	Analytical Method	Program Objective Reporting Level
Water Column Nutrients:		
Total Phosphorus	052	0.02 mg/l
Soluble Ortho-phosphorus	052	0.02 mg/l
Total Kjeldahl Nitrogen	041	0.20 mg/l
Ammonia Nitrogen	043	0.05 mg/l
Nitrite+Nitrate N	045	0.01 mg/l
Carbon and Organics:		
Total Organic Carbon	121	1 mg/l
Dissolved Organic Carbon	121	1 mg/l
Chlorophyll-a (Corr)	017	0.001 mg/l
Pheophytin	017	0.001 mg/l
BOD-5, N-Inhib (CBOD)	006	2.4 mg/l
COD	046	5.0 mg/l
General:		
Dissolved oxygen	001	0.25 mg/l
Total Suspended Solids	056	1 mg/l
Alkalinity	026	1 mg/l
Hardness	031	5 mg/l
Field pH	Field	0.1 unit
Salinity/Conductivity	013	1 umho/cm
Temperature	Field	0.5°C
Turbidity	018	0.5 FTU
Bacteria:		
Enterococcus	084	1/100 ml
Metals: (dissolved and total):		
Aluminum	112	80* ug/l
Cadmium	118	0.5ug/l
Chromium(Hex)	111	10 ug/l
Copper	118	5.0 ug/l
Iron	112	100 ug/l
Lead	118	3.0* ug/l
Zinc	112	20 ug/l

* = Current Delaware laboratory instrumentation cannot reliably measure below the applicable water quality criterion for this metal.

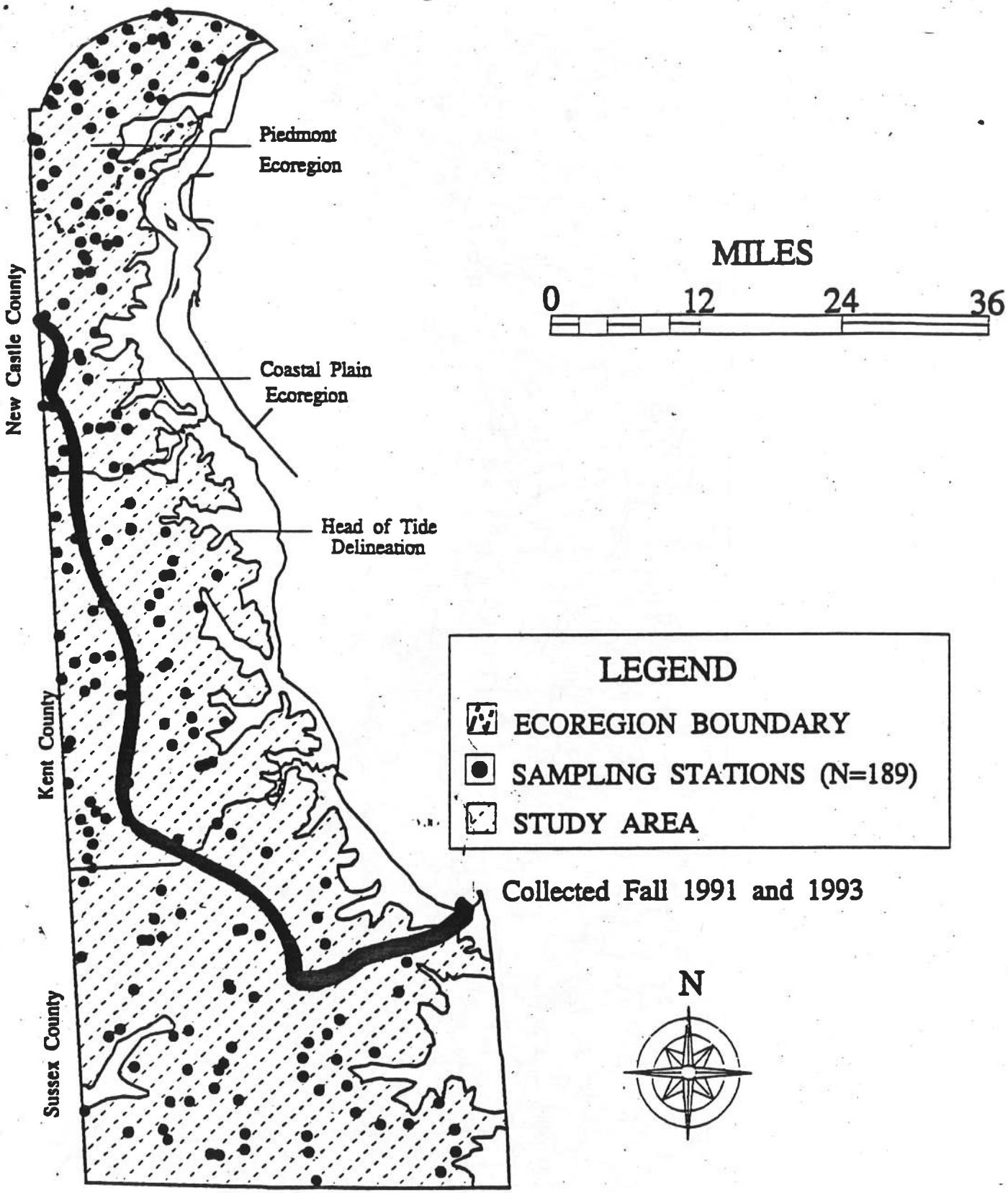


Figure B1. Biological monitoring by the State of Delaware in nontidal streams.

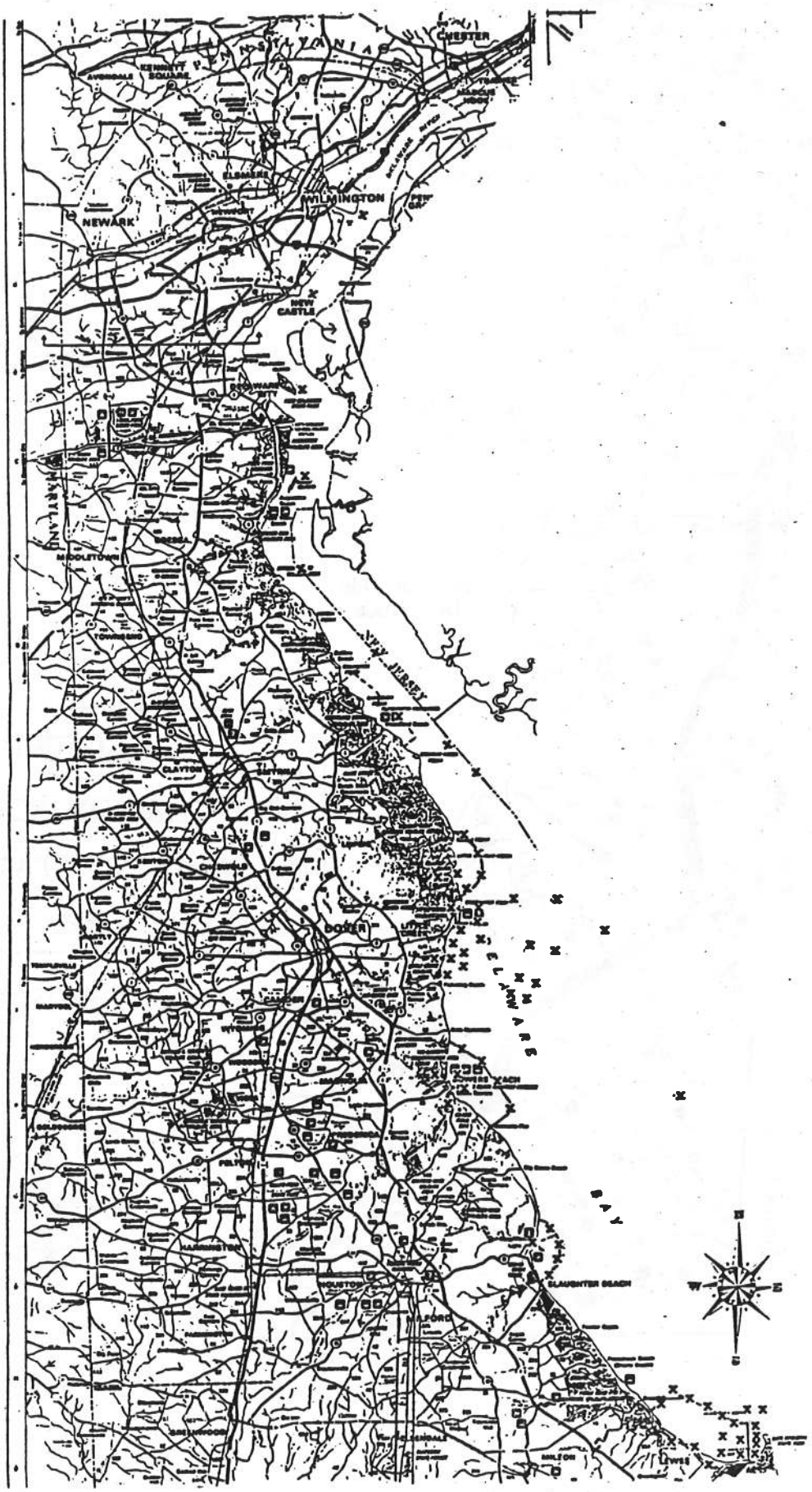


Figure B2. Stations sampled for the State of Delaware shellfish monitoring program.

