National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries: Results of Pilot Studies

Executive Summary

Three Pilot Studies were conducted during calendar year 2007 to further refine and test the concepts of a National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries (Network). Representatives of monitoring organizations in Delaware Bay, Lake Michigan, and San Francisco Bay worked as volunteers to prepare their individual reports and contribute to this summary report. They identified the major management issues in their study area and how well those issues would be addressed by a fully-implemented Network. Each Pilot Study conducted an inventory of all on-going monitoring and compared that to the design specifications of the Network to identify gaps in monitoring. Data management and access were considered as part of the gap analysis. The costs of both existing monitoring and that needed to fill the gaps were estimated for each Pilot.

Major conclusions from the Pilot Studies include:

- The primary management issues identified during the Pilot studies are relatively small in number and similar to those identified during the Network design and a nationwide survey. A fully-implemented Network would contribution to many of the most important resource management issues in each of the Pilot studies.
- Improvements in data management would help resource decision-makers make better use of the monitoring that is currently underway as well as that specified by the Network design.
- The monitoring underway in the Pilots does not fully meet the Network design. There are gaps in the numbers of sites, sampling frequency, and the need for additional analytes.
- Analysis by the Delaware and Lake Michigan Pilots reinforced the need for local expertise to make decisions to add monitoring of tributary rivers not specifically mentioned in the Network design report.
- The San Francisco Bay Pilot recommends some level of flexibility in decisions about biological measurements so that monitoring can be most relevant to local conditions and issues. This concept is currently incorporated in the Network design in that the approach for biological monitoring includes a tiered approach which acknowledges the need for some national consistency along with flexibility to address local needs.
- Experts from the Pilot Studies made significant contributions to refining the Network design for wetlands monitoring.

- The annual estimated costs for full implementation of the Network design for each Network estuary and its tributaries would be in the range of $5-7 million depending on size and complexity. Based on the cost estimates from Lake Michigan, the costs for each of the Great Lakes could be about $12 million. These estimates do not include the costs for near shore and off shore monitoring. It is important to note that only some of the costs are new as there is a significant amount of monitoring already underway.

Introduction

This report summarizes the results and conclusions of three Pilot Studies undertaken during 2007 to test the concepts of the National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries, hereinafter referred to as the Network. A link to the individual Pilot Study reports which contain much more detail can be found at http://acwi.gov/monitoring/network/pilots. The Pilot Studies, which are the second phase of Network implementation, were conducted with participation of over 50 individuals representing about 20 federal, state, and local agencies, academic institutions, non-governmental organizations, and others within the monitoring community. There was significant coordination and cooperation among all Pilot Study partners in order to accomplish the tasks described in this report within less than one year. The Pilot Study partners worked as volunteers to prepare their reports and to contribute to this synthesis.. That effort demonstrates the interest of the monitoring community and their support for the comprehensive coverage that the Network could provide. The next phase of implementation will be Demonstration Studies during which new funds will be directed towards increased data collection, improved data management tools, and other actions necessary to increase the amount of data and information available for resource managers in these and, perhaps, other areas.

Quality assured and comparable monitoring data are considered essential for developing and tracking environmental conditions and status of ecosystems through a set of environmental indicators at scales that are most appropriate for their use, including national-level indicators. In recent years there have been several attempts to develop indicators of water quality. One important example of these attempts was led by the Heinz Center using a consensus-based approach of specialists from government, academia, and the private sector to identify a select group of environmental indicators. There 2002 report on the status of the nation's ecosystems pointed out that the basic data needed to support environmental indicators is often lacking. In 2006, the Heinz Center identified the most important data gaps from the 2002 effort and recommended, "urgent attention be given to filling ten key information gaps that prevent effective reporting on key indicators of the condition and use of U.S. ecosystems and thus limit our capacity for informed decision making". Among the ten most important data gaps were the following:

- Key habitat elements such as wetlands;

- Chemical contaminants related to human exposure such as edible portions of wild fish;
- Nitrogen fluxes in rivers that can degrade water quality especially in coastal areas; and
- Extent and impacts of non-native species.

When fully implemented, the Network would make meaningful contributions to filling all of the gaps related to coastal water resources.

A general lack of data was noted by the Commission on Ocean Policy (2004) as well as in several recent assessments of the quality, completeness and accessibility of environmental information. Each of those reports called for a strategic focus, organization and commitment in order to minimize current shortcomings in environmental monitoring and utility of monitoring data. Notable among them are reports by the National Research Council (2000) and the Pew Oceans Commission (2001). . In addition, the Government Accountability Office has issued a number of findings and recommendations for coordination and integrating observations at different levels for environmental reporting and measuring progress in environmental management and restoration at regional and national scales (GAO 2003; GAO 2004 (a); GAO 2004 (b); GAO 2004 (c)). For example, the 2004(a) GAO report said that "Improved coordination of water quality data collection can help watershed managers make more informed decisions." More recently, the U.S. Comptroller General personally reiterated the need for a set of key, reliable indicators for managing the Nation's natural resources effectively and efficiently at a meeting of the Organization for Economic Cooperation and Development (June 2007) and at a policy forum at the National Academy of Sciences (September 2007).

