United States
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Developing and Implementing an Estuarine Water Quality Monitoring, Assessment, and Outreach Program

The MYSound Project

EMPACT

Environmental Monitoring for Public Access & Community Tracking

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DEVELOPING AND IMPLEMENTING AN ESTUARINE WATER QUALITY MONITORING, ASSESSMENT, AND OUTREACH PROGRAM

THE MYSOUND PROJECT

U.S. Environmental Protection Agency
National Risk Management Research Laboratory
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FOREWORD

In collaboration with the U.S. Environmental Protection Agency's (EPA's) Office of Environmental Information, the Technology Transfer and Support Division of the EPA Office of Research and Development's (ORD's) National Risk Management Research Laboratory initiated the development of this handbook. The purpose of the handbook is to help interested communities learn more about the Monitoring Your Sound (MYSound) EMPACT project and provide these communities with information to help them conduct similar projects. ORD, working with the MYSound project team, produced this handbook to maximize EMPACT's investment in the project and minimize the resources needed to implement similar projects in other communities.

You can order both print and CD-ROM versions of this handbook online at ORD's Technology Transfer Web site at *http://www.epa.gov/ttbnrmrl*. You can also download this handbook from the MYSound Web site at *http://www.mysound.uconn.edu*. Finally, you can order a copy of the handbook by contacting:

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We hope that you find this handbook worthwhile, informative, and easy to use.

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1 INTRODUCTION

In September 1998, EPA's Long Island Sound Project Office and the University of Connecticut initiated a prototype marine environmental monitoring network for Long Island Sound. This project, known as Monitoring Your Sound or MYSound, provides comprehensive, timely water quality data on Long Island Sound and its harbors and estuaries. The data from the monitoring network, along with educational information about marine water quality, are available in real time[1] on the project Web site, *http://www.mysound.uconn.edu*.

1.1 ABOUT THIS HANDBOOK

This handbook has been designed with two goals in mind. The first goal is to present a case study of the MYSound project, including the successes achieved and challenges faced in acquiring and disseminating real-time marine water quality data. The second goal is to provide information and suggestions for developing similar projects in other communities. Using the MYSound EMPACT project as well as other programs as models, this handbook presents recommendations and tips on ways to:

1. Collect and analyze real-time marine water quality data.
2. Develop systems to manage and deliver real-time marine water quality data.
3. Accurately and effectively communicate marine water quality information to stakeholders and members of the public.
4. Develop a long-term plan to sustain the program through partnerships with key stakeholders.

The handbook is organized into the following chapters:

Chapter 2 discusses marine water quality in the context of coastal and estuarine systems, and its importance to human health and the environment. The chapter begins with an overview of coastal and estuarine systems, circulation patterns, and pollution problems that affect water quality. Particular attention is paid to Long Island Sound and the current pollution problems and water quality status and trends observed in the Sound. The chapter also presents an overview of the role of water quality monitoring and key parameters of interest for coastal and estuarine areas.

Chapter 3 discusses the development of a marine environmental monitoring strategy for coastal and estuarine waters with emphasis on water quality monitoring. It describes the important considerations in forming a water quality monitoring network: who, why, when, where, what, and how. Only when these issues have been thoroughly considered can an implementation plan for the monitoring project be successfully developed. The chapter addresses key steps such as getting to know the marine environment and identifying previous and ongoing monitoring programs; selecting program partners (who); determining the goals of the monitoring program (what will be monitored and why); delineating the scope of the monitoring effort (when and where); and determining the general methodologies and instrumentation to be used in the effort (how). The chapter also discusses the development of a funding strategy.

Chapter 4 focuses on data collection, management, and delivery. It presents general "how-to" information about establishing and operating water quality monitoring stations to collect and transmit real-time

[1] For the purposes of this document, the term "real time" takes into account a lag time of less than 15 minutes between when data is collected and when it is available on the MYSound Web site.

data. It addresses key considerations such as site selection, station configuration, sensor selection, and data processing and power requirements. It describes the basic quality assurance/quality control (QA/QC) activities that must be conducted and provides references to help develop a project-specific QA/QC plan. Chapter 4 also provides general cost estimates for deploying and maintaining the monitoring network.

Chapter 5 presents information on Web site design and operation. It describes how the data can be presented in the form of statistical and time-series data summaries both in real time on the Web, or incorporated into annual reports. Alternative methods of information dissemination are also addressed.

Chapter 6 focuses on the communications/outreach project element. It provides information on how to accurately and effectively communicate various types of information—including timely marine water quality data—to the public at large. The chapter presents the detailed steps needed to create a comprehensive outreach plan and provides resources that can provide help with presenting technical water quality information to the public. It also describes various mechanisms for obtaining feedback about who is using the data and how useful it is.

Chapter 7 addresses the issue of how to sustain a marine water quality monitoring network. It describes some of the future directions and options under consideration for MYSound and how the project has successfully developed a strategy called "distributed stewardship."

This handbook addresses multiple audiences, including prospective monitoring project partners (such as environmental managers, researchers, and educators) as well as stakeholders (key user groups who can champion the project and often provide in-kind logistics and outreach support). It is designed to be understandable to both technical and non-technical individuals and provide useful information to both. *Chapter 2* presents an overview of water quality issues for readers who are not familiar with the subject of water quality, as well as the general goals and strategies for implementing a water quality monitoring program. Managers and decision-makers will likely find the introductory sections in *Chapters 4* and *5* to be most helpful. The latter sections of these chapters present more detailed guidance most applicable to technicians, operators, and professionals tasked with implementing a timely water quality data delivery project. *Chapter 6* is targeted towards personnel tasked with implementing the communications an outreach portions of the project. *Chapter 7* is useful for managers and decision-makers contemplating beginning or expanding a marine monitoring program, and seeking to make it sustainable in the long term.

About the EMPACT Program

This handbook was developed by EPA's Environmental Monitoring for Public Access and Community Tracking (EMPACT) program. EPA created EMPACT to promote new and innovative approaches to collecting, managing, and communicating environmental information to the public. Working with communities across the country, the program takes advantage of new technologies to provide community members with timely, accurate, and understandable environmental information they can use to make informed day-to-day decisions about their lives. EMPACT projects cover a wide range of environmental issues, including water quality, groundwater contamination, smog, ultraviolet radiation, and overall ecosystem quality. While some of these projects were launched by EPA, others were launched directly by EMPACT communities.

In addition to MYSound, EMPACT funded several other water quality monitoring projects involving real-time water quality monitoring and data distribution, including the Lake Access—Minneapolis Project *(http://www.lakeaccess.org)*, the Chesapeake Bay Project, and the Jefferson Parish (Louisiana) Project (described in Appendix D). Although the monitoring strategy, parameters measured, and instrumentation employed differs from project to project, there are similarities and lessons learned that are noteworthy in each. Comprehensive technology transfer handbooks similar to this one have been prepared for these three projects.

Following Chapter 7 is a glossary of terms used throughout this handbook *(Appendix A). Appendix B* contains a MYSound outreach brochure. *Appendix C* contains selected E-mails from visitors to MYSound's Web site. *Appendix D* contains brief overviews of two other coastal water quality monitoring programs: the Jefferson Parish, Louisiana and Chesapeake Bay EMPACT projects.

Throughout this handbook are lessons learned and success stories related to the MYSound EMPACT project. Also provided are references to supplementary sources of information, such as Web sites, guidance documents, and other written materials that present a greater level of technical detail.

1.2 HISTORY AND OVERVIEW OF THE MYSOUND PROJECT

Monitoring the health of coastal and estuarine ecosystems has become increasingly important over the past decade. As human activities continue to affect these waters, the nation is becoming more aware of the need to take a more comprehensive approach to protecting freshwater and marine water resources. The health of an estuary is subject to many factors and can be manifested in both short-term events and subtler long-term trends. An ideal environmental monitoring program requires continuous, long-term measurement of a variety of physical, chemical, and biological parameters over a wide geographic area to represent the overall health of the ecosystem.