Appendix C - Current New Jersey Monitoring Activities

Water Quality and Biological Monitoring

The New Jersey water quality, sediment, biological, and hydrological program monitoring in the Delaware Estuary can be separated into 6 categories as is shown in Table C1 with cost estimates and frequency of monitoring

Subtributaries:

1. A cooperative program between New Jersey and USGS at 29 stations on subtributaries in the upper (19) and lower (15) Delaware River basin (see Bauersfield et al, 1994). Sampling is done five times a year with three sampling times centered around low flow. Sediments are sampled on a three year cycle.

2. Ambient Biological Network (AMNET): There are 191 completed stations in the Upper Delaware Basin. These extend from the New Jersey/New York border to the the Cooper River basin below Camden. The Lower Delaware Basin extending from Cooper River to Cape May containing approximately 175 stations will not be completed until early 1996. All the stations will be resampled on a five year cycle.

3. Surface Water Stream Gaging Network: The network is a cooperative program between USGS and New Jersey. The object is to collect continuous stage and discharge data at various stream sites to define the hydrologic conditions. The data collected are published annually in "USGS Water Resources Data – New Jersey, Volume 1."

Bay Network:

4. Shellfish sanitation growing water network program – total and fecal coliform at 178 stations in lower bay and subtributaries. Sampling frequency varies with statioons, a minimum of five times a year, some as much as ten times a year.

5. At twenty shellfish sanitation stations in lower bay, sampling for dissolved oxygen and nutrients; sampling is done quarterly.

6. At one station in Delaware Bay, chlorophyll and phytoplankton speciation sampling is done. This is part of a larger network of stations with the others being on the Atlantic Ocean coast.

Land Use/Land Cover Monitoring (Mapping)

The NJDEP has completed a detailed statewide land use/land cover (LULC) mapping initiative at level 2, Anderson et al. 1976, to 1986 ortho-photoquads, at 2.5 acre minimum polygon size. The LULC was then integrated manually to USGS floodprone areas, recompiled county soil surveys, and geology, then scanned into an Arc/INFO coverage by county, creating an Integrated Terrain Unit Map (ITUM). In addition, the NJDEP has also recently completed a statewide mapping of the freshwater wetlands to the 1986 orthophoto quarterquads (Cowardin System). This data is now being integrated digitally into the ITU to create a super ITU of extremely detailed LULC which has been successfully used in many studies already.

These county coverages will be used as a baseline for environmental analysis for such projects as GAP, trend analysis, regulation and enforcement activities, openspace acquisition, and monitoring. Other statewide and regional coverages are listed in the attachment.

The NJDEP has worked with the USGS and private sector to fly the state in 1986, 1991 and March 1995 (scheduled). Black and white digital imagery was produced from the 1991 overflight (quad and quarterquad scales) and color infrared digital imagery will be produced from the 1995 mission. This digital imagery has been used to update many data layers included LULC to indicate habitat loss, degradation, trends, and fragmentation. The County of Gloucester has a grant from the NJDEP to update the 1986 LULC to 1991 for trend analysis and to assess opportunities for openspace acquisition. Digital imagery also makes an excellent backcover for viewing and analyzing all types of data.

These data development projects have costs exceeding $10 million, but with the advent of digital imagery and updating software, the cost for maintaining currency should be very reasonable. Creating and updating of these data should also be initiatives which can then be accessed or distributed via RIMS, to the DELEP user community. In addition, the creating of data sharing/development partnerships helps hold down the cost of duplicative data development and should be encouraged through all sectors of the DELEP community. The NJDEP has created formal cooperative data sharing agreements with the EPA Region II, Fish & Wildlife Service (Bombay Hook, Charlestown, Hadley), the Philadelphia Corps of Engineers, Pinelands Commission, Rutgers University, to name a few. These partnerships assist the DEP in assisting and pooling resources to create and update digital data in a variety of studies including, Watershed Based Wetland Assessment Method for the New Jersey Pinelands (Rutgers & Pinelands Commission), GAP analysis (FWS, planned), Pinelands Long Term Monitoring Program (Pinelands Commission, National Park Service), for instance.

The NJDEP has created a GIS user community network in NJ by assisting 13 counties in obtaining GIS and providing quality data layers and mapping bases. Counties are now taking the lead in some detailed data development in monitoring and parcel analysis. State mapping issues are loosely organized through a volunteer State Mapping

Advisory Committee which welcomes all sectors of the mapping community. Each year the SMAC and Mid-Atlantic URISA host a Symposium on GIS/Mapping as an information/technology exchange.

The states of Pennsylvania and Delaware have GIS systems and some initiatives similar to that of New Jersey. What the DELEP needs is a forum to take advantage of the strengths of all programs such that estuary-wide databases are similar enough to accommodate scientific analysis across political boundaries. This should occur as soon as possible, before monies are spent inappropriately, or on efforts which are not, but could have been, compatible with existing high quality data sets.

DIGITAL DATA INVENTORY
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF INFORMATION RESOURCES MANAGEMENT
(All Data NAD83)

STATEWIDE DIGITAL DATA

CAFRA - Coastal Area Facility Review Act regulatory line.

CEDAR - Atlantic White Cedar stands in the State Forests of New Jersey, delineated from 1:24000 photoquads (1986).

CLIMATEMUN - Municipality boundaries coded with precipitation and temperature data.

COAST - Statewide map of coastline/shoreline delineated 1:24000 photoquads (1986).

FRESHWATER WETLANDS - Freshwater wetland delineations as per the Freshwater Wetlands Act from 1:12000 quarterquads for Bergen, Cape May, Cumberland, Essex, Gloucester, Hudson, Hunterdon, Mercer, Middlesex, Morris, Monmouth, Passaic, Salem, Somerset, Sussex, Union, Warren (other counties in production). Note: until mapping is completed, a charge is applied for the data.

GEOLATLAS - Statewide map of atlas sheet geology compiled at 1:63,360.

GEONAMES - Point locations with labels as found on the USGS quads; schools, rivers, places etc.

HAZWASTE - Hazardous waste side locations from the Status Report

HMDC - Outline of the Hackensack Meadowlands District.

HOT - Head of Tide (points).

HYDRO - Waterfeatures for entire state, by county. Poly (lakes) and line (streams) coverages.

INTAKES - Public surface water supply intakes.

NATREG - Sites less than 10 acres in size, on the National Register of Historic Places.

OPENSPACE - Statewide federal and state openspace.

PINELAND - The state regulated Pineland Protection Boundary.

STATECO - County boundaries from 1:24000 topoquads.

STATEMUN - Municipal boundaries from 1:24000 topoquads.

SWL - Solid waste landfill locations.

TIDELANDS - Riparian claims line for all lands presently or historically flowed by mean high water.

WSMA - Potable water supply reservoirs, and wellfields over 50 acres.

QUARTERQUADS - State plane coordinate templates and tics for data entry or transformation at 1:12000, 624 maps.

COUNTYWIDE DIGITAL DATA

HYDROPT - Location of surface water quality monitoring sites (Camden).

ITU - Integrated terrain unit coverages containing soils, land use/land cover, geology, and flood prone areas, interpreted and compiled at 1:24000 scale (Atlantic, Bergen, Burlington, Camden, Cape May, Essex, Gloucester, Hudson, Mercer, Middlesex, Monmouth, Morris, Ocean, Somerset Union, Warren). Other counties in progress.

COASTAL NEW JERSEY

Historic Shorelines - Shorelines from the 1800's to present as available.

Shore Structures - Jetties, groins, revetments from the 1986 photoquad basemaps.

Beach Nourishment - Beach nourishment projects from 1940 to 1992.

High Hazard Line - Recompiled high hazard line from FEMA maps for the Atlantic coastline (incomplete coverage).

Shoreline Classification - Shoreline classes as beach, marsh, bulkheaded, etc.

South Jersey Marsh - Coastal wetland classification in detail for portions of Cape May and Cumberland Counties.

REGIONAL DIGITAL DATA

The Department, from time to time, takes on regional mapping functions to support Departmental initiatives. Two such studies were made for the Barnegat Bay Ocean County area above the Route 72 bridge, north to the Monmouth County border for the drainages into the Barnegat Bay and for the Arthur Kill/Kill van Kull area.

Bargegat Bay Watershed Area

BARNEGAT BAY STUDY AREA - Study area boundary.