The Network design addresses monitoring-related issues explicitly and thoroughly. It is geographically comprehensive and hierarchical, capable of providing data for assessing water quality conditions on a regional or national basis and providing estimates with statistical confidence. In addition, the design accommodates experimental studies, requiring targeted sampling, to elucidate cause-effect relationship between environmental variables. Thus, it will contribute to the efficacy and credibility of indicators in support of decision-making. The Network design also accounts for the dynamics of ecological systems by measuring selected parameters at different spatial scales and temporal frequencies. In addition, the Network design offers guidance on data collection objectives and quality control, assuring data sharing and comparability, and establishing means for data access and retrieval.

The holistic nature of the Network design provides for both a continuum of observations from the watershed to the coastal ocean, and connectivity with the likely sources of coastal contamination; it also builds upon existing federal and non-federal observational capabilities and monitoring programs. The required coordination among monitoring entities and integration of data necessitated a pilot phase before the Network could be implemented nationally. The intent of the pilot studies is to better evaluate different facets of the Network design, modify any sampling or data management approaches, and outline a more efficient means for Network implementation nationwide.

Background

In 2004, the U.S. Commission on Ocean Policy recommended a national monitoring network to improve management of ocean resources.[1] In response to this report, the Council on Environmental Quality (CEQ), the National Science and Technology Council (NSTC) Subcommittee on Water Availability and Quality (SWAQ), and the Joint Subcommittee on Oceans Science and Technology (JSOST) charged the Advisory Committee on Water Information (ACWI) with the task of designing a national water quality monitoring network. ACWI is a federal advisory committee, which has membership representing federal and non-federal interests with a wide range of responsibilities for water resources. ACWI formally accepted the charge in February 2005 and delegated leadership for the effort to the National Water Quality Monitoring Council (Council), a subcommittee of ACWI which was asked to preparing a design by early 2006. The Council worked with about 80 individuals who represented 40 different organizations, including federal and state agencies, academia, interstate organizations, and the private sector to design the Network.

The report describing the Network design, "A National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries", was accepted by ACWI in April 2006 and presented to CEQ, SWAQ, and JSOST. The full report can be found at http://acwi.gov/monitoring/network/design. Because of the scope and scale of the Network design, ACWI recommended one or more Pilot Studies to test and refine the design. ACWI also recognized the need to engage the monitoring community to refine some elements of the design by further developing core measurements, including nutrients, contaminants, wetlands and biological parameters. Refinements to the Network design are presented in a companion report, "Summary of refinements to the design of the National Water Quality Network for U.S. Coastal Waters and their Tributaries". As a result of ACWI's recommendations, in January 2007, the Cabinet Committee on Ocean Policy (COP) asked ACWI to develop and conduct Pilot Studies with a January 2008 target date for completion.

An announcement of the pilot phase of Network implementation was widely distributed among the monitoring community with a request for expressions of interest. As described in the announcement the primary goals for the Pilot Studies were:

(1) inventory current data and information collection in the study area;
(2) identify gaps between existing monitoring and that indicated by the Network design;
(3) estimate costs on on-going monitoring and costs to fill the gaps;
(4) investigate data comparability and data sharing issues;
(5) identify management issues in the study area that would be better addressed if the gaps were filled; and
(6) prepare a report documenting activities and accomplishments of the Pilot Study.

The Pilots were to be conducted without additional funding from Federal agencies. A subcommittee of the Council selected three Pilot Studies: Delaware Bay, Lake Michigan, and San Francisco Bay, in March 2007 from twelve expressions of interest based on criteria included in the announcement. It is important to note that San Francisco Bay actually contains two of the 149 Network estuaries: San Francisco Bay and Central San Francisco/San Pablo/Suisun Bays.

Pilot Study Characteristics

The major characteristics of the Pilot study areas are summarized in Table 1. Land use in the watersheds of Delaware Bay and San Francisco Bay are very similar. Lake Michigan has a slightly higher percentage of agricultural land than the other two pilots. All three have a significant amount of undeveloped land in spite of the fact that major metropolitan areas are in or near each of the study areas. Millions of these people obtain their water from tributaries to the two estuaries and the waters of Lake Michigan. For example, 15 million people rely on water from the Delaware basin for drinking water supply, including 7 million in New York City and northern New Jersey who live outside the basin. Water in the Sacramento and San Joaquin Rivers, the major tributaries to San Francisco Bay, is diverted to provide drinking water for much of California. Lake Michigan provides drinking water for eleven million people in the urbanized area along the southern shore of the lake, including Milwaukee and Chicago.