Numerous environmental data collection efforts have been undertaken in Long Island Sound and other estuarine systems over the years. Government agencies and university researchers have conducted intensive data collection efforts as part of specific projects (such as an environmental impact assessment for a dredging project or nuclear power plant), specific research efforts, or specific pollution problems (such as toxic chemical contamination in a certain location). Monitoring of an entire estuary typically consists of sampling a few parameters, at a handful of points over a wide area, at specific times of the year. While such sampling provides a general indication of environmental trends in the estuary on a month-to-month or year-to-year basis, it does not provide enough information to detect episodic water quality degradation and its causes and impacts, or to understand the long-term dynamics that govern the estuarine ecosystem.

The monitoring technologies used in these efforts have had limitations. Most programs have relied on point sampling in the field and analysis in the laboratory, which can be time-consuming and expensive. Often the data from these monitoring efforts become available to the wider community of users and other interested parties only after a significant period of time has elapsed.

Several developments in the past decade hold the promise of streamlining this process. First, recent advances in physical and chemical oceanographic instrumentation, improvements in data transmission technologies (via radio, cell phone and satellite telemetry), and advances in on-board microcomputer data processing have made real-time oceanographic data acquisition and transmission feasible. A number of real-time coastal marine environmental monitoring systems are now up and running around the country, such as the Chesapeake Bay Observing System (CBOS) inaugurated by the University of Maryland's Center for Environmental Science, the Rutgers University Long-Term Ecosystem Observatory (LEO) Project begun in 1996, and the Gulf of Maine Ocean Observing System (GOMOOS) begun in 1999. Smaller regional and local real-time monitoring efforts are under way in various estuaries, rivers, and harbors around the country. These projects gather and integrate data from real-time continuous monitoring stations, wide-area survey sampling by vessels, and satellite remote sensing data to provide a comprehensive, long-term view of the physical, chemical, and in some cases, biological environmental parameters throughout the estuary.

Second, additional stakeholders, such as local schools and environmental organizations, have become active in marine environmental monitoring efforts. Their efforts usually target a particular coastal area or estuary, and often a specific harbor, river, or wildlife preserve within the estuary. Often these volunteer monitoring efforts are supported by federal agencies, university outreach and extension services, or a larger umbrella organization. Data are generally acquired through conventional, low-technology sampling procedures and are limited to near-shore locations and favorable weather conditions. However, the cumulative contribution of these more focused sampling efforts can be significant, particularly if the data are subject to approved quality assurance and quality control (QA/QC) procedures, and the data can be compiled and made accessible to other stakeholders.

These new developments provide an emerging opportunity to significantly upgrade coastal and estuary environmental monitoring programs. Recognizing this opportunity, EPA's Long Island Sound Office and the University of Connecticut undertook the MYSound project, a marine environmental monitoring network for Long Island Sound.

The goal of the project is to provide comprehensive, real-time marine water quality monitoring data on Long Island Sound (LIS) and its harbors and estuaries, both to serve the needs of specific users and to increase public understanding of water quality. The first step in providing these data was to establish estuarine water quality monitoring stations in the vicinity of Bridgeport and New London, Connecticut, in the first year of the project (1998). Data from these stations are collected, analyzed, supplemented, and integrated with complementary data from other agency, municipal, and volunteer water quality monitoring efforts. Real-time data are compiled and disseminated on the project Web site *(http://www.mysound.uconn.edu)* along with interpretive information to enhance understanding of the data by students, teachers, and the public at large.

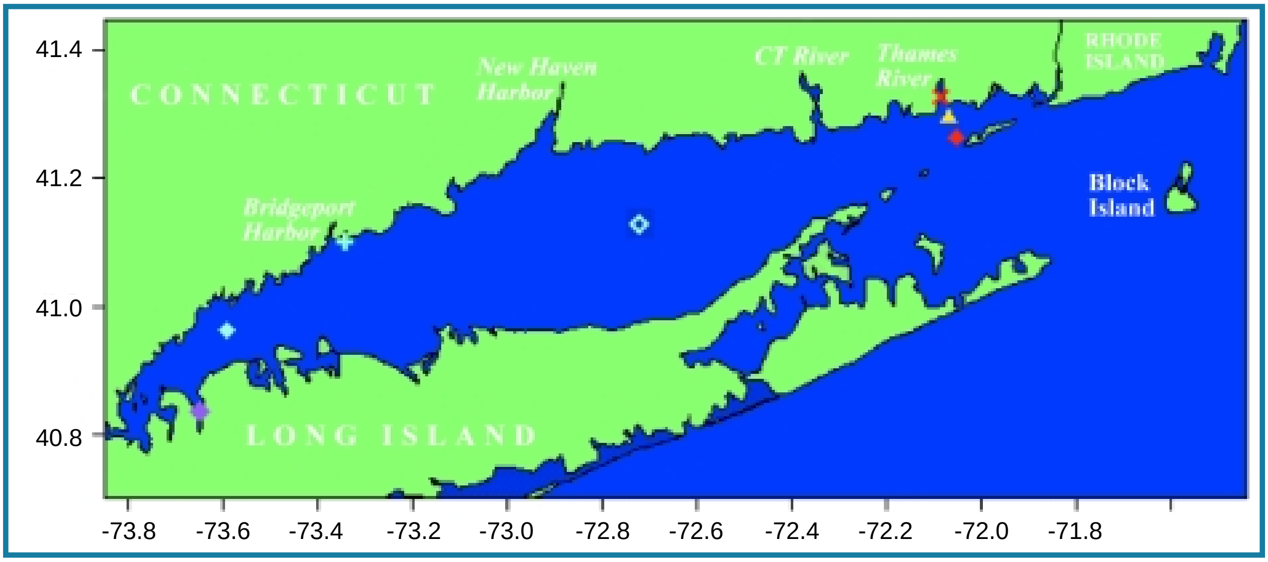
Four monitoring stations currently form the basic network. These are deployed in the vicinity of Bridgeport, New London, and at the western end of the Sound. MYSound has also established a link with a real-time monitoring station in Hempstead Harbor on the New York side of the Sound (operated by the Hempstead Harbor Protection Committee and the Coalition to Save Hempstead Harbor). Table 1 below shows the locations of all five monitoring stations. Figure 1.1 shows the distribution of stations throughout Long Island Sound.

Table 1 - Long Island Sound Marine Environmental Monitoring Network Stations

Station	Offshore New London	Inshore New London	Inshore Bridgeport	Offshore Western LIS	Inshore Hempstead Harbor
General Location	Eastern LIS Dredging Disposal Site	Thames River Near Coast Guard Academy	Bridgeport Harbor	Offshore Greenwich	Adjacent to Glen Cove Marina
Location Coordinates	41-16N 72-04W	41-22N 72-05N	41-10N 73-10W	40-57N 73-35W	40-49N 73-39W

The baseline suite of observations includes measurement of water temperature, salinity/conductivity, and dissolved oxygen. Measurements are obtained at two points on the vertical (near bottom and immediate sub-surface [1 meter depth]) at 15-minute intervals. Meteorological stations are installed and operating on Ledge Light at the entrance to New London Harbor, and on the Central LIS buoy located southeast of New Haven Harbor. In the future, additional parameters, including nutrient/nitrate concentration and chlorophyll *a*, may be measured at selected sites by in situ sensor measurement and/or water sample capture and laboratory analysis.

Figure 1.1 Map showing the general location of MYSound water quality monitoring and meteorological stations.



Real-time data from all stations are available on the MYSound Web site. Archived data can be retrieved directly from the Web site via FTP download. The Web site also provides a wealth of interpretive and educational material, links to other data sources, and an online survey to query users on the usefulness of the site and their understanding of its content.

The primary customer for the project is the public at large in the communities surrounding Long Island Sound. Other users of the data include:

Federal, state, and local environmental managers, who can use the data to gauge the effectiveness of coastal zone management and pollution control initiatives (e.g. local non-point source management initiatives)

Policy-makers, who can use the data to illustrate the need for improved water protection policies.