BATHYMETRY - Barnegat Bay depth readings (point).

BOATRAMPS - Boatramp locations (point).

COLIFORM - Mean total coliform 1976, 1980 (point and/or poly).

COLONIAL NESTING BIRDS - Colonial nesting birds by species.

DREDGE AREAS - Selected areas where dredging has occurred.

DREDGE DISPOSAL AREAS - Dredge material disposal areas.

EELGRASS BEDS - Areas of eelgrass submerged vegetation.

HARDCLAMS - Hardclam (quahog) distribution.

MARINAS - Marina point locations.

MUSSELS - Blue mussels shellfish distribution.

POINT SOURCES - NJPDES permitted facilities.

PUBLIC BEACHES - Public Beach point locations.

SEDIMENTS - Bay sediment sampling locations.

SEWER SERVICE AREAS - Sewer service areas as delineated by the New Jersey Office of State Planning.

SHELLFISH WATER CLASSIFICATION - Classification of waters for growing shellfish.

STORET POINT DATA - Fecal coliform geometric mean concentrations for wet and dry days in summer 1980, 1987.

STORMWATER MANAGEMENT AREAS - Stormwater management areas for the Cedar and Kettle Creek watersheds.

SURFACE WATER QUALITY (C-1) AREAS - C-1 designated waters.

SURFACE WATER QUALITY (f-1) - F-1 designated waters.

WATERFOWL STAGING AREAS - Migratory waterfowl staging areas.

ZONING - Municipal zoning aggregated into categories.

ARTHUR KILL/KILL VAN KULL

BUILDINGS - Large buildings.

ESI AREAS - Environmentally sensitive index area data from NOAA maps.

ESI SHORELINE - Environmentally sensitive index shoreline data from NOAA maps.

ESI SITES - Environmentally sensitive site data from NOAA maps.

PIERS - Large piers.

TANKS - Tank locations.

TIDAL WETLANDS - Intertidal and high marsh, and intertidal flats.

UWL - Upper wetlands limit line.

OTHER SOURCES

BASINS (Watersheds) - Contact USGS, West Trenton 771-3900

TIGER - Twenty-one 1:100,000 county line coverages containing roads, hydrography, railroads, utilities. Contact the State Data Center, (609) 292-0076

1991/92 DIGITAL IMAGERY - Contact MARKHURD, 1-800-MAP-HURD

1986 and 1991/92 PHOTOBASEMAPS (quads and quarterquads) - Contact MARKHURD, 1-800-MAP-HURD

HISTORIC AIRPHOTOS - Contact Mike Ryan, Tidelands Element, NJDEP (609) 633-7369

Hardcopy maps, geology, USGS topoquads, paper prints of 1986, 1991/92 photobasemaps - Contact Map Sales, NJDEP, (609)777-1039

Fish Trawl Sampling

Since 1991, NJDEP has been using the 16 foot trawl for sampling, primarily nearshore (stations shown in Figure 2, following p. 22). Sampling is done monthly from April to October. There had been some previous sampling with this program, but not continuous.

In addition, the NJDEP ocean survey with 100 ft trawl includes 3 or 4 stations that are at the mouth of the bay. They have been sampled 5 times a year since 1988.

In all trawl samples, all fish are counted and sized; the inventory includes horseshoe crabs.

Beach Seine Sampling

NJDEP performs beach seine sampling from about Artificial Island to Trenton. The sampling is done in DE, NJ, and PA waters. Since 1980, sampling has been done 3 months annually in August, September, October. A total of over 200 samples are collected at 16 fixed sites and more random stations.

This beach seine collection covers juveniles of pelagic as well as demersal fish, and of residential as well as migratory species. Analyses of the data uses juvenile indices. Species that are emphasized in evaluation include striped bass, shad, white perch, menhaden, and anchovy. The program shows increases in the number of species since 1980 in the lower and middle regions; this indicates primarily increased abundance, most of the species were there or nearby, now they are more abundant and ubiquitous.

Table C1. Six water quality and toxics monitoring programs in the Delaware Estuary region undertaken by the New Jersey Department of Environmental Protection.

PROGRAM	STATIONS	FREQUENCY (/yr)	ANNUAL COST
Shellfish growing water network	178	6x	$32,500
Marine Estuarine network	19	4x	$16,500
Delaware River tributaries monitoring (downstream Trenton) (COOP with USGS)	34	5x	$31,320
Delaware Bay algal monitoring	1	1x	$ 600
Biological study in upper and lower Delaware	Upper 191 Lower Approx. 175	1x/every 5 years	$203,500
Surface water stream gage network	9	Continuous	$150,000
Total			$434,320

NEW JERSEY'S AMBIENT BIOLOGICAL MONITORING NETWORK

DELAWARE RIVER BASIN

Water Monitoring Management

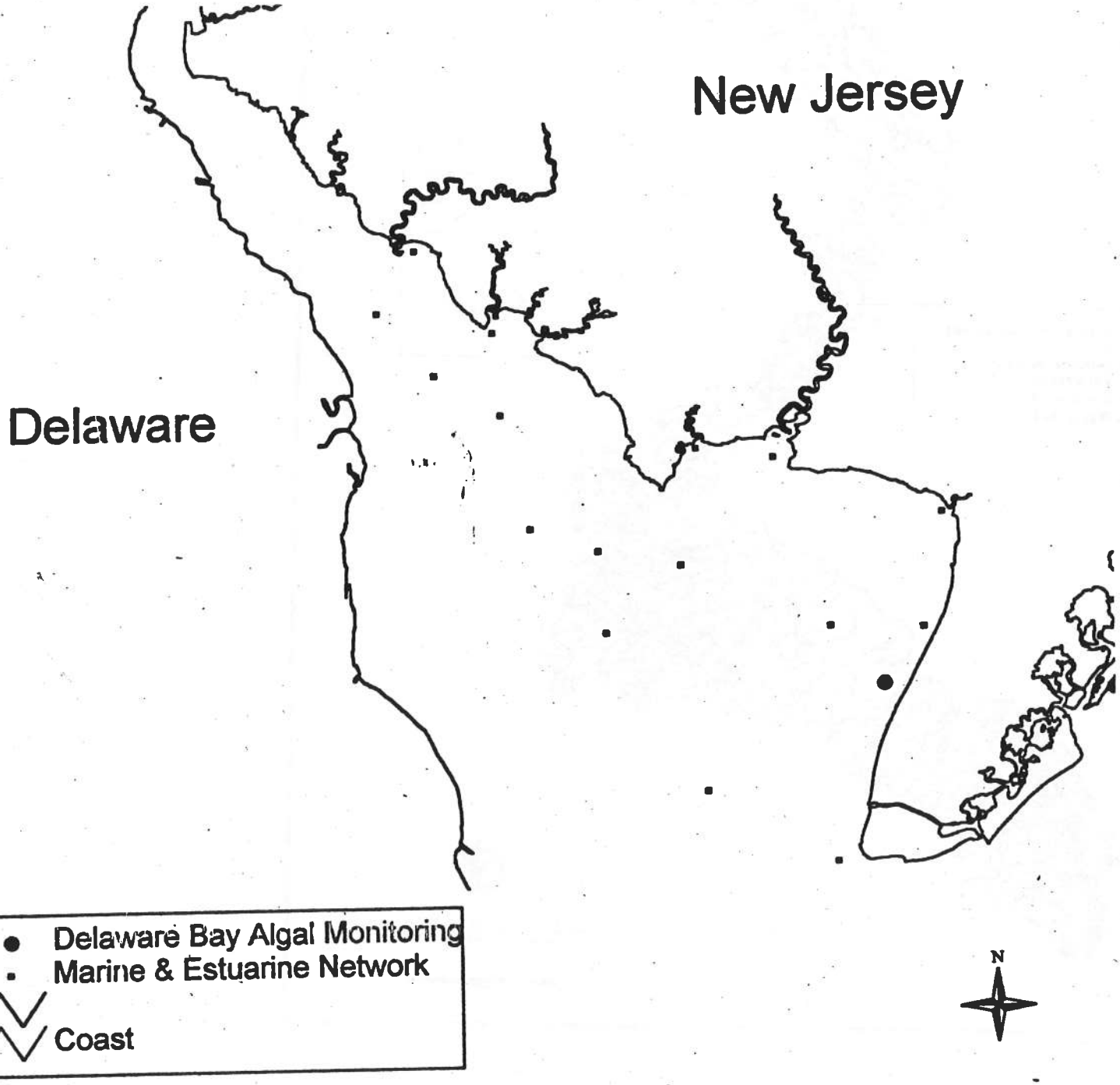
- Biological Monitoring Site
- Primary Basin Boundaries
- River or Stream
- Water Body

N

Produced by the New Jersey Department of Environmental Protection Geographic Information System