Each of the Pilot Study areas has its own important characteristics that make them important study areas as well as places to test Network design concepts. The Delaware River is the longest un-damned river in US with about three quarters of the non-tidal river (about 150 miles) included in National Wild and Scenic Rivers system. The tidal portion of the Delaware is over 133 miles long with several important tributaries entering the river below the head of tide at Trenton, New Jersey. The Delaware basin has the world's largest freshwater port complex and is one of the Nation's largest oil and container ports.

Lake Michigan is the sixth largest lake in the world and the only Great Lake entirely within the U.S. The Great Lakes represent 95% of the nation's surface fresh water. Projections indicate that by 2025-2030 the built landscape surrounding southern Lake Michigan will grow by nearly 40% and another 2 million people will be added. The water supply of the Great Lakes is regulated by international treaty, Supreme Court Decree, and a congressionally approved compact. Population and water use projections indicate that Lake Michigan area will face significant water supply challenges in the future.

The San Francisco Bay estuary is the largest estuary on the west coast. Its watershed covers about 40% of California and receives 50% of the state's runoff. The area immediately surrounding the Bay is dominated by urban land use. The Sacramento-San Joaquin Delta, where the two major tributary rivers meet, is a complex mosaic of wetlands, farmland, and urban land use. Agriculture is very important in the Delta and Central Valley. The percentage of undeveloped land in the watershed (68.5%) may seem high; this is explained by the fact that the watershed extends into the Sierra Nevada Mountains and foothills.

Resource Management Issues

The Network is designed to provide data and information that is relevant to important management issues at the regional and national level as well as for management issues related to individual Network estuaries and major tributaries. It also provides a context for more detailed monitoring to address local issues. Eight major management issues were identified as part of the Network design (see Table 2). Some of these issues are very broad. For example, habitat degradation includes a variety of changes that might result from land and water use in the watershed including changes in water levels or changing freshwater flows resulting from drought or water diversion. The contaminants issue includes contaminants in water, sediment, and biota. Five of the issues included in the Network design were also identified by over 50% of the 230 responses to a survey of resource managers conducted by the Coastal States Organization.[2]

The management issues identified for each of the Pilots, which are summarized in Table 2, are the result of focused efforts to gain participation from a variety of constituents. Both the San Francisco Bay and Delaware Bay estuaries are part of the Clean Water Act's National Estuary Program which helps to provide a structure to articulate and address the major management issues facing these estuaries. Recently, the San Francisco Estuary Program updated its Comprehensive Conservation and Management Plan based on input from more than 80 representatives from federal and state agencies, local governments, environmental groups, business and industry, academia, and the public. This revised 2007 plan is the best consensus statement of the major management issues facing the Bay. The management issues listed in the Delaware Pilot report arose from the biennial Estuary Science conference held in 2005 and attended by more than 250 scientists and managers as well as a workshop held in late 2005 that was also broadly representative of those with interest in and knowledge of Delaware Bay and the Delaware River. Management issues for Lake Michigan are based on the Lakewide Management Plans that have been developed for each of the Great Lakes as part of the US-Canadian Great Lakes Water Quality Agreement (GLWQA) and its amendments of 1987.

Pilot Study partners are actively addressing many of the issues seen in other coastal areas of the United States. Important management issues in the Delaware Pilot include maintaining freshwater flows and freshwater quality, reducing loading of toxic chemicals, public health issues such as beach contamination and the safety of drinking water and seafood, ecological risks from oil and other chemical spills, and loss of habitat and status of the population of key species such as the oyster, the horseshoe crab and American shad. In addition, the Delaware estuary has extensive fresh, brackish, and saltwater

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[2] Coastal States Organization; *Improving Links Between Science and Management: Results of a Survey to Assess U.S. State Coastal Management Science and Technology Needs*; prepared by Urban Harbors Institute, University of Massachusetts Boston and the University of New Hampshire Survey Center for The Coastal States Organization; Washington, D.C.; 2004.

marshes. A major management goal is maintaining and conserving the health of these wetlands. San Francisco Bay management issues include habitat for many threatened and endangered species, legacy contaminants such as mercury, PCBs, and chlorinated pesticides, restoration of Bay wetlands and Delta habitat, and management of sediment, some of which dates from gold rush days. The Bay has a very large number of invasive species that have had major effects on food chain dynamics. Issues in Lake Michigan include fish consumption advisories because of legacy toxic chemicals in sediments and beach closures because of potential pathogenic organisms. One of the major management issues is continued remediation of Areas of Concern that have various kinds of use impairment including degradation of benthos, pending restrictions on drinking water supply, loss of habitat (especially coastal wetlands), undesirable algae, and beach closings among others. The lake's aquatic food web is impaired due to aquatic invasive species.