University researchers, who can use the data to support specific ecological investigations and to calibrate and verify predictive models. The site-specific, time-series data will provide an excellent opportunity to assess the temporal and spatial variability of water quality in the Sound, and study changes in water quality and the resulting biological regime due to short-term, high-energy aperiodic events such as high winds, heavy rainfall, or extreme temperature fluctuations.

Marine educators (at both the K-12 level and university level), who can use the information in developing marine and environmental science curricula, and can integrate use of the Web page into class projects.

Non-government organizations (NGOs), which can use the data to complement their own volunteer water quality monitoring efforts, and to focus attention on the Sound and the importance of marine water quality to its health.

Marine transportation companies and fishermen, who can use the data on wind, wave, and current conditions in the Sound in planning operations.

Aquaculture companies (companies that cultivate the natural produce of water, such as fish and shellfish), which can use the information in selecting aquaculture sites.

Marine environmental monitoring sensor development companies, which can use the data to develop design parameters for their instruments, and can use the monitoring stations as test and evaluation platforms for prototype sensors.

2 MONITORING WATER QUALITY IN ESTUARIES AND COASTAL AREAS: AN OVERVIEW

This chapter presents an overview of marine water quality, and how threats to coastal and estuarine systems can affect human health and the environment. Section 2.1 describes the nature and dynamics of estuaries, including the natural and anthropogenic phenomena that affect these environments. Section 2.2 discusses the water quality problems encountered in Long Island Sound, including the primary pollution problem in the Sound: decreased levels of dissolved oxygen, or hypoxia. Section 2.3 presents an overview of marine water quality monitoring for the physical, chemical, and biological parameters of concern in estuaries and coastal areas. This section also lists Web sites for further information on the ecology and pollution problems of watersheds, estuaries, and coastal regions.

2.1 THE NATURE AND DYNAMICS OF ESTUARIES

To develop and implement an effective plan for a comprehensive estuarine monitoring network, it is important to understand the nature and dynamics of estuaries in general, and also to understand the details of the particular estuary, embayment, harbor, or river to be monitored. These details include the bathymetry, tidal range, circulation patterns, and pollution problems that are being encountered.

The estuarine environment is a complex blend of continuously changing habitats. Unlike fresh water rivers and lakes, estuaries can produce a wide range in the values of physical and chemical parameters that will be recorded, and frequent changes occur in these values both with tidal cycles and meteorological events. In streams, rivers, and lakes, water quality parameters are more likely to fluctuate within a well-defined range largely determined by rainfall and season, and these values are often homogenous throughout the water body. In an estuary, in contrast, these parameters can change abruptly in time and space, are dependent on the measurement location, and may or may not reflect general environmental conditions throughout the estuary.

Two key phenomena that control physical and chemical parameters in estuaries are tidal flushing and stratification (vertical or horizontal). Tidal flushing is the net transport for water (as well as sediments and contaminants) out of an estuary with tidal flow and river flow. Stratification is layering of the estuary generally associated with the inflow of denser salt water at depth and the outflow of more buoyant fresh water at the surface. Layering can also occur when seasonal heating causes a sharp differential or thermocline (interface where temperature changes rapidly with depth) so that the warm surface layer is isolated from the colder bottom layer. A good overview of estuarine dynamics as they relate to monitoring is provided in the publication *Volunteer Estuary Monitoring—A Methods Manual* (http://www.epa.gov/owow/estuaries/monitor) developed by EPA and the Center for Marine Conservation (now the Ocean Conservancy).

Superimposed on these naturally occurring variations are changes caused by human intervention, including modification of flow and bathymetry (for example, through construction of barriers to flow or dredging) and the input of pollutants, including excess nutrients and toxics. Often the status, trends, and episodic changes in the levels of these pollutants are the focus of a monitoring effort. Typical pollution problems in estuaries include nutrient enrichment leading to accelerated eutrophication (excessive plant growth); low dissolved oxygen (DO) levels associated with eutrophication and/or flow restrictions; toxics in the water column or sediments, particularly petroleum hydrocarbons and heavy metals from point discharges and non-point source runoff; algal blooms, which can be toxic to marine organisms and humans; and the proliferation of invasive species.

What Are Estuaries, and Why Are They Important?

Unlike many features of the landscape that are easily described, estuaries are transitional zones that encompass a wide variety of environments. Loosely categorized as the zone where fresh and salt water meet and mix, the estuarine environment is a complex blend of continuously changing habitats. To qualify as an estuary, a waterbody must fit the following description:

> ***"a semi-enclosed coastal body of water which has free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage."***

The estuary itself is a rather well-defined body of water, bounded at its mouth by the ocean and at its head by the upper limit of the tides. It drains a much larger area, however, and pollutant-producing activities near or in tributaries even hundreds of miles away may still adversely affect the estuary"s water quality.

While some of the water in an estuary flows from the tributaries that feed it, the remainder moves in from the sea. When fresh and salt water meet, the two do not readily mix. Fresh water flowing in from tributaries is relatively light and overrides the wedge of more dense salt water moving in from the ocean. This density differential often causes layering or stratification of the water, which significantly affects both circulation and the chemical profile of an estuary.

Estuaries are critical for the survival of many species. Tens of thousands of birds, mammals, fish, and other wildlife depend on estuarine habitats as places to live, feed, and reproduce. They provide ideal spots for migratory birds to rest and refuel during their journeys. Many species of fish and shellfish rely on the sheltered waters of estuaries as protected places to spawn, giving estuaries the nickname "nurseries of the sea." Hundreds of marine organisms, including most commercially valuable fish species, depend on estuaries at some point during their development.

Besides serving as an important habitat for wildlife, the wetlands that fringe many estuaries perform other valuable services. Water draining from upland areas carries sediments, nutrients, and other pollutants. But as the water flows through wetlands, much of the sediments and pollutants are filtered out. This filtration process creates cleaner and clearer water, which benefits both people and marine life. Wetland plants and soils also act as natural buffers between the land and ocean, absorbing floodwaters and dissipating storm surges. This protects upland organisms as well as valuable real estate from storm and flood damage. Salt marsh grasses, mangrove trees, and other estuarine plants also prevent erosion and stabilize the shoreline.

Among the cultural benefits of estuaries are recreation, scientific knowledge, education, and aesthetic value. Boating, fishing, swimming, surfing, and bird watching are just a few of the numerous recreational activities people enjoy in estuaries. They are often the cultural centers of coastal communities—focal points for commerce, recreation, history, customs, and traditions. As transition zones between land and ocean, estuaries are invaluable laboratories for scientists and students, providing countless lessons in biology, geology, chemistry, physics, history, and social issues. Estuaries also provide a great deal of aesthetic enjoyment for the people who live, work, or recreate in and around them.

Finally, the tangible and direct economic benefits of estuaries should not be overlooked. Tourism, fisheries, and other commercial activities thrive on the wealth of natural resources that estuaries supply. Protected estuarine waters also support important public infrastructure, serving as harbors and ports vital for shipping, transportation, and industry.

From *Volunteer Estuary Monitoring—A Methods Manual*
http://www.epa.gov/owow/estuaries/monitor

2.2 ENVIRONMENTAL ISSUES AND WATER QUALITY IN LONG ISLAND SOUND

Long Island Sound is the largest and most heavily utilized estuary in the Northeast. The waters of Long Island Sound support a large and diverse ecosystem which includes tidal marshes, benthic communities, commercially valuable fish and shellfish, marine bird populations, and marine mammals. Its waters also support a wide variety of human activities, including marine transportation, commercial fishing, aquaculture, and recreation. More than 8 million people live in the Long Island Sound watershed and millions more flock yearly to the Sound for recreation. More than $5 billion is generated annually in the regional economy from boating, commercial and sport fishing, swimming, and beachgoing.