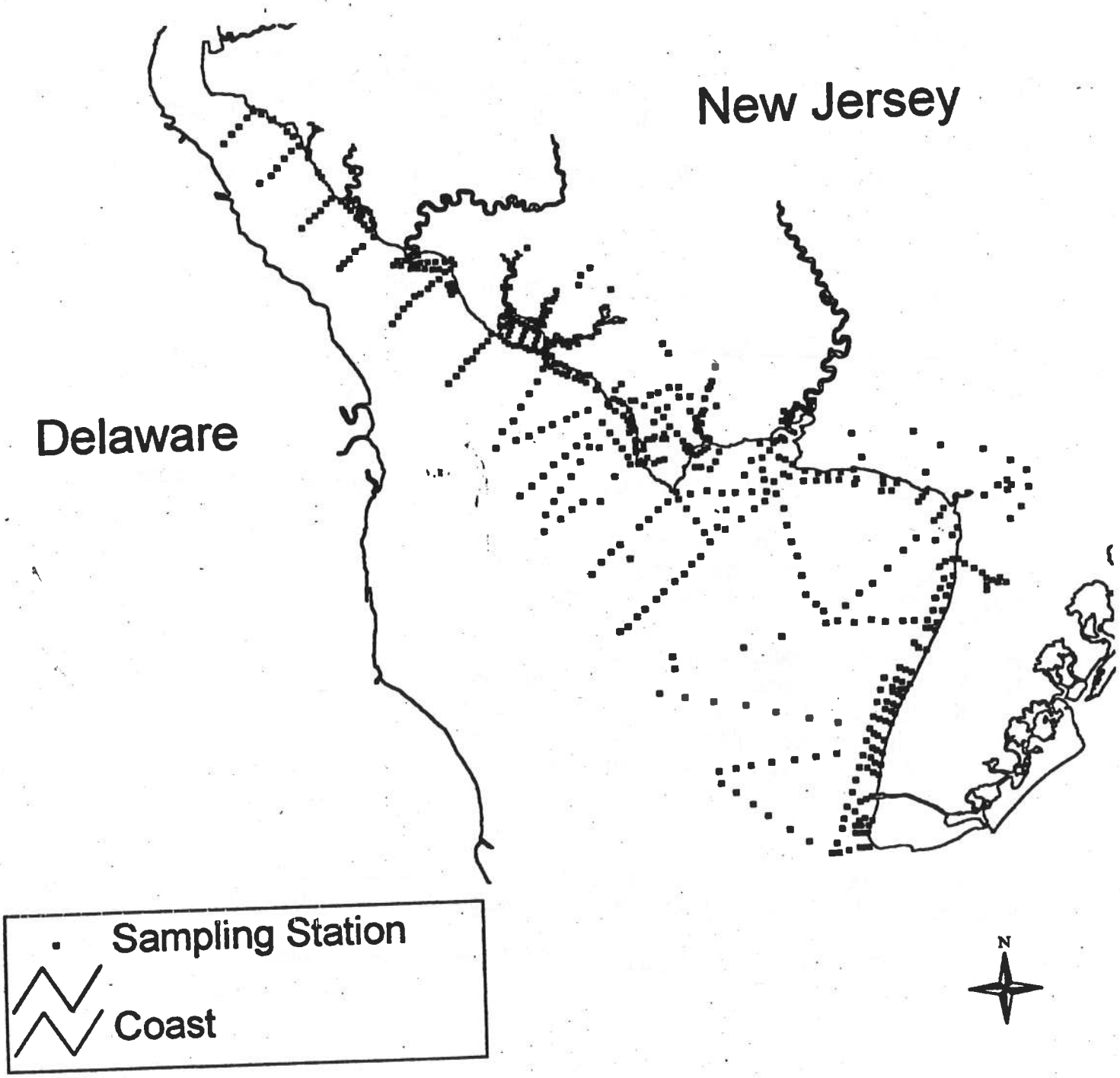
Marine & Estuarine Network
Algal Monitoring

New Jersey Department of Environmental Protection



Shellfish Growing Water Network

New Jersey Department of Environmental Protection



Appendix D - Current Pennsylvania Monitoring Activities

Pennsylvania Water Quality Network (WQN)

The Pennsylvania Department of Environmental Resources (DER) currently samples monthly at seven (7) locations in the area of the Delaware estuary. These stations are part of the statewide, 168 station Water Quality Network (WQN). The stations are:
Delaware River (WQN 101) - Trenton Avenue (SR2060) bridge near Morrrisville
Delaware River (WQN 182) - 2,000 yards upstream from Buoy R6M (1,000 feet above PA/DE border)
Schuylkill River (WQN 110) - Falls bridge in Philadelphia
Brandywine Creek (WQN 105)) - U.S. Route 1 bridge near Chadds Ford
Neshaminy Creek (WQN 121) - PA Route 213 bridge near Langhorne
White Clay Creek (WQN 149) - SR3006 (Yeatman Road) bridge, London Britain Township, Chester County
Red Clay Creek (WQN 150) - SR3013 (Marshall's bridge), Kennett Township, Chester County

The routine chemical analyses performed monthly at each station are:

STANDARD FIELD ANALYSES - All stations.

pH Temperature Dissolved Oxygen

STANDARD LABORATORY ANALYSIS - WQN - Std (010) - All routine stations.

pH - pH
Alk - Alkalinity
SO_4 - Sulfates
Hard - Hardness
NO_3-N - Nitrate Nitrogen
NO_2-N - Nitrite Nitrogen
NH_3-N - Ammonia Nitrogen
TDS - Total Dissolved Solids
$P_{(T)}$ - Total Phosphorus
Susp. Sol. - Suspended Solids
TOC - Total Organic Carbon
Sp Cond - Specific Conductivity
$Al_{(T)}$ - Total Aluminum
$Cu_{(T)}$ - Total Copper
$Fe_{(T)}$ - Total Iron
$Mn_{(T)}$ - Total Manganese
$Ni_{(T)}$ - Total Nickel
$Pb_{(T)}$ - Total Lead
$Zn_{(T)}$ - Total Zinc

The two Delaware River stations and the Schuylkill River station are included in a toxics subset of stations which receive the following additional analyses:

TOXIC - WQN - TOX (011). Includes standard assays from 010 plus:

Phen - Phenols CN - Cyanides (Total & Free)
Oil & Gr - Oil & Grease F - Fluoride

In addition, the stations on White Clay Creek and Red Clay Creek are analyzed for pesticides. The parameters list is:

a-BHC	Endrin Aldehyde
Lindane	Endosulfan Sulfate
Heptachlor	Endrin Ketone
Endosulfan I	Toxaphene
Dieldrin	Chlordane (tech)
Endrin	Alachlor
ppDDD	Cyanazine
ppDDT	Metolachlor
Methoxychlor	Simazine
b-BHC	Atrazine
d-BHC	Propazine
Aldrin	Malathion
Heptachlor Epoxide	Trifluralin
g-Chlorane	PCB's
a-Chlordane	Ethyl Parathion
ppDDE	Methyl Parathion
Endosulfan II	

Stream flow data, measured at USGS gaging stations, are gathered for each sample. This will allow for calculation of load and/or flow-correlated trends.

WQN sampling also includes collection of benthic macroinvertebrate and sometimes fish tissue data. Benthic macroinvertebrates are collected annually. All but one of the seven stations are sampled semi-quantitatively using a modification of the EPA Rapid Bioassessment Protocols. Organisms are collected from riffle areas using a D-frame net, and individuals from a 100-organism subsample are identified and enumerated. Various community metrics are then calculated based on the subsample. In the tidal portion of the Delaware estuary (WQN 182), the benthos is sampled using a modified Hester-Dendy multiplate sampler. The organisms colonizing the sampler are identified and counted.

WQN fish tissue sampling is conducted on a five-year rotation; that is, each station is sampled once every five years. The target species is a recreationally important species, of legal size (if obtainable). Samples are generally a composite of skin-on, scaled fillets from five (5) fish. Catfish samples are skin-off, and American eel samples consist of one inch sections from skinned and gutted individuals. Samples are analyzed for PCB, chlorinated pesticides, and five metals, including mercury.