Overall, the Pilot Studies share most of the management issues identified in the Network design and in the Coastal States Organization's survey. The major exception is that none of the Pilots face oxygen depletion which is so often found in other settings. The Pilot Study partners identified three additional management issues. In all three Pilot Study areas, habitat and living resource restoration projects are planned and underway and monitoring is needed to support these projects. In addition, loss of wetlands and the health of the remaining wetlands were identified as important issues in each of the Pilot Studies. Finally, loss of native species including several key fish species is a significant management issue for San Francisco Bay. In each of the Pilot Study areas, the partners are working with the emerging Integrated Ocean Observing System (IOOS) regional associations to leverage their efforts and their understanding of coastal systems. This will help to ensure that IOOS progress in understanding coastal water quality can reinforce existing programs and help to address management issues.

The Pilot Studies were asked to determine how a fully-implemented Network might better address their management needs. Table 3 summarizes the results of this analysis. An important conclusion is that all three of the Pilots indicate that better data management is needed. This is an acknowledgement of the fact that while there is a significant amount of data collection underway, more effort is needed to link data. This will lead to more insightful data interpretation and advance understanding of the systems and apply that understanding to management needs. Another conclusion is that a fully-implemented Network would provide the data to calculate concentrations and loads of nutrients and contaminants moving into coastal waters which would help to address several of the important management issues. Finally, additional biological monitoring would be relevant to management issues in all three of the study areas.

Inventory of Current Monitoring

The results of inventories of current monitoring in the Pilot Study areas are summarized in Table 4. The data in this table are total numbers of monitoring organizations that have either a major or minor level of effort for each resource component. There is often more than one program from an individual monitoring organization so if the individual programs were counted rather than the organizations, the numbers would be higher. Also some monitoring organizations have on-going efforts for more than one environmental compartment. Thus, the numbers in the major and minor columns for each of the Pilots will not sum to the total at the top of the table. The inventories focused on those monitoring organizations that were part of the overall Pilot effort but also included other organizations that are known to have monitoring underway even if they were not part of the Pilot Study partnership. Because some monitoring organizations may either be unknown to the Pilot Study partners or may not have reported their efforts, it is possible that there is actually more monitoring than is reflected in the table. Nevertheless, given the short time frame for the inventory, the information in Table 4 summarizes the monitoring that is most relevant to the Network's goals.

The level of monitoring for each organization is classified as either major or minor to give some sense of scale. If an effort is classified as minor it does not mean that its contributions are unimportant. It just means that monitoring is restricted in extent, has been underway for a relatively short time, or has a lower cost. One of the important features of the Network design is that it will integrate monitoring data from both major and minor efforts to augment the results from individual organizations. Decisions about whether a specific organization has a major or minor effort were based on three factors: its cost, duration, and geographic extent. If an organization is making a major effort for at least two of these factors, it was judged to be a major effort overall. If an organization has a major effort underway for only one of the factors and a minor effort for the other two, it was judged to be a minor effort overall. If an organization has a minor effort underway for all three factors, it was judged to be a minor effort overall. The following guidelines are used to determine whether the effort is major or minor:

- **Cost**: Major efforts are those for which an organization spends over $1.0 million within a 5-year period; minor efforts are those that cost less than $1.0 million. These funds are cumulative over 5 years because of the Network's 5-year rotation for probabilistic monitoring of estuaries and near-shore coastal environmental compartments.
- **Duration**: Major monitoring efforts are those that have been underway for 3 or more years; minor efforts are those underway for less than 3 years. The table is intended to show current efforts; thus, organizations that conducted monitoring at some point in the past but which are no longer active were not included. It is important to note that some monitoring programs that are not currently actively made important contributions to the management of these areas.
- **Geographic Extent**: Major indicates that an organization uses standard procedures and protocols over large areas such as (i) 50% or more of a Network estuary; or (ii) measurement of rivers at the drainage point of HUC-6 or other important river; or (iii) major aquifers in the study area. Minor indicates specific studies in smaller portions of the study area. For example, research studies focused on a few sites would be minor in geographic extent.

Although it was an important effort for the Pilots, it is likely that the inventory of existing monitoring was easier than it might be in other areas because the Pilot Study partners have been part of cooperative efforts for some time. For example, the results of the effort to identify major management issues reflects the fact that there have been broadly-based communications among federal, state, and local agencies, universities, non-governmental organizations, the private sector, and the public. This cooperation and communication makes it likely that the Pilot Study partners were at least generally aware of all major monitoring efforts in their study areas.

Inspection of the inventory data shows that there is some monitoring in all of the major environmental compartments in each of the pilot studies with the exception that no ongoing effort for ground water is reported for the San Francisco Bay study. There is a regional understanding of hydrogeologic conditions based on prior work by the USGS, the California State Geological Survey and academic institutions. However, land rights considerations have hindered continuous monitoring so that some knowledge gaps exist about groundwater in the watershed.