Unfortunately, until fairly recently, many decisions regarding the uses of Long Island Sound and the surrounding watershed were made without considering the impacts on the Sound's water quality and biological diversity. In general, increased residential, commercial, and recreational developments—and their pollution-related effects—are the main threats to Long Island Sound. By altering land surfaces, increasing runoff of rainwater, and reducing the natural filtration of undeveloped landscapes, this development has greatly intensified the rate at which pollutants (including toxic chemicals, nutrients, and pathogens) reach the Sound from the land. Air pollutants such as those from car emissions reach Long Island Sound as well.

Obsolescent sewer systems and poorly maintained septic systems are also major sources of pollutants (nutrients, toxic substances, and pathogens) entering Long Island Sound. Many older sewer systems were designed with combined sewer overflows (CSOs) to let rainwater runoff flow through the same pipes as sewage. During mild precipitation, the rainwater and sewage remain separated due to a dividing wall inside the pipes. To accommodate a surge of rainwater during heavy precipitation, engineers included a gap at the top of the dividing wall allowing overflowing rainwater to come in contact with untreated human sewage. This contaminated rainwater bypasses treatment and is dumped directly into Long Island Sound. These combined sewer overflow systems are currently in use in eight cities around the Sound: New York City, Norwalk, Jewett City, Derby, Norwich, Shelton, Bridgeport, and New Haven.

Nearly half of the homes and businesses in the Long Island Sound watershed have septic tank waste disposal systems. When these systems are properly sited and maintained on a regular basis, they provide an excellent waste management alternative. When they are situated in areas that do not allow for proper operation, however, or are not pumped out regularly, they often contaminate surface water and groundwater. Other sewage-related pollution sources include inadequately treated sewage discharges from boats, illegal connections to storm drain systems, and waterfowl and animal wastes.

These pollution problems can result in hypoxia, or decreased levels of dissolved oxygen. Excess nutrients from pollutants entering the Sound cause rapid growth of marine plants. As the organic matter produced sinks to the bottom, bacteria use DO in the water to decompose it. Because of the unusually large numbers of decomposing plants, the oxygen levels in the Sound's deeper waters can become dangerously low, threatening the health of bottom-dwelling species.

While the surface water layer of Long Island Sound stays oxygenated through contact with the atmosphere and photosynthesis, oxygen cannot penetrate down into deeper water layers due to a barrier called a pycnocline. (A pycnocline is a separation between two layers of different densities.) The differences in density between the top and lower layers of water prevent the mixing of surface and bottom waters. Oxygen from top layers of water, therefore, doesn't reach the bottom layers of water.

In Long Island Sound, hypoxia has been directly linked to a number of ecosystem impacts, including:

- Reduction in the number and variety of adult finfish.
- Reduction in the growth rate of juvenile lobsters and winter flounder.
- Dying off of species such as lobster, starfish, bay anchovy, menhaden, cunner, tautog, and sea robin.

The presence of pathogens (disease-causing organisms) carried in sewage and runoff may also adversely affect the health of many species—including humans. People exposed to pathogens through the ingestion of improperly cooked contaminated shellfish, or by swimming in contaminated waters, can contract diseases such as salmonellosis and hepatitis A. Beaches and shellfishing areas are often closed due to pathogen contamination.

Another concern is elevated levels of heavy metals and toxic chemicals created through human activity (industry, marinas, precipitation runoff, sewage treatment plants, car exhaust, pesticides, and household chemicals) that are collecting in the sediments of Long Island Sound. While the health risks of these chemicals on local animal and plant life are still in question, Connecticut and New York have issued "consumption advisories" for species known to carry concentrated amounts of polychlorinated biphenyls (PCBs). These include striped bass, bluefish, eels, lobsters, and crabs.

More detailed information on status and trends in the health of Long Island Sound can be found on the EPA Long Island Sound Office Web site at *http://www.epa.gov/region01/eco/lis*.

2.3 THE ROLE OF WATER QUALITY MONITORING

Keeping track of water quality status and trends requires close monitoring of a number of physical, chemical, and biological parameters. A systematic and well-planned monitoring program can identify water quality problems and help answer questions critical to their solutions. These questions include:

- Is there a problem?
- If so, how serious?
- Does the problem affect only a portion of the estuary, or the entire body of water?
- Does the problem occur sporadically, seasonally, or year round?
- Is the problem a naturally occurring phenomenon or caused by human intervention, or a combination of the two?

If monitoring activities have not been undertaken in the past, the monitoring project can be used to establish a baseline even if a pollution problem has not been identified. If reliable historical data exist for comparison, the current monitoring project can document changes in the estuary from past to present. These data may serve as a warning, alerting environmental managers to the development of an environmental problem, or on the positive side, confirm the effectiveness of restoration initiatives.

Many different parameters contribute to overall water quality, including the amount of oxygen in the water, the concentration of nutrients available to marine life, and turbidity (the number of particles in the water blocking sunlight). Water temperature, salinity, and current speed and direction are parameters that affect the distribution and impact of pollutants and the resulting health of a body of water. How all these parameters vary down through the water column is also important. The current state of technology allows scientists to measure these parameters continuously at different depths. Continuous monitoring lets us see whether or not the management initiatives used by many towns in the state are working to improve water quality.

Monitoring can be conducted at regular sites on a continuous basis ("fixed station" monitoring); at selected sites on an as-needed basis or to answer specific questions (intensive surveys); on a temporary or seasonal basis (for example, during the summer at bathing beaches); or on an emergency basis (such as after a spill). Increasingly, monitoring efforts are aimed at determining the condition of entire watersheds—the area drained by rivers, lakes, and estuaries. This is because scientists have come to realize the impact of land-based activities on the waters that drain the land, and the interconnectedness of all types of waterbodies, including those beneath the ground.

There are many ways to monitor water conditions. Monitoring specialists perform chemical measurements to monitor the constituents in water, sediments, and fish tissue, such as levels of dissolved oxygen (DO), nutrients, metals, oils, and pesticides. Physical measurements of general conditions such as temperature, flow, water color, and the condition of stream banks and lake shores are also important. Biological measurements of the abundance and variety of aquatic plant and animal life and the ability of test organisms to survive in sample water are also widely used to monitor water conditions.

Generally, water quality monitoring focuses on the physical and chemical parameters, and a few key biological parameters such as indicator bacteria associated with sewage contamination. These key parameters are summarized below. These parameters and their importance in monitoring the health of an estuary are described in detail in *Volunteer Estuary Monitoring—A Methods Manual* at *http://www.epa.gov/owow/estuaries/monitor.* (Note that the MYSound program currently is using only certain parameters that are affordable and technically straightforward to monitor: temperature, salinity, and dissolved oxygen)

2.3.1 PHYSICAL PARAMETERS

Temperature—Temperature is a commonly measured water quality parameter, and is a critical factor influencing chemical and biological processes in an estuary. For instance, increased temperature decreases the level of oxygen that can be dissolved in the water column. Water temperature influences the rate of plant photosynthesis, the metabolic rates of aquatic organisms, and the sensitivity of organisms to toxic wastes, parasites, diseases, and other stresses. Temperature is recorded in degrees Celsius (Centigrade) or Farenheit.

Salinity—Salinity is the amount of salts dissolved in water expressed in parts per thousand (ppt) or 0/00. It controls the type of species that can live in an estuary but also influences physical and chemical processes such as flocculation and the amount of DO in the water column.

Suspended Material Concentration and Turbidity—Suspended material concentration is the amount of material that is suspended in the water column and is measured as the amount of material retained in a filter. Smaller particles are considered dissolved solids. The sum of suspended and dissolved solids is referred to as total solids. All three measures are recorded in terms of mg/l. Turbidity is a measure of water clarity, that is, the ability of water to transmit light, and is influenced by the level of suspended material in the water column. Turbidity is often measured visually using a Secchi disk. Elevated levels of suspended material and turbidity occur naturally through erosion, storm runoff, and the input of plant material on a seasonal basis. However, these parameters can also indicate degraded water quality if the elevated levels are caused by excessive erosion due to upland development, organic material due to nutrient enrichment, or uncontrolled discharges from sewage treatment plants and industrial facilities.