Pennsylvania DER Water Quality Network
Active Stations

WQN	Name	Stream Code	Station Location	Municipality	County	DER Region	USGS Gauge	Gauge Location	DA abv Gauge (Sq Mi)	Comments	SAC	Start Date
101	DELAWARE RIVER	00002	SR2060 (TRENTON AVENUE BR.) NR MORRISVILLE	FALLS TWP.	BUCKS	SE	01463500	450' UPSTR FR CALHOUN ST BR. @ TRENTON NJ	6780.0		011	7/62
105	BRANDYWINE CREEK	00004	SR0001 (US RTE 1) BR. @ CHADDS FORD.	PENNSBURY TWP.	CHESTER	SE	01481000	RXR BR. @ CHADDS FORD; 1200' DNSTRM FR US RTE 1	287.0	TELEMARK	010	7/62
110	SCHUYLKILL RIVER	00833	FALLS BR.	PHILADELPHIA	PHILADELPHIA	SE	01474500	150' UPSTR FR FAIRMONT DAM	1893.0	RADIOLOGICAL; TELEMARK	011	7/62
121	NESHAMINY CREEK	02484	SR0213 (PA RTE 213) BR. NR LANGHORNE	MIDDLETOWN TWP.	BUCKS	SE	01465500	PA RTE 213 BR.	210.0	TELEMARK	010	7/62
149	WHITE CLAY CREEK	00373	SR3006 (LR15016) YEATMAN RD BR.	LONDON BRITAIN TWP	CHESTER	SE	01478230	T314 BR. (SHARPLESS RD)	60.0	PESTICIDES	010	11/72
150	RED CLAY CREEK	00374	SR3013 (LR15037) MARSHALL'S BR.	KENNETT TWP.	CHESTER	SE	01479820	400' UPSTRM FR MARSHALL'S BR. (SR3013)	28.3	PESTICIDES	010	11/72
182	DELAWARE RIVER	00002	2000 YDS UPSTRM FR BUOY R6M-1000 FT ABOVE DEL BORDER	MARCUS HOOK	DELAWARE	SE	01463500	450' UPSTR FR CALHOUN ST BR @ TRENTON NJ	6780.0	RADIOLOGICAL	011	3/88

*Reference Station

Pennsylvania
Water Quality Network
Active Stations
Maps

FIGURE
SUBBASIN 2
CENTRAL DELAWARE RIVER

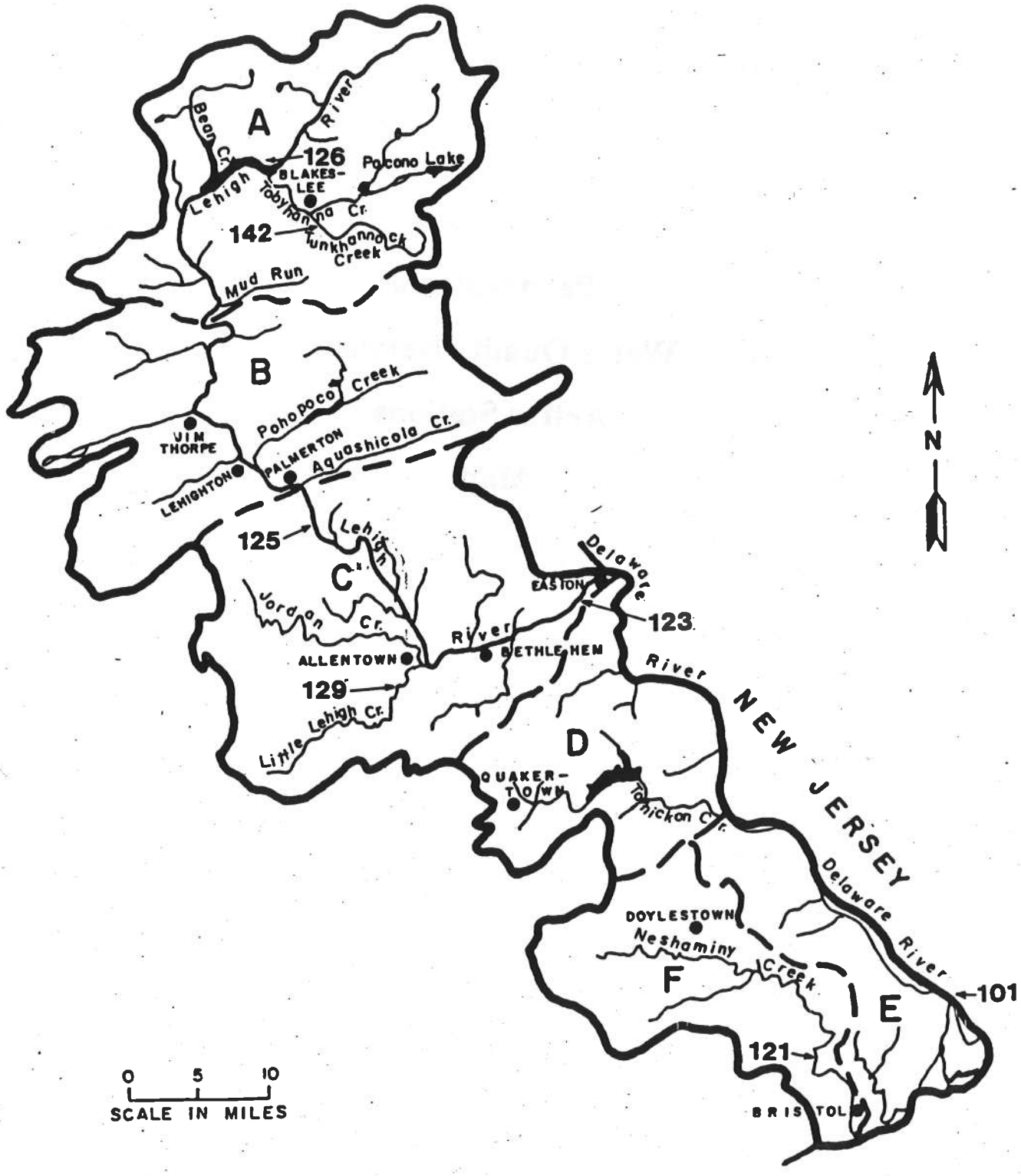
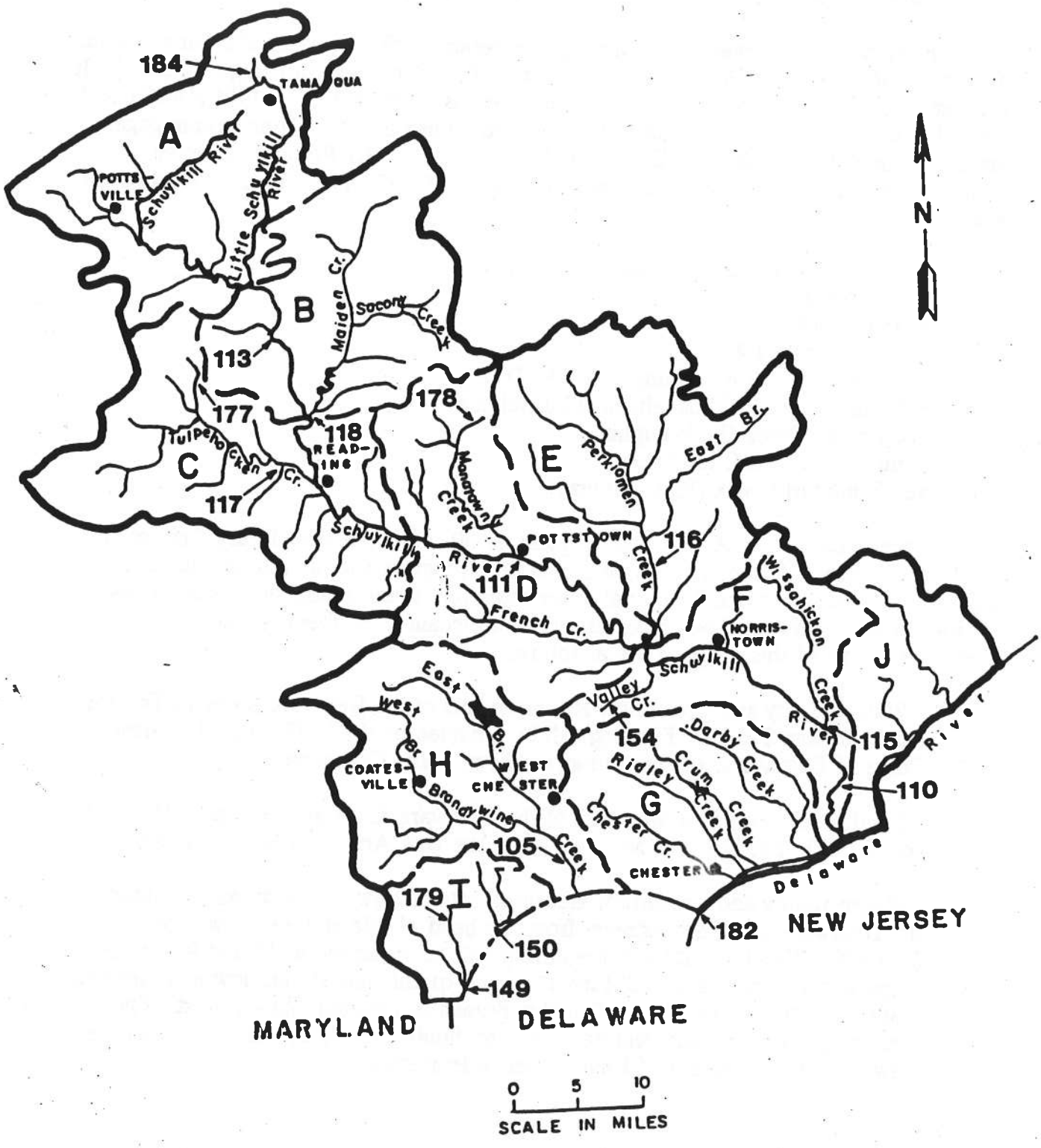


FIGURE
SUBBASIN 3
LOWER DELAWARE BASIN



Appendix E - Current USGS Monitoring Activities

The USGS maintains gaging stations through cooperative arrangements with state governments and local communities. From reporting documents (Bauersfield et al., 1994; White et al, 1993; James et al, 1993), the monitoring activities can be separated as New Jersey, Pennsylvania, and Delaware efforts.