The most significant wetlands monitoring efforts in the San Francisco Bay pilot region are associated with major restoration efforts and their permitting processes. As a result, these efforts are highly variable depending on the duration of the restoration, stage of permitting and other considerations. None of these wetlands monitoring efforts have secure, dedicated funding. Rather they are budgeted line items within the larger restoration projects. This is in contrast to other resource compartments where independent monitoring programs are mandated and/or supported on an ongoing basis (e.g. beaches monitoring in accordance with AB411, air quality monitoring through the Bay Area Air Quality District). Finally, there is some off-shore monitoring by NOAA and CalCOFI for fisheries resources and satellite imagery of the area; however, the extent of these efforts is difficult to quantify for purposes of the inventory.

Data Access, Management, and Delivery

The Network is based on the concept that existing monitoring needs to be incorporated into the Network, thereby decreasing incremental costs for full implementation. To accomplish this, it is necessary that data providers have appropriate metadata, allow access to data electronically and make search and retrieval straightforward for an expanded number of data users. The importance of data access to management needs is illustrated by the fact that all three Pilots reported that improved data management would be a major benefit from Network implementation. Some work to improve data sharing is already underway in the pilot areas. For example, the Delaware Pilot reports that they are in the process of developing a prototype for a watershed-to-ocean observing system that will allow the display of data from a large variety of data sources. As such programs evolve, they will help to fill some of the shortfalls in data management and access that were identified during the Network design phase and by the Pilot Studies.

As part of the Network design, a workgroup of the Council developed criteria for the free flow of data which is described in detail in Chapter 5 of the design report. During their deliberations about data access, management, and delivery, the workgroup developed a survey which was applied to the data holdings of 173 monitoring programs from Chesapeake Bay, Delaware Bay, the Gulf of Mexico, and the Pacific Northwest plus four Federal agencies. The results of that survey are presented in the last column of Table 5. Each of the Pilots conducted a similar review of data holdings in their study area. The numbers in the table represent the percentages of all programs in the study area, including both major and minor efforts as described in the inventory discussion above. For example, 19% of the programs in Delaware Bay have data that are not easily available to the public which means that access to the data is limited to the data originator and close collaborators. Half of the data for the Delaware Pilot are available via automatic machine to machine transfer.

The Network design includes the expectation that data will be available for direct machine to machine transfer from the monitoring database to the computers of data analysts; that the databases can be searched by location to retrieve individual values; that there will be full compliance with ACWI metadata standards; and that data will be preserved in failure-resistant systems and stored as back-up files in multiple geographic locations. These attributes are highlighted in Table 5. All of these characteristics are self-evident except for the ACWI metadata standards. These provide full information about who collected the data; how, where and when samples were collected and analyzed, and for what purpose. A full list of the ACWI metadata standards can be found at http://acwi.gov/methods/data_projects/index.html. It is important to point out that the adoption of metadata standards by ACWI is relatively recent and it is likely that monitoring organizations are moving towards fuller use of these standards as they update and improve their data management systems.

A clear majority of monitoring organizations nationwide and the Pilots have data available in digital format (which also includes web services) with the Pilots having more ability for direct machine to machine transfer than the organizations in the Council survey. All three Pilots have a higher percentage of data holdings than the national survey that can be searched by location and retrieved by individual values. This feature is important because the capacity to search by location makes it easier to find data and to tailor the data query to specific issues or management problems and thus avoid costly indiscriminate retrievals. In regard to metadata, Lake Michigan has a very high percentage of programs that are either partially or fully compliant with ACWI standards. Most monitoring programs in the San Francisco Bay Pilot have metadata for the database as a whole but minimal documentation for individual entries. For the Delaware Pilot, 38% of the programs have no metadata documentation, another 38% have documentation for the database as a whole, and 24% have full compliance. It is difficult to compare the metadata availability in the Pilot Studies to the results of the Council survey because almost half of the programs in the survey had an unknown level of metadata documentation. A higher percentage of monitoring programs in the Pilot Studies have redundancy in their archive methods than in the Council survey,. However, there is a significant amount of data that are either at risk or for which the archive method is unknown in the Pilots as well as for monitoring organizations nationwide.

Gap analysis

The gap analysis was a significant effort for the Pilot study partners. Each of them compared the monitoring specified by the Network design with the efforts currently underway in their study area, as determined by the inventory. In some resource compartments, the on-going monitoring is consistent with the Network design. More often there is a need to add stations, increase sampling frequency, or add constituents to the current list of analytes. The summary tables for each Pilot's gap analysis are included in this report as Table 6 for San Francisco Bay, Table 7 for Delaware Bay, and Table 8 for Lake Michigan. These tables are very rich in data, although somewhat complicated. Unlike some of the other analyses conducted by the Pilots, they are included in their entirety rather than summarized. The amount of information in the gap analysis tables demonstrates both the level of effort involved and provides insights to the size of the gaps that exist for each environmental compartment. A full explanation of the analysis and interpretation of the importance of various gaps is found in the individual Pilot Study reports. The results of the gap analysis provide the basis for the cost estimates presented in the next section of this report.