Current Speed and Direction—Understanding the current velocity in an estuary, and how it changes spatially and with depth, can provide valuable insight in interpreting changes in other physical and chemical parameters. For instance, high current velocities near the bottom can entrain sediment and increase turbidity. Flow into an estuary from the sea on an incoming tide can raise salinity and lower temperature. Current velocity is specified by direction (0 to 360 degrees) and speed (m/sec).

Meteorological Parameters (Weather)—The meteorological parameters typically measured are wind speed and direction, air temperature, and rainfall. Information on meteorological conditions can be very valuable in interpreting water quality data and explaining changes in water quality parameters. For instance, elevated temperatures and light winds can cause thermal stratification in an estuary, which may lead to decreased mixing and DO, particularly at depth. High winds associated with passage of a storm or cold front can promote vertical mixing, which will increase DO and possibly suspended material concentration, particularly in shallow water. Increased rainfall will decrease salinity in surface layers and perhaps lead to density stratification.

2.3.2 CHEMICAL PARAMETERS

Oxygen is a key parameter of interest in water quality monitoring, because nearly all aquatic life needs oxygen to survive. The two oxygen parameters monitored are DO and biological oxygen demand (BOD). DO is the level of oxygen in the water column in molecular form that is available to support life and is reported in milligrams per liter (mg/l). The DO level is controlled by mixing at the air/water interface, temperature and salinity, the level of photosynthesis (which produces oxygen), and decomposition of organic material (which depletes oxygen). Generally, DO levels of greater than 4 mg/l indicate an adequate supply of DO to support marine species growth and activity, while levels from 1-3 mg/l indicate hypoxic conditions, which are detrimental to marine life. DO below 1 mg/l indicates anoxia, a condition in which no life that requires oxygen can be supported. BOD measures the amount of oxygen that organisms would require in decomposing the organic material in the water column and in chemical oxidation of inorganic matter, and is indicative of pollution levels. For instance, unpolluted water has a BOD of less than 5 mg/l, while raw sewage has a BOD of 150 to 300 mg/l. Wastewater effluent might have a BOD from 8 to 150 mg/l.

Nutrients—especially nitrogen and phosphorus—are key water quality parameters in estuaries, because they have significant direct or indirect impacts on plant growth, oxygen concentrations, water clarity, and sedimentation rates. They influence both the overall biological productivity of the estuary and the decline of the estuary through eutrophication. Nitrogen is essential in protein and DNA synthesis in organisms and photosynthesis in plants. Phosphorus is critical to metabolic process. Primary nitrogen species of interest in the estuarine environment include nitrate (NO_3), nitrite (NO_2), and ammonia and ammonium (NH_3 and NH_4). Nutrient concentrations are reported in mg/l. Unlike DO, there are no set criteria for nutrient levels because nutrients themselves are not a threat to marine life, although they can contribute to problems such as excessive plant growth, low DO, and accelerated eutrophication. Excessive nutrients can also trigger toxic algae blooms. However, these adverse effects are dependent on other factors besides nutrient levels.

pH and Alkalinity are two additional parameters that provide insight into changing water quality conditions in an estuary. Both can be determined by simple tests. Although these parameters are generally not as critical as DO and nutrients, they are important to ecosystem health because most aquatic plants and animals are adapted to a specific range of pH and alkalinity. Sharp variations outside of this range can be detrimental. In addition, pH and alkalinity influence the estuarine carbon cycle, which involves the movement of carbon from the atmosphere into plant and animal tissue and into water bodies. The pH of water is the measure of how acidic or basic it is. A pH level of 1 to 7 indicates degrees of an acidic solution, while a level of 7 to 14 indicates degrees of a basic solution. Alkalinity is a measure of water's capacity to neutralize acids and is influenced by the presence of alkaline compounds in the water such as bicarbonates, carbonates, and hydroxides. Alkalinity is reported as mg/l of calcium carbonate ($CaCO_3$).

Chlorophyll a—Chlorophyll *a* is a green pigment found in phytoplankton, which represents the first trophic level in the primary production cycle. The amount of chlorophyll *a* in the water column is indicative of the biomass of phytoplankton, which in turn can indicate nutrient levels in the water column (or excess nutrients if the chlorophyll *a* values are elevated). Excessive nutrients and plant growth can in turn decrease DO levels and increase turbidity.

Toxic Contaminants—With the industrialization of many estuaries, the amount of toxic contaminants entering estuaries has greatly increased. These contaminants include heavy metals (such as mercury, lead, cadmium, zinc, chromium, and copper), petroleum hydrocarbons, and synthetic organic compounds such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides (e.g., dichlorodiphenyl-trichloroethane). Many of these toxic contaminants are persistent, can be incorporated into sediments, and can be concentrated in the food chain, so that they pose a magnified threat to animals at higher trophic levels and to humans. They are generally measured through laboratory analysis (which can often be complex and time-consuming), although field test kits are available for some heavy metals and other contaminants. The contaminant concentrations are usually reported in mg/l.

2.3.3 BIOLOGICAL PARAMETERS

Pathogens (Indicator Bacteria)—A key parameter of interest, particularly for estuaries in urban areas, is the presence of pathogens. Pathogens are viruses, bacteria, and protozoans that can cause disease. They are a critical concern in areas where waters are used for swimming, boating, fishing, shellfishing, or other pursuits that lead to human contact or food consumption. Direct testing for pathogens is very expensive and impractical. Instead, the potential levels of pathogens in estuaries are tracked by monitoring "indicator bacteria"—so called because their presence indicates that fecal contamination has occurred. The four indicators commonly monitored include total coliform, fecal coliform, E. coli, and enterococci, all of which are bacteria normally prevalent in the intestines and feces of warm blooded animals, including wildlife, farm animals, pets, and humans. The indicator bacteria themselves are not pathogenic. Values are recorded as the number of bacteria per ml of water. Environmental managers establish numerical standards for limits to these values for swimming, shellfishing, and other activities.

Selected Web Sites on the Ecology and Pollution Problems of Watersheds, Estuaries, and Coastal Regions

EPA Office of Wetlands, Oceans, and Watersheds—*http://www.epa.gov/owow*
- **Coastal areas—*http://www.epa.gov/owow/oceans***
- **Estuaries—*http://www.epa.gov/owow/estuaries***
- **Watersheds—*http://www.epa.gov/owow/watershed***
- **Water quality monitoring—*http://www.epa.gov/owow/monitoring***

This site provides a wealth of background information on monitoring, protecting, and restoring estuaries, watersheds, and coastal wetlands.

Estuary-Net Project *http://inlet.geol.sc.edu/estnet.html*
Estuary-Net was developed by the National Estuarine Research Reserve System in response to water quality issues arising in coastal areas. This project strives to develop collaborations among high schools, community volunteer water quality monitoring groups, local officials, state Coastal Zone Management (CZM) programs and National Estuarine Research Reserves (NERRS) to solve non-point source pollution problems in estuaries and their watersheds.

Estuary-Live Project *http://www.estuarylive.org/*
The Estuary-Live Project is an educational Web site focusing on estuarine ecology and environmental protection.

Restore America's Estuaries *http://www.estuaries.org*
This Web site is maintained by Restore America's Estuaries, an NGO alliance of regional and community-based environmental organizations. It provides information on legislation to protect America's estuaries and information on estuary restoration programs.

Chesapeake Bay *http://www.aqua.org/education/teachers/chesapeake.html*
This site is maintained by the National Aquarium in Baltimore and supported by the Chesapeake Bay Foundation. It provides a comprehensive source of information on the protection of Chesapeake Bay and large estuarine ecosystems in general.

NOAA Coastal Services Center *http://www.csc.noaa.gov*
The NOAA Coastal Services Center provides valuable information to coastal resource managers on smart coast growth, coastal hazards, habitat protection, and coastal monitoring (including water quality monitoring, remote sensing, and GIS development).

A comprehensive inventory of coastal and estuary monitoring programs is provided on the **Coastal Ocean Observing System page *http://www.csc.noaa.gov/coos***

Coastal America *http://www.coastalamerica.gov*
Coastal America is a unique partnership of federal agencies, state and local governments, and private organizations. This Web site is an excellent source of information and links on protecting, preserving, and restoring the nation's coasts.