Four stations are maintained through cooperative effort between the Pennsylvania district of USGS and DRBC (Reedy Island, Ft. Miflin, Ben Franklin Bridge, Chester). It is estimated that the annual cost of these four stations is $82,400. The 1994 NASQUAN effort by the PA district was $17,000 but was discontinued in 1995. Nine stream gages are maintained as a cooperative agreement between the USGS, PADER, Chester County, and Philadelphia with a total annual cost of $97,470. These stations (and coop) are:

Darby Creek (Chester County)
Crum Creek (DRBC)
Ridley Creek (PADER)
Chester Creek (PADER)
Neshaminy Creek near Langhorne (PADER)
Schuylkill River at Philadelphia (Philadelphia)
Poquessing Creek (Philadelphia)
Pennypack Creek (Philadelphia)
and Frankfurt Creek (Philadelphia)

From October 1, 1994, through September 30, 1995, the New Jersey District of the U.S. Geological Survey (USGS) will operate a program with an annual budget of $275,400 to measure streamflow, tidal-water level, and water quality at 19 surface-water stations in the Delaware River Basin at and downstream from Trenton (table 1, fig. 1). The components of this program are as follows:

--Water-quality and streamflow measurements of the Delaware River at Trenton, N.J., will cost $48,200. Funding will be provided by the USGS, the U.S. Army Corps of Engineers, and the Delaware River Basin Commission.

--Tidal-water-level measurements of the Delaware River at Burlington, N.J., will cost $5,800. Funding will be provided by the U.S. Army Corps of Engineers.

--Water-quality and streamflow measurements of New Jersey streams tributary to the Delaware River downstream from the head of tide at Trenton will cost $221,400. Water-quality and streamflow will be measured at 16 and 9 stations, respectively. The USGS will fund the water-quality and streamflow measurements made at station 01466500, McDonalds Branch in Lebanon State Forest. The remaining measurements will be made and funded jointly by the USGS and the New Jersey Department of Environmental Protection.

The Delaware District of the USGS measures stream flow at the following surface water stations through a cooperative effort with the State of Delaware Geological Survey, Newark. Costs are split between the two agencies.

Station No.	Location
01478000	Christiana River (near Cooch's Bridge Road)
01477000	Shellpot Creek (near Wilmington)
01479000	White Clay Creek (near Newark)
01480000	Red Clay Creek (Woodale, Highway 48)
01480015	Red Clay Creek (Stanton, Highway 4)
01480095	Little Mill Creek (near Newark)
01481500	Brandywine River (at Wilmington)
01483200	Blackbird Creek
01483700	St. Jones River (at Dover)
01484100	Beaverdam Branch, Misspillion River (at Houston)

Tide gauges are maintained at two stations in conjunction with DEDNREC and are fully funded by the State.

Station No.	Location
01480065	Christiana River (at Newport)
01481602	Delaware River (at mouth of Christiana River)

Table 1. U.S. Geological Survey surface-water stations operated by the New Jersey District in the Delaware River Basin at and downstream from Trenton, New Jersey, October 1, 1994 through September 30, 1995

['X' indicates measurement made at station]

Station number	Station name	Type of measurement		
		Surface-water-quality	Stream-flow	Tidal-water-level
01411456	Little Ease Run near Clayton, N.J.		X	
01411500	Maurice River at Norma, N.J.	X	X	
01412800	Cohansey River at Seeley, N.J.	X		
01463500	Delaware River at Trenton, N.J.	X	X	
01463620	Assunpink Creek near Clarksville, N.J.	X		
01464000	Assunpink Creek at Trenton, N.J.	X	X	
01464500	Crosswicks Creek at Extonville, N.J.	X	X	
01464515	Doctors Creek at Allentown, N.J.	X		
01464598	Delaware River at Burlington, N.J.			X
01465850	South Branch Rancocas Creek at Vincentown, N.J.	X		
01466500	McDonalds Branch in Lebanon State Forest, N.J.	X	X	
01467000	North Branch Rancocas Creek at Pemberton, N.J.	X	X	
01467069	North Branch Pennsauken Creek near Moorestown, N.J.	X		
01467081	South Branch Pennsauken Creek at Cherry Hill, N.J.	X	X	
01467150	Cooper River at Haddonfield, N.J.	X	X	
01467329	South Branch Big Timber Creek at Blackwood Terrace, N.J.	X		
01477120	Raccoon Creek near Swedesboro, N.J.	X	X	
01477510	Oldmans Creek at Porches Mill, N.J.	X		
01482500	Salem River at Woodstown, N.J.	X		

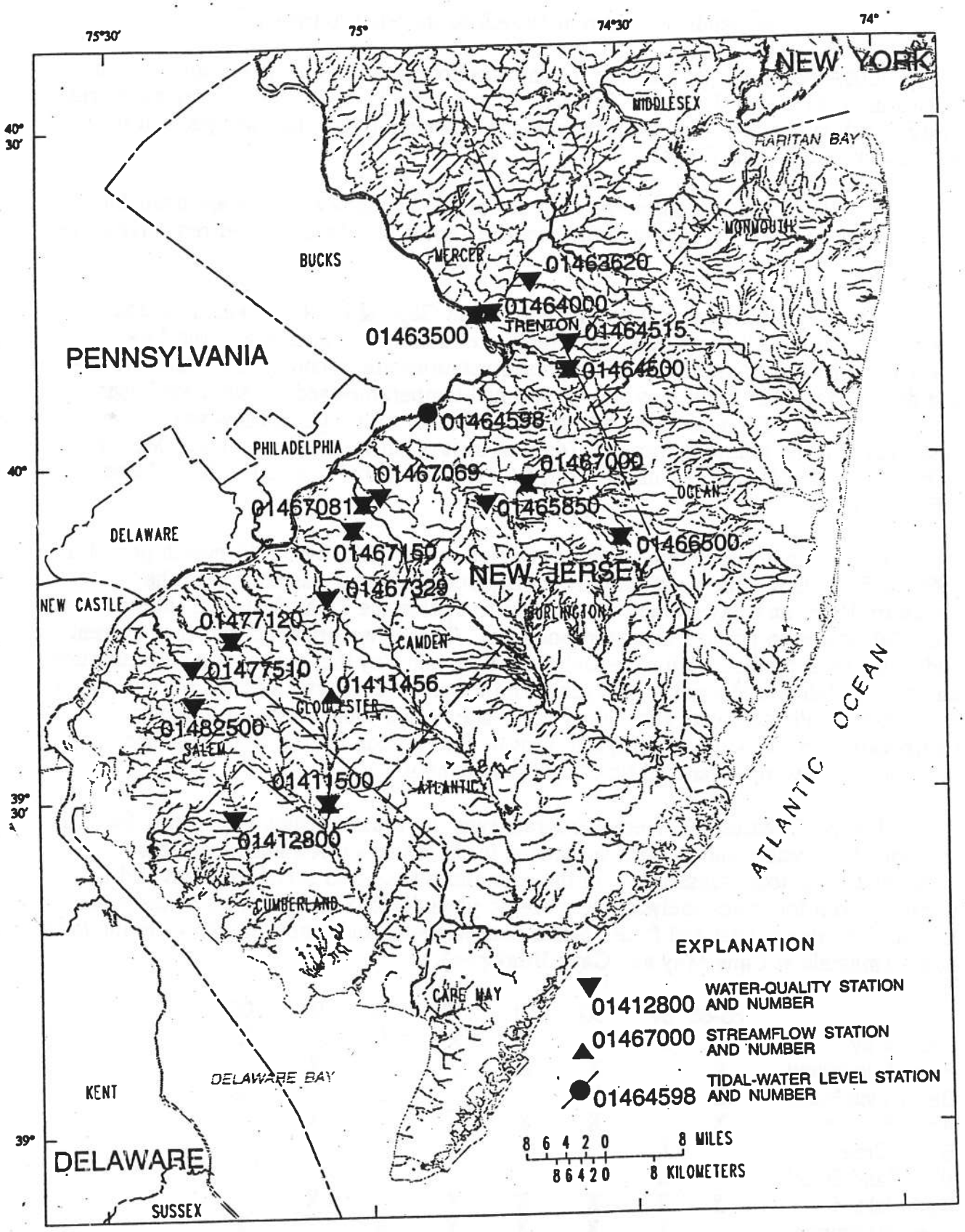


Figure 1. U.S. Geological Survey surface-water stations operated by the New Jersey District in the Delaware River Basin at and downstream from Trenton, New Jersey, October 1, 1994 through September 30, 1995.