Selected conclusions of the gap analysis for each of the Pilots are presented separately in this report. First, however, an overview of the organization of the tables is appropriate. Although there are some minor differences in the way that each of the Pilots approached the task of presenting the gap analysis, the efforts were coordinated and all used a similar template. The monitoring design and the various kinds of gaps are organized in the columns which represent environmental compartments. In some cases an environmental compartment has more than one column because the Network design specified several approaches. These approaches are briefly described in the first row of the tables. For example, the Network calls for up to four approaches for monitoring estuaries. To monitor conditions, a probabilistic approach is used. Transport is monitored by monitoring stations distributed along a salinity gradient. Short-term variability is monitored by using continuous sensors. Other monitoring as determined by local experts us also provided for in the Network design. If the design for an environmental component is not specified in the Network design, that cell is generally left blank. For a full description of the Network design for each compartment, see Chapter 3, "Design Specifications" of the Network design report. The various types of gaps are presented in the rows of the tables. Most are self-explanatory. In the bottom row some Pilots included existing monitoring that goes beyond the Network design. Typically this is needed to address local management issues. Although not specified by the Network design, this monitoring is relevant because it provides additional detail and insights into issues that are important in the study area.

<u>Selected conclusions from the San Francisco Bay gap analysis:</u>

1. There are missing elements for nutrients, contaminants, and especially biology in the **near-shore coast**. There is some on-going monitoring of the **off-shore region** but it is difficult to quantify.
2. **Nutrient monitoring** in the estuary is lacking for several key analytes as identified by both the Network design and local needs. Increased temporal coverage is also a high priority. Nutrient monitoring of the Sacramento and San Joaquin Rivers occurs monthly at 12 stations, although there are some gaps in the suite of analytes.
3. **Contaminant monitoring** in the estuary is lacking 40% of analytes. Periodic surveys of analytes that are not routinely monitored, including emerging contaminants, would help to determine which need to be incorporated into regular monitoring. Additional monitoring of wet season and high-flow events could supplement the existing contaminant monitoring. Contaminant monitoring at river sites only occurs in the summer.
4. **Biological monitoring** in the estuary does not meet the Network design. There is no on-going monitoring of disease and deformities in fish, seagrass cover, macro-algae, chlorophyll a and ocean color by satellite or aircraft, or habitat mapping of the shoreline. A key local and Network design biological gap is monitoring of zooplankton and phytoplankton. There is extensive monitoring of sentinel species (marine mammals, birds, and fish), bird community assessments, fish and shellfish landings, presence of non-indigenous species, and endangered species.
5. Monitoring of **atmospheric deposition** is not extensive enough to meet local needs or the Network design.
6. For **ground water**, there is a good idea of the location of principal aquifers, how much water is used from these aquifers, and the general flow directions and gradients. Areas of known or potential sea-water intrusion have been identified. There is a fairly complete inventory of substances (natural and human-derived) in ground water. Gaps exist in (i) the quantification of ground water volumes and velocities discharging into waters if interest; (ii) quantification of vertical movement of ground water; and (iii) properties and processes in aquifers that may cause changes in quality along hydrologic gradients.
7. At the time of the gap analysis, the Network refinement for monitoring **wetlands** was still underway. The current Network design proposes a three-tiered approach including a landscape assessment using remote sensing and wetlands mapping, representative sampling, and more detailed studies. Work planned for the San Francisco Bay study area in the near future will include this approach; however, there is no current monitoring that completely matches the design.

<u>Selected conclusions from the Delaware Bay gap analysis:</u>

1. There is currently no monitoring of the **near-shore coast** that matches Network design specifications. There is, however, considerable monitoring including remote sensing (both satellite and aircraft), automated monitoring (autonomous underwater vehicles) and vessel-based monitoring. Monitoring of the **off-shore coast** is conducted primarily by the Mid-Atlantic Regional Coastal Ocean Observation Lab (MARCOOS) using satellites, high-frequency radar systems deployed along the shore, and a fleet of robotic gliders flying beneath the ocean