3 DEVELOPING A WATER QUALITY MONITORING PROGRAM

This chapter presents some of the "nuts and bolts" involved in planning and setting up a marine water quality monitoring program, based on the experience of MYSound. Section 3.1 describes the initial information and contacts needed to begin the planning process. Section 3.2 provides suggestions for developing a strategy for the monitoring program—deciding "Who, Why, When, Where, What, and How." Section 3.3 presents information about how to obtain funding for the program and the importance of partnerships in this regard.

3.1 PRELIMINARY INFORMATION GATHERING, NETWORKING, AND PLANNING

In designing and implementing an effective and efficient water quality monitoring program, the most important step is to develop a clear vision of the requirements for the effort, the scope of the effort, and who will participate. This requires some up-front information gathering, networking, and planning on the part of the project leaders and prospective partners, even before a project proposal is developed. As most monitoring projects originate with a few key stakeholders, these stakeholders must assume a leadership role in taking these initial steps.

The initial partners for the MYSound project were EPA and the University of Connecticut, along with the Connecticut Department of Environmental Protection (DEP). All three were already involved in monitoring efforts in Long Island Sound before the concept for the MYSound network was developed. Through their involvement with the Long Island Sound Study, the lead partners were familiar with the environmental issues in Long Island Sound. During informal discussions, the partners conceptualized a water quality monitoring effort that combined the more traditional point-sampling water quality surveys in the Sound with monitoring provided by continuous, real-time sampling stations. The partners also attended workshops and conferences on Long Island Sound issues to identify partners and funding opportunities.

Entities most likely to be interested in water quality monitoring include government environmental agencies (such as EPA and NOAA), state environmental agencies, policy-makers seeking to restore and protect marine environments, universities having a marine sciences department, aquaria, and marine environmental NGOs. These agencies and organizations can be identified and partnerships cultivated by informal networking at regional conferences and workshops. More specific information on their goals, activities, and monitoring programs can be obtained from their outreach literature and their Web sites.

In addition, information and ideas on monitoring technologies, data management methods and software, data presentation schemes, and communications and outreach programs can be obtained through literature and Web searches for marine monitoring programs nationwide. These organizations can then be contacted for additional information, and sought out at national monitoring conferences. The MYSound project conducted a nationwide monitoring search and produced a comprehensive database on marine monitoring programs, which was disseminated to other programs. This is also a good way of networking with other potential partnering organizations.

Once the various prospective partners have been identified, it is often useful to convene an initial planning session to collectively form a vision of what the monitoring network may look like. This can often be accomplished as part of another conference or workshop and serves as a brainstorming session. Such a meeting was held two years in advance of submitting the MYSound EMPACT proposal, but proved invaluable in bringing together the partnership and in acquiring seed money to begin the effort.

In developing its strategic plan, MYSound found that the following key issues needed to be addressed:

- What are the major problems and priorities in the specific estuary or sampling area?
- What sampling parameters or conditions might be monitored to characterize the status of the estuary?
- How large a monitoring program should be attempted based on partner capabilities and the general availability of funding?
- Who are the end users of the data, and how can the data best be managed and disseminated?
- Where are potential funding sources for the project? What in-kind resources are available?

Information gathered during the initial strategic planning meeting on these issues will help in formulating an overall monitoring program strategy and preparing proposals to potential funding sources. It will also allow the project leaders to sort out partners (active project participants) from stakeholders (data users and interested parties) and form a smaller partners' working group to begin the proposal development for the project.

3.2 DEVELOPING AN OVERALL STRATEGY (WHO, WHY, WHEN, WHERE, WHAT, AND HOW?)

Before embarking on the tasks of buying equipment, taking samples, and analyzing and compiling data, it is important to develop an overall strategy that will guide the effort. All too often, water quality monitoring efforts are started because of an emergent issue or because of the interest of an individual stakeholder, and then continued beyond the point where the issue is relevant or the interest remains. This constitutes data collection for its own sake, which may seem fashionable, but depletes program resources without providing further insight. To avoid this, MYSound developed its strategy by developing answers to the following questions:

- *Who should be conducting the monitoring effort—who is leading the effort and who is contributing to it?*

Traditionally, government agencies have directed and funded water quality monitoring efforts, while government laboratories, universities, or technical consulting companies provided the resources to carry out the work. This arrangement is often associated with performing an environmental assessment or checking for compliance. In some cases, individual government or university researchers monitor water quality as a component of investigating a specific scientific issue. Recently, environmental NGOs and educational institutions have conducted monitoring projects to identify and highlight pollution problems for environmental managers and the public, and as an educational tool. More recently, monitoring efforts have been conducted by a coalition of stakeholders contributing to the process. However, in all cases it is important for the stakeholders to have a clear vision of their motivation for participating in the monitoring effort, and their expectations for the results and benefits of the program.

MYSound Partners

U.S. EPA Region I
EPA Long Island Sound Office
Connecticut Department of Environmental Protection
Connecticut Department of Environmental Conservation
New York Department of Environmental Protection
Coalition to Save Hempstead Harbor
Save the Sound, Inc.
Maritime Aquarium at Norwalk
Mystic Aquarium
Bridgeport Regional Vocational Aquaculture School
The Sound School
Spectrogram Corporation
U.S. Coast Guard Academy
Suffolk County Health Department
Connecticut Coastal Audubon Center

- *Why is the monitoring effort being undertaken?*

Monitoring can be conducted for many purposes, including:

- – Characterizing waters and identifying changes or trends in water quality over time.
- – Identifying specific existing or emerging water quality problems.
- – Gathering information to design specific pollution prevention or remediation programs.
- – Determining whether program goals—such as compliance with pollution regulations or implementation of effective pollution control actions—are being met.
- – Responding to emergencies, such as spills and floods.
- – Providing supplemental data for a research project.
- – Documenting illegal discharges.
- – Attracting public attention to a pollution problem.
- – Providing an educational and outreach tool.
- – Measuring the success of newly implemented water protection programs and facilities (such as upgraded sewage treatment plants).

Understanding and documenting the rationale is important for obtaining funding for, structuring, and evaluating the effectiveness of the monitoring effort.

- *When should the monitoring be conducted (how often and for how long)?*

Long-term monitoring to establish an environmental baseline for an estuary may require sampling over many years to delineate current status and trends. Monitoring to spot check for pollution problems and illegal discharges may occur randomly and be based on visual evidence that a problem exists or a discharge has occurred. Monitoring as part of a research project may be conducted for the period of time in which the phenomena of interest are being studied. Monitoring to raise public awareness or provide an educational experience may be conducted over a month or season, or be an ongoing effort, depending on the needs of the stakeholder in the specific situation.

- *Where should the monitoring be conducted (geographic extent of the monitoring)?*

Establishing an overall water quality baseline for an estuary may require sampling throughout the entire estuary, even if the samples or stations are widely separated. Monitoring to detect specific problems or uncover illegal discharges may involve sampling at pre-determined sites where the problem/discharge will be obvious (e.g., in a small cove directly downstream of a sewage treatment plant). Monitoring to raise public awareness may involve sampling near a well-recognized landmark and at a location where conditions are known to be representative of the estuary as a whole (e.g., a popular bathing beach). Monitoring for educational purposes may be conducted at points that are readily accessible to teachers and students.

Section 4.2 presents more detailed considerations of monitoring locations.

- *What parameters will be monitored?*

Characterizing the general water quality of an estuary can be accomplished by measuring temperature, salinity, DO, turbidity, and perhaps chlorophyll *a* as an indicator of nutrient enrichment. A more extensive investigation of an estuary where widespread pollution is known or suspected may require nutrient and indicator bacteria sampling as well. Sampling for toxic contaminants would be required if a known or suspected problem exists due to ongoing industrial discharges in the past or episodic spills of a particular material. The logical approach is to sample the least expensive set of parameters that provides an adequate data set to meet the goals and objectives (the "why") of the monitoring program.