Appendix F - Current NOAA Monitoring Activities

NOAA has three programs of routine monitoring that are of importance to our monitoring plan for the Delaware Estuary. They are National Marine Fisheries Services (NMFS) fish landing surveys, the National Ocean Service (NOS) tide gauges, and the NOS Status and Trends Program.

The NMFS fish landing surveys are performed annually and data are available. They have been used extensively in the past and should also be examined regularly in the future.

The NOS maintains tidal gauging stations at Cape May, NJ, Lewes, DE, and Philadelphia, PA. All three have "near real time" data dissemination and the Lewes (1947-present) and Philadelphia (1922-present) stations also record surface temperature and density data (the Cape May station also had temperature and density data logging from 1965-1982). There are also long term tide stations for high and low water level observation at the following locations (date of start of operation given): Cape May, NJ (1965), Trenton, NJ (1977), Philadelphia, PA (1900), Reedy Point, DE (1956), Lewes, DE (1919).

An extensive circulation study was carried out by NOS over a 15-month period in 1984-1985. This was the most extensive circulation study ever carried out in the Delaware River and Bay region. It was used to update the Tidal Current Tables and Tide Tables and to provide input for modelling. The survey provided real-time current and water level predictions for the Delaware Rive and Bay that is used for all future tide and current table production. As a result of the survey, telemetry systems were installed at Cape May, Philadelphia, and Lewes and remain there today for the automatic interrogation to check data quality and provide information for the NOS data base (reference above for "near real time" data dissemination.

The NOS Status and Trends Program runs the Mussel Watch monitoring for toxic compounds. Oysters and mussels suspended in the water are retrieved to assess accumulation of toxic substances. In the past, there were also some sediment and fish samples taken for toxics analysis; there are no plans for future collections of these two media. The recent past and future oyster sampling sites and times are shown in the table below (mussels at Cape May and Cape Henlopen).

Site	86-88	89	90	91	92	93	94	95
Cape May		X	X	X	X	X		X
False Egg Island	X		X	X	X	X	X	
Ben Davis Point	X	X	X			X		X
Arnolds Point	X		X	X	X		X	
Hope Creek		X						
Woodland Beach		X						
Kelty Island	X	X	X	X	X		X	
Cape Henlopen		X	X	X	X	X		X

	96	97	98	99	00
Cape May	X		X		X
False Egg Island	X		X		X
Ben Davis Point	X		X		X
Arnolds Point	X		X		X
Kelty Island	X		X		X
Cape Henlopen	X		X		X

Appendix G - Delaware Valley Regional Planning Commission Activities

The Delaware Valley Regional Planning Commission (DVRPC) has a regular mapping activity of special interest to DELEP monitoring needs. The mapping activity consists of aerial photography to produce maps. From the maps, evaluation of land use/land cover is made on a regular basis and special projects are also undertaken.

The low-level aerial photography has been undertaken every 5 years for 9 counties (Bucks, Chester, Delaware, Montgomery, and Philadelphia in PA and for Burlington, Camden, Gloucester, and Mercer in NJ). In 1995, 5 additional NJ counties (Salem, Cumberland, Cape May, Atlantic, and Ocean) will be added and similar coverage was also offered to the 3 DE counties, but was declined, probably due to cost. Figure G1 shows all of the counties of interest except Sussex County, DE. From the surveys, black and white photo prints are available at a scale of either 1 inch = 400 feet or 1 inch = 800 feet. The cost of the regular 9 county survey is between $150,000 and $200,000 and is paid for by transportation funds through the regular work program of DVRPC. The coverage of 5 additional 1995 counties are being paid for by the counties. An example of the type of photograph that can be produced is shown in Figure G2.

For the 9 counties regularly covered, DVRPC has recently made a complete analysis of land use/land cover from the 1990 aerials. The analysis determined land use/land cover in one of 14 categories through interpretation of the 1 inch = 400 foot aerials, then digitized that information into their CAM/GIS system registered to USGS maps of 1 inch = 2000 feet. The 14 categories are indicated in Table G1. The resulting information is thus able to be mapped in color at any scale and to be analyzed for area calculations. The 1990 information was also used to compare to a similar effort in 1970 to see net changes over time (DVRPC, 1994a). The land use/land cover analysis of 1990 cost approximately $150,000 which was paid for through DVRPC regular work program budget; subsequent efforts would cost less. It is currently estimated that the next analysis of this type will occur in the year 2000.

DVRPC also routinely undertakes a wide variety of monitoring activities as part of their regular data collection and mapping program for the 9 counties. This includes updating of base system maps to include new roads or transit lines, mapping of parks and certain natural resource features and mapping of public water and sewer systems. Many of these maps have been compiled in a recent *Atlas of the Delaware Valley* (DVRPC, 1994b). An example of the type of map is given with solid and hazardous waste facilities in Figure G3. DVRPC also regularly prepares data bulletins of available Census or other information.

In the past year, DVRPC has conducted a demographic and social monitoring analysis of status and trends for the Delaware Estuary watershed for the DELEP. This analysis included population density, age, race, and income; housing and employment data; building permits; and available future forecast information. The data were compiled for all or parts of the 22 counties of the DELEP watershed boundary. The cost of this analysis was $50,000.

Table G1. Land use categories for DVRPC aerial photography interpretation.

Single family - detached units including lots where boundaries are evident.
Multi-family - duplexes, row houses, apartments, group quarters, mobile homes.
Manufacturing - area devoted to fabrication and/or assembly of raw materials or components.
Transportation - areas devoted to rail, air, marine, and highway transportation
Utilities and communications - power generation, substations, transmission lines; radio, TV, and microwave towers; water filtration and storage; wastewater treatment; landfills.
Commercial - retail, wholesale, personal and professional services, hotels and motels.
Community services - hospitals and clinics, government buildings, educational facilities, churches, cemeteries.
Military - air bases, forts, naval bases and air stations, coast guard bases, national guard installations.
Recreational - parks, playgrounds, amusement parks, resorts and camps, public assembly, golf courses.
Agricultural - land devoted to crops, pastures, orchards, tree farms, etc.
Mining - quarries, sand pits.
Wooded - forested areas determined by continuous canopy or solid tree cover, woodlands, natural lands, marshes, and swamps.
Vacant lot - not clearly wooded, agricultural, developed, or tied to other uses.
Water - rivers, streams, lakes, and ponds.