surface. MARCOOS is a regional observatory funded through the NOAA Integrated Ocean Observing System (IOOS) program.
2. The full tidal length of the **Delaware Estuary** is monitored regularly through the Delaware River Basin Commission (DRBC) Boat-Run program which has been operated continuously, since 1967. The boat-run monitoring is conducted with consistent discrete sampling and analyses along a transect of the estuary. A long term biogeochemical research effort conducted at the University of Delaware, which has been integrated with the DRBC monitoring, was started in 1978 and continues. Continuation of these discrete sampling programs will assist in guiding management in the future; however, for more comprehensive management for the entire estuary, additional real-time continuous measurements are also needed.
3. The Network design for **rivers** calls for monitoring only at the Delaware River at Trenton which is over 133 river miles from the Atlantic Ocean. Several moderate sized tributaries discharge to the Delaware River south of the Delaware gage. <u>It is a recommendation of the Pilot Study Steering Committee that these sites be included in the Network to monitor for flows and contaminant loads into the estuary downstream of the head of tide at Trenton. Current monitoring at the Delaware River at Trenton needs additional frequency and/or additional analytes to meet Network design specifications for nutrients and contaminants.</u>
4. Currently no organization has the responsibility for monitoring **wetlands** extent and condition. A workgroup broadly representing the Delaware Bay Pilot Study partners was formed to prepare a monitoring and assessment design for tidal wetlands and to provide advice to those working on Network refinement for wetlands. This plan is described in the Pilot Study report and is consistent with current plans for the Network.

<u>Selected conclusions from the Lake Michigan gap analysis:</u>

1. The Network design defined 87 **embayments** within the Great Lakes basin. Fifteen of these are along the Lake Michigan shoreline. At this point, there is no comprehensive monitoring program focusing specifically on embayments in the basin. Seven of the 15 Lake Michigan embayments have at least some monitoring conducted within their boundaries; yet, none of these embayments are currently being measured for the suite of physical, chemical, and biological constituents recommended in the design report. However, various elements are sampled within a number of embayments as part of some other monitoring program.
2. There is very little monitoring in the **shallow near-shore** zone and no monitoring in the **medium near-shore** zone that matches Network specifications.
3. All 20 of the **river** sites being proposed for the Lake Michigan portion of the national monitoring network currently have streamflow gaging stations on them. Fifteen sites have some ongoing water quality monitoring. None of the sites has the complete proposed constituent monitoring data set or complete correspondence with the proposed frequency.
4. Significant gaps currently exist in **wetlands** monitoring. The Great Lakes Coastal Wetlands Consortium (GLCWC) plans to release complete coastal wetland monitoring protocols in the near future. The protocols will cover assessment of

wetland chemistry and landscape features, as well as biological indicators for fish, macroinvertebrates, vegetation, birds, and amphibians. With the establishment of these protocols, it is hoped that coastal wetland monitoring data will be less fragmented across the basin and more easily shared among agencies and organizations.

5. Strategic monitoring of **beaches** that involves spatial, temporal, and source tracking methods is needed. Improvements to beach water quality will be accomplished with a thorough knowledge of the beach and its watershed and a routine monitoring program. However, to develop more progressive monitoring strategies, limited funding for routine monitoring programs may need to be redirected towards start-up costs associated with improved technology.

Cost estimates

An important effort for the Pilot Study teams was determining the total cost of monitoring in their study areas. The cost tables provided in each of the study reports are included as Appendices F, G, and H to this report. To the extent feasible, the costs for each environmental component are broken out in these appendices; however, it was not always possible to calculate all costs. For example, Delaware Bay has no estimates for on-going or incremental monitoring costs for beaches. San Francisco Bay has no estimates of the costs of ground water monitoring, current costs for off-shore monitoring, and the incremental costs of wetlands monitoring. Lake Michigan was unable to estimate current and incremental costs for monitoring embayments and near-shore monitoring. If all of these environmental components were included, the costs for on-going and incremental monitoring would be significantly greater.

The results of the Pilot Study analysis are summarized in Table 9. All costs are estimates, based on information from the organizations participating in the Pilots. The estimates include salaries, analytical costs, ship time, administrative costs, etc. The costs for data management are also included either as an independent estimate or as a percentage of direct costs. All costs in Table 9 are presented as $1000s and are rounded to the nearest $50,000. Costs for all environmental components are aggregated to report the annual costs of monitoring in the study area as specified by the Network design and the incremental costs to fill the gaps in monitoring identified through the gap analysis. The sum of these costs would be the cost of full implementation of the Network.

The costs for monitoring near-shore and off-shore waters are not included in the cost tables. The Network design did not specify many details for monitoring these environmental compartments. Instead, much of the design was deferred to the IOOS Regional Associations. The Network design did, however, indicate that monitoring should be for an entire IOOS region rather than for individual estuaries or an individual Great Lake. Thus, providing costs for monitoring at the IOOS Regional scale is beyond the scope of the Pilot Studies. IOOS Regional Associations are still in the process of reaching consensus on the level and type of monitoring necessary for each IOOS Region. Current estimates of off-shore monitoring obtained by the Pilot projects are highly variable. No cost estimate is available for Lake Michigan. The estimated cost for the Central California near-shore and off-shore regions is $15,000,000.