- *How will the monitoring be accomplished?*

There are three general methodologies to consider: sample capture and analysis in the laboratory, parameter measurement and recording on site using a portable instrument, or automated real-time measurement and data transmission using in situ sensors and telemetry. Table 2 provides an overview of which methodologies are feasible for the key water quality parameters discussed above.

In general, on-site sampling using a portable instrument is the simplest and least costly mode but only provides point sampling in space and time. Sample capture and laboratory analysis is somewhat more time consuming but is often done in conjunction with portable-instrument sampling as a QA/QC check. Deploying in situ monitoring stations is the most complex and expensive mode, but may be warranted if continuous or real-time time-series data are required to understand water quality dynamics. The important factors in selecting a monitoring mode are need for the parameter, budget, and level of technical expertise required to operate and maintain the equipment.

Table 2. General Modes Available for Monitoring Various Water Quality Parameters

Parameter Monitored	Sample capture/ lab analysis	In situ with portable instrument	Remote in situ with sensor
Temperature*		X	X
Salinity*	X	X	X
Dissolved Oxygen*	X	X	X
Suspended Solids	X		X
Turbidity	X	X	X
pH & Alkalinity	X	X	X
Chlorophyll *a*	X	X	X
Nutrients	X		X
Toxics	X		
Indicator Bacteria	X		
Current Velocity		X	X

*Baseline suite of measurements taken by MYSound

In some cases, a combination of all three modes can be effectively employed. For instance, monitoring with portable instrumentation can provide good spatial coverage of basic parameters (T, S, DO, and turbidity) throughout the estuary at a reasonable expense with sampling conducted at selected sites and at a predetermined interval (e.g. weekly or monthly). Sample capture and laboratory analysis of selected parameters can provide QA/QC data for in situ sampling and spot check for toxic contaminants and indicator bacteria. Real-time, in situ monitoring can be conducted at strategically selected sites to provide insight into the dynamics of circulation and pollution problems, and to collect data during periods when on-site sampling is not feasible (e.g. winter and storm periods). This combined approach is the one currently being employed in Long Island Sound, with the on-site sampling being conducted by environmental agencies and volunteer water quality monitoring groups, and the real-time remote monitoring provided by the MYSound project.

Developing a Monitoring Strategy: Key Points and Lessons Learned from MYSound

- **To develop an effective plan for a comprehensive estuarine monitoring network, it is important to understand the nature and dynamics of estuaries in general, and also understand the details of the particular estuary, embayment, harbor or river where monitoring stations are being placed. Fortunately, a number of water quality studies that can provide this basic understanding have already been completed on many estuaries.**
- **In structuring an estuarine monitoring program, several key questions must be addressed. These questions include:**
  - **Is there a problem?**
  - **If so, how serious?**
  - **Does the problem affect only a portion of the estuary, or the entire body of water?**
  - **Does the problem occur sporadically, seasonally or year round?**
  - **Is the problem a naturally occurring phenomena or is it caused by human activity?**
- **A monitoring program may include a wide range of physical, chemical, and biological parameters. However, the greater the number of parameters measured, the greater the expense and logistics requirements. Therefore, program managers must have a clear understanding of the reason for including each parameter, and be selective in choosing them. Because hypoxia occurs in portions of Long Island Sound, particularly western Long Island Sound, MYSound has chosen temperature, salinity, and dissolved oxygen as the main parameters of interest.**

3.3 FUNDING AND OTHER CONSIDERATIONS

Once the goals, objectives, scope, and participants for the project have been identified, the project partners are in a position to market the concept and seek funding for the monitoring network. This requires identifying, tracking, and responding to funding opportunities that present themselves. One way to market the concept is by developing a "concept paper" that describes the effort and the participants. MYSound developed several versions of such a paper, ranging from two to five pages. This document forms the basis of the follow-on proposal, and can be also be widely distributed to potential funding organizations and stakeholders. In addition, the "concept paper" can be used as the basis for presentations at workshops and meetings. This will help identify funding opportunities, because funding agencies and stakeholders can alert the project team to relevant solicitations. Routine checks can also be made of the Web sites of key agencies and funding organizations such a NOAA, EPA, and the National Science Foundation (NSF).

In seeking funding, it is not necessary (or desirable) that the project be supported from a single source. Because the monitoring network concept has components that can be developed as discrete projects, it may be possible to establish the "network" as several integrated "projects." In some cases, this allows individual project partners to acquire portions of the necessary funds by targeting agencies and organizations who have traditionally sponsored their programs. For instance, a university marine science department may seek a portion of the funding from NSF, while a volunteer monitoring group may seek funding from a national environmental NGO. Obtaining funding from several sources also helps ensure the longer term sustainability of the project (discussed in detail in Chapter 7).

Many solicitations for marine monitoring programs in recent years have required or given special preference to efforts that have multiple partners, involve private entities (including NGOs and private companies), and support education and public outreach and awareness efforts. EMPACT is a prime example of such a funding source, as is the National Ocean Partnership Program (NOPP).

Many solicitations also require a cost-share on the part of the project participants, either in actual dollars or by providing labor and infrastructure to the project at no cost or at a reduced rate. These solicitation attributes should be taken into account in the initial planning of the project to secure the necessary partner commitments to rapidly produce a successful proposal.

Developing a Water Quality Monitoring Program: Key Points and Lessons Learned

- **Up-front networking among agencies, institutions, and organizations is an important first step in establishing a water quality monitoring program. For MYSound, establishing a dialogue on monitoring requirements for Long Island Sound over the years allowed the partners to quickly formulate the concept of a water quality monitoring effort that combined the more traditional point-sampling water quality surveys in the Sound with monitoring provided by continuous, real-time sampling stations.**
- **Initial literature and Web searches can provide valuable information and ideas on monitoring technologies, data management methods and software, data presentation schemes, and communications and outreach programs.**
- **A key step in building a marine monitoring program is building a coherent strategy for the program. Developing an implementation plan for the project requires answering the Who, Why, When, Where What, and How of the monitoring program.**
    - ***Who should be conducting the monitoring effort both in terms of who is leading the effort and who is contributing to the effort?***
    - ***Why is the monitoring effort being undertaken?***
    - ***When should the monitoring be conducted (how often and for how long)?***
    - ***Where should the monitoring be conducted (geographic extent of the monitoring)?***
    - ***What parameters will be monitored?***
    - ***How will the monitoring be accomplished?***

Each of these questions must be carefully considered to ensure that the project is properly focused, realistic in scope and complexity, efficient, and affordable.

- **The key factors for successfully obtaining both start-up and maintenance funds are marketing, networking, and partnering. Marketing the concept will help identify potential stakeholders. Networking with stakeholders will lead to formation of partnerships. Partnerships will broaden the funding and in-kind support base, which is favorably regarded by many agencies and organizations that provide funding to water quality monitoring projects.**

4 IMPLEMENTING A MARINE WATER QUALITY MONITORING NETWORK: DATA COLLECTION, MANAGEMENT, AND DELIVERY

This chapter focuses on how to collect, manage, and deliver data from a marine water quality network. Section 4.1 presents an overview of the basic activities involved in a marine water quality monitoring program. Section 4.2 provides recommendations for determining the number and location of the monitoring stations. Section 4.3 discusses the configuration and components of monitoring stations (those used by MYSound as well as options available for programs facing different circumstances). Section 4.4 presents recommendations for deploying and maintaining the monitoring stations. Section 4.5 describes how data from the monitoring stations can be compiled, verified, and stored for further processing. Section 4.6 discusses quality control and quality assurance procedures, while Section 4.7 addresses ways that the data can be archived and disseminated.