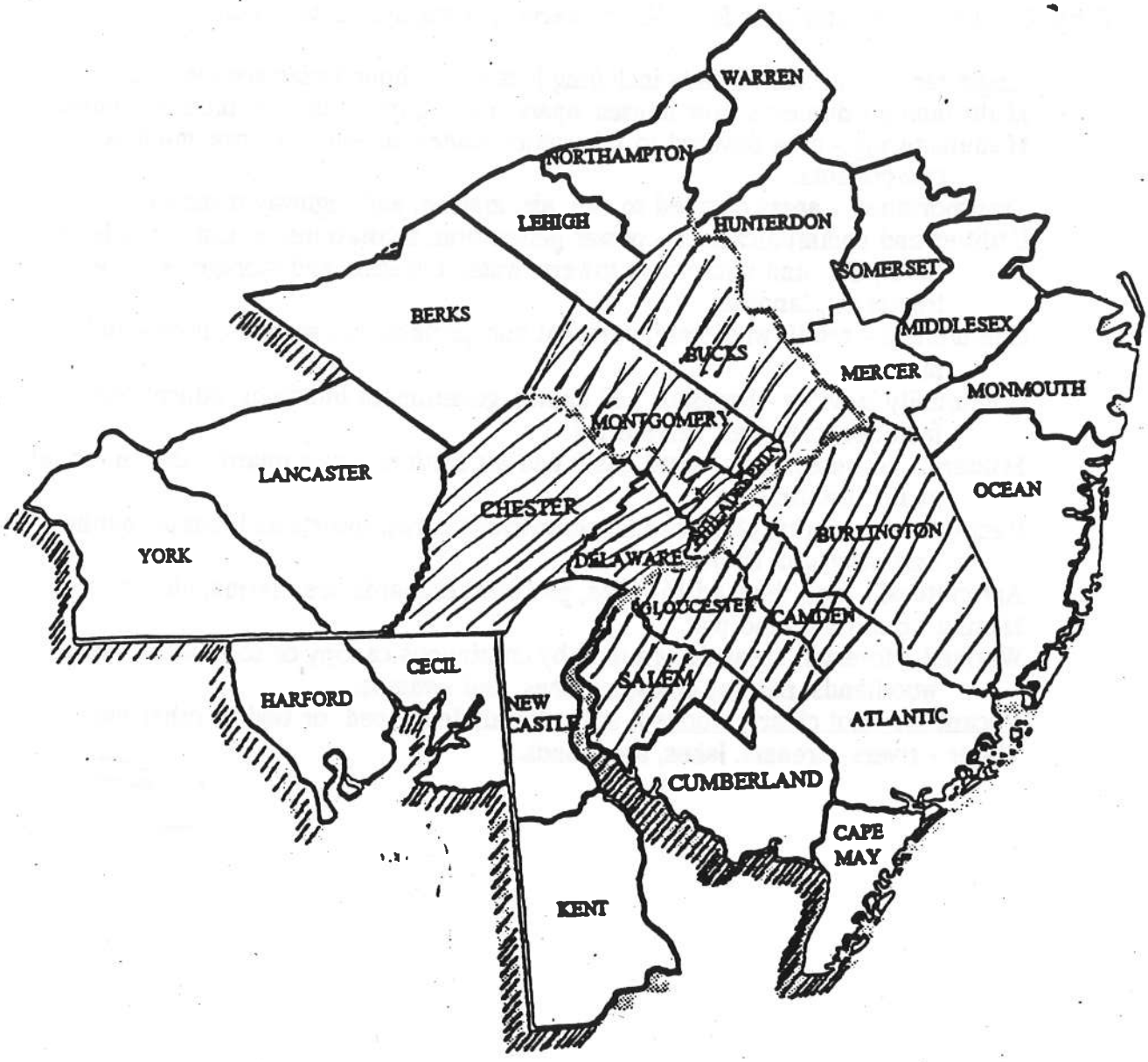


Figure G1. The counties of the Delaware Estuary region (not including Sussex County, DE). The nine shaded ones are those regularly covered with aerial photography by the Delaware Valley Regional Planning Commission.

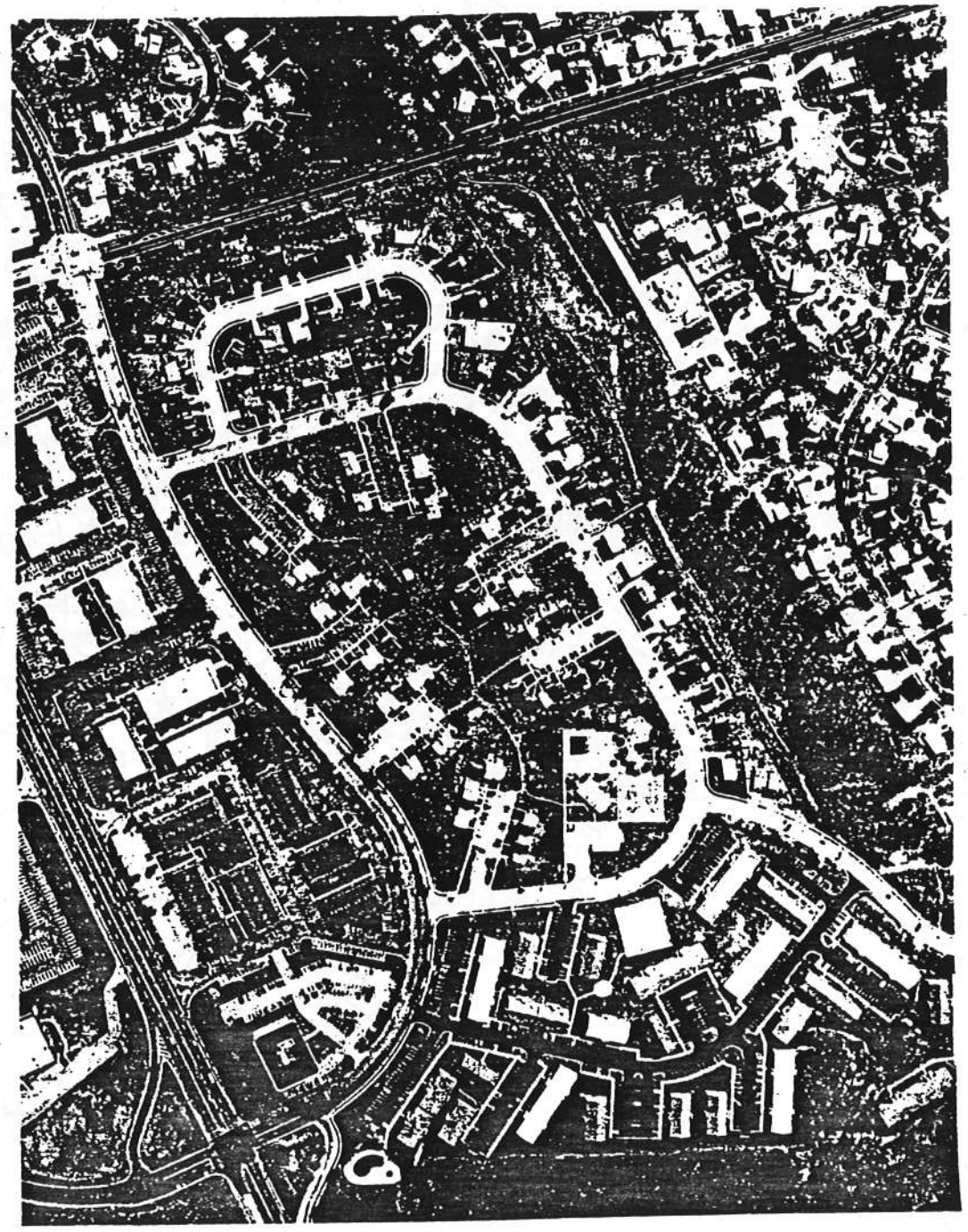


Figure G2. Typical photograph from aerial mapping by Delaware Valley Regional Planning Commission.

Appendix I. Participants in Developing Monitoring Plan

The following participated in formulating this monitoring plan by attending workshops and/or submitting comments on drafts of the plan or information about activities in their agencies.

John Balletto
Public Service Electric & Gas

Scott Bills
U.S. Army Corps of Engineers

Mike Boyer
PA Dept. of Environmental Resources

John Brady
U.S. Army Corps of Engineers

Daniel Brauning
PA Game Commission

Greg Breese
U.S. Fish & Wildlife Service

Edward Brezina
PA Bureau of Water Quality Management

D.J. Campbell
Mobil Corporation

Kathy Clark
NJ Dept. of Environmental Protection

Bob Connell
NJ Dept. of Environmental Protection

Joe Davis - Retired

Tom Fikslin
Delaware River Basin Commission

Lisa Gelvin-Innvaer
DE Division of Fish & Wildlife

Rick Greene
DE Dept. of Natural Resources
and Environmental Control

Ward Hickman
U.S. Geological SurveyPeter Himchack
NJ Dept. of Environmental Protection

Karen Holm
Delaware County Planning Dept.

Steve Howard
New Jersey Conservation Foundation

Desmond Kahn
DE Dept. of Natural Resources
and Environmental Control

Charles Kanetsky
U.S. EPA, Region III

Sue Kilham
Drexel University

Jay Laubengeyer
Cumberland County Planning &
Development

Alvin Maiden
Environmental Consulting Services, Inc.

Rick McCorkle
U.S. Fish & Wildlife Service

Kathy McKenna
PA Bureau of Forestry

Roy Miller
DE Dept. of Natural Resources
and Environmental Control

James Mumman
NJ Dept. of Environmental Protection

Larry Niles
NJ Dept. of Environmental Protection

Robert Nyman
U.S. EPA, Region II

John O Herron
Environmental Consultant

Harry Otto
DE Dept. of Natural Resources
and Environmental Control

Jack Pingree
DE Dept. of Natural Resources
and Environmental Control

David Pollison
Delaware River Basin Commission

Ralph Powell
Mobil Corporation

Charles Rehm
PA Dept. of Environmental Resources

John Ronafalvy
Public Service Electric & Gas Co.

Debbie Rouse
DE Dept. of Natural Resources
and Environmental Control

Rob Ryan
PA Dept. of Environmental Protection

Dan Salvito
Public Service Electric & Gas

Phil Sandine
Environmental Liability Management, Inc.

Barry Seymour
Delaware Valley Regional Planning
Commission

Jonathan Sharp
University of Delaware

Frank Steimle
NOAA National Marine Fisheries Service

Fred Stine
Delaware Riverkeepers NetworkClay Sutton
Herpetological Associates, Inc.

Larry Thornton
NJ Dept. of Environmental Protection

James Walsh
PA Dept. of Environmental Resources

Joan Walsh
New Jersey Audubon Society

Marria O Malley Walsh
U.S. EPA, Region III

Paul Webber
Delaware River Basin Commission

Chuck Wood
U.S. Geological Survey