The incremental costs included in the estimates from the Pilots reflect, to some extent, the costs needed to improve the Network design, including that for beaches and wetlands which did not have a fully-described approach. For example, the Delaware Pilot determined that it would be necessary to have 5 river monitoring sites in addition to the Delaware River to capture 95% of the freshwater inflow to the Bay. This is consistent with the design document which included the option of adding tributaries to adequately determine flow and loads of chemicals from smaller rivers that might be significant sources of contaminants. For Lake Michigan, beach quality is a very important management issue. Although an approach for beach monitoring based on current specifications of the nation-wide BEACHES program was included in the Network design, Lake Michigan would expand on that effort based on the importance of the resource to the area. Wetlands are an important issue for both the Delaware Pilot and for San Francisco Bay. Thus, both of these Pilots have either a significant level of current effort or project significant costs to expand wetlands monitoring.

The Pilot Studies provided estimates of the costs of existing monitoring that is not part of the Network design but that is needed to address local needs. It is likely that there is additional monitoring beyond what is presented in the tables because a great deal of compliance monitoring, monitoring at the end of the pipe and monitoring in small watersheds may not be included. Also there is significant monitoring done for unique purposes that may not be at the appropriate scale for the Pilot Study reports. The costs of monitoring that is beyond the Network design are included to present a reasonably full accounting of current monitoring. There may be a temptation to think that some of these funds could be re-directed towards Network implementation; however, the Network design report and all presentations about the Network have always acknowledged that monitoring to address local issues, smaller watersheds, and other monitoring beyond the scope or the scale of the Network design is and will continue to be important. The resources that are used for such monitoring should not be thought of as being in competition with the Network but as necessary to address specific management issues that require data and understanding beyond what can be provided by even a fully implemented Network.

As might be expected, there are different levels of on-going monitoring in the Pilots and corresponding differences in the additional costs to fully implement the Network design. For example, San Francisco Bay estimates about $13 million for on-going monitoring with a relatively shallow gap of around $1.5 million needed to fill gaps and bring the monitoring to the Network design. In the case of the Lake Michigan Pilot, the current expenditures for monitoring are low compared to San Francisco Bay and the costs needed to fill the gaps are therefore higher. However, the total costs for Network implementation (on-going plus filling gaps) in these two Pilots are roughly comparable. Further analysis will be needed to understand why the Delaware Bay Pilot has significantly lower total costs for Network implementation. Certainly part of the reason is that Delaware is one estuary; whereas, San Francisco Bay includes two Network estuaries. Therefore, one might expect that the total cost for Delaware Bay would be about half that for San Francisco. Even factoring this consideration into the analysis, the costs for Delaware Bay are a bit low compared to San Francisco. Given these uncertainties, the best estimate at this time is that the cost for full Network implementation for an estuary and its tributaries, including wetlands, beaches, and atmospheric deposition would be in the range of $5-7 million depending on size and complexity. Based on the estimates from the Lake Michigan Pilot, the total costs for implementing the Network design in one of the Great Lakes would be about $12 million.

Major Conclusions from the Pilot Studies

1 The Delaware River basin, the Sacramento and San Joaquin Rivers, and Lake Michigan are the source of public water supply for millions of people. The Pilot Studies may be more important as sources of public water supply than the drainage basins of most of the other Network estuaries.

2. The primary management issues identified during the Pilot studies are relatively small in number and similar to those identified during the Network design and the Coastal States Organization survey. A fully-implemented Network would make contributions to many of the most important resource management issues in each of the Pilot studies.

3 Improvements in data management would help resource decision-makers make better use of the monitoring that is currently underway as well as that specified by the Network design.

4. The Pilots Studies are more consistent with the data management and access specifications of the Network than a nationwide survey. This may reflect the fact that there was pre-existing coordination and collaboration in the Pilot Study areas that may have lead to improvements in data sharing. However, there is still room for improvement in each of the Pilots in regard to data access, management, and delivery.

5. The monitoring underway in the Pilots does not fully meet the Network design. There are gaps in the numbers of sites, sampling frequency, and the need for additional analytes.

6. Analysis by the Delaware and Lake Michigan Pilots reinforced the need for local expertise to make decisions to add monitoring of tributary rivers not specifically mentioned in the Network design report.

7. The San Francicso Bay Pilot recommends some level of flexibility in decisions about biological measurements so that monitoring can be most relevant to local conditions and issues. This concept is currently incorporated in the Network design in that the approach for biological monitoring includes a tiered approach which

acknowledges the need for some national consistency along with flexibility to address local needs.

8. Experts from the Pilot Studies made significant contributions to refining the Network design for wetlands monitoring.

9. The annual estimated costs for full implementation of the Network design for each Network estuary and its tributaries would be in the range of $5-7 million depending on size and complexity. Based on the cost estimates from Lake Michigan, the costs for each of the Great Lakes could be about $12 million. It is important to note that these are not all new costs as there is a significant amount of monitoring already underway.

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