4.1 OVERVIEW OF IMPORTANT FUNCTIONS IN ESTABLISHING A REAL-TIME MARINE WATER QUALITY MONITORING NETWORK

The basic processes to be considered in establishing a marine water quality monitoring program include parameter measurement, data collection and compilation, data processing and management, and data and information dissemination. These activities are required regardless of the scope and complexity of the monitoring effort. In a simple water quality monitoring effort, such as those conducted by volunteer monitoring groups, parameters are measured by hand-held instruments and water sample capture, followed by basic laboratory analysis. The data are recorded on data logs and usually compiled in simple, commercially available database management software packages. The data are then screened for obvious errors, analyzed to determine basic statistical trends and parameters, and disseminated, usually in hard copy report form.

For MYSound and comparable projects, the basic activities are the same, except that the equipment is more sophisticated and much of the process is automated through the use of advanced technologies. The general scheme of the MYSound monitoring system is represented in Figure 4.1. The water quality parameter measurements are made from remote locations using electronic sensors mounted on a monitoring buoy or a fixed platform. The measurements are fed to a signal processor and datalogger, and from there are transmitted (generally through telemetry) to a receiving computer where they are compiled and screened to eliminate data that is obviously erroneous (wild point editing). The data then take two separate paths. They are immediately posted as provisional data on the Internet (on the MYSound Web site), but are also subjected to more rigorous, semi-automated data processing and management, which involves visual plotting and screening and inter-instrument comparisons to detect anomalies. After this thorough quality control process, the data are archived and made available to potential users through direct download from the MYSound Web site as well as via traditional electronic media (e.g., computer CDs).

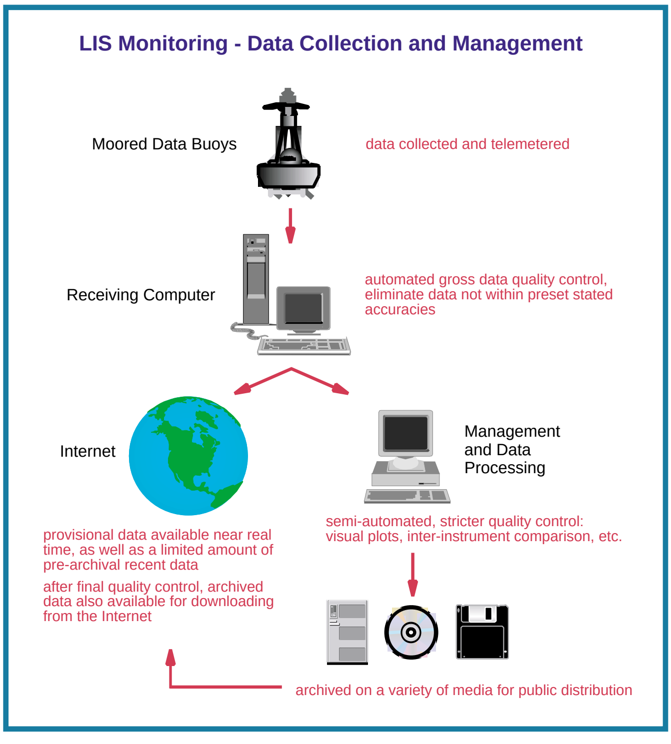


Figure 4.1. Top-level schematic for a real-time marine environmental monitoring system such as MYSound

Within this basic set of activities, further options are available for establishing the infrastructure and processes that make up the marine water quality monitoring program. These options, summarized in the decision flow diagram in Figure 4.2, are discussed in the following sections.

4.2 ESTABLISHING THE MONITORING STATION LOCATIONS

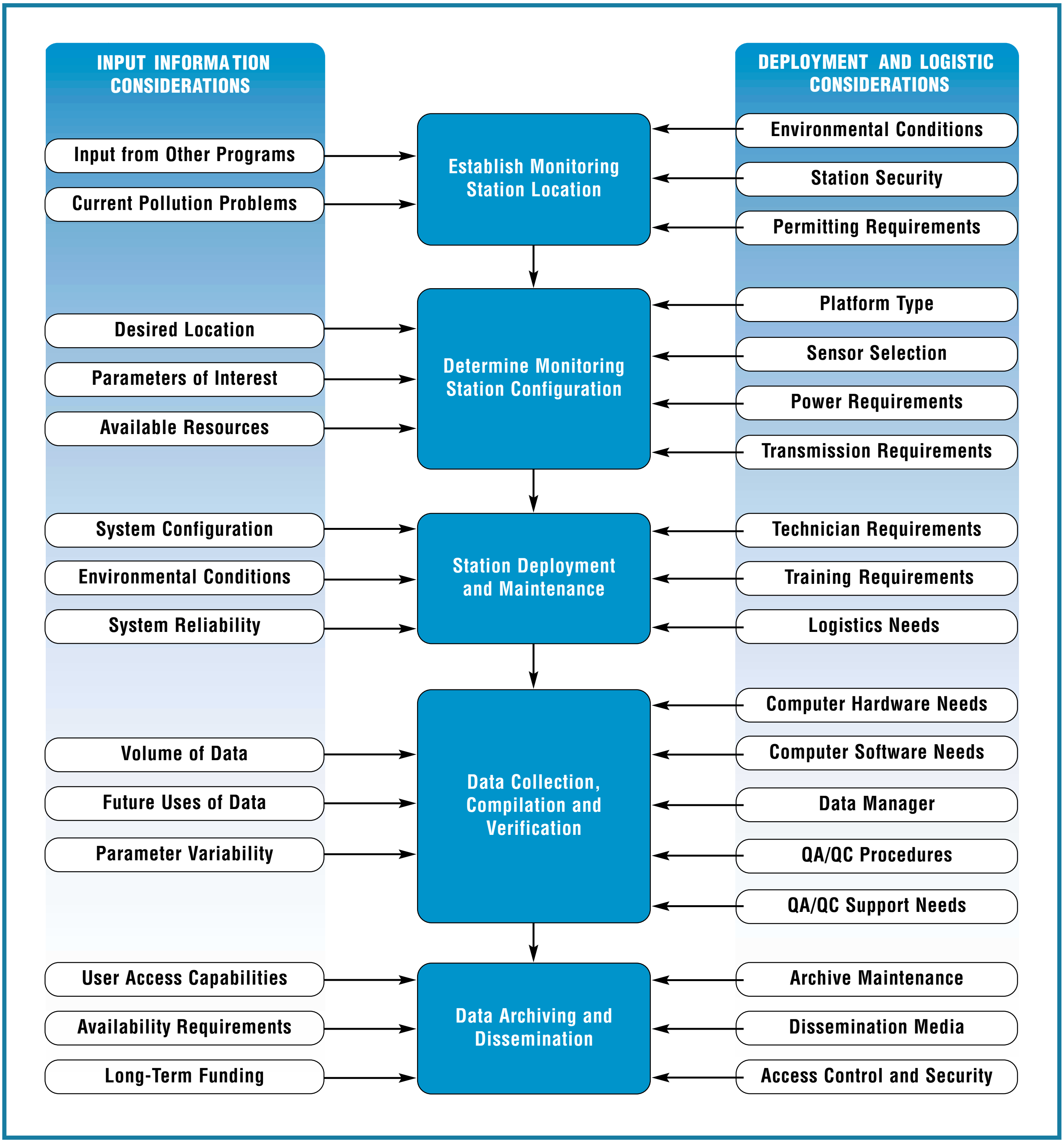


Figure 4.2. Basic decision flow diagram for implementing a marine environmental monitoring network

Determining the number and location of the monitoring stations is the first important consideration in establishing the monitoring network infrastructure. To a large extent, the number of stations in the network is determined by the funding that is available to purchase and maintain the stations and the amount of in-kind logistics support that program partners can provide. For instance, the MYSound project found that it costs between $15,000 and $30,000 to establish a basic monitoring station ($15,000 for a fixed-platform inshore station and $30,000 for a buoy-mounted offshore station) and an additional $5,000 to $10,000 per station per year to provide replacement equipment and refurbishment. However, these costs can vary significantly, depending on the complexity of the station configuration, the environmental conditions experienced at the station, and the logistics required to reach and service the station. In a start-up program, it would probably be wise to deploy one or perhaps two monitoring stations initially to gauge the maintenance expense and workload associated with each.

With respect to station location, each station should be sited to address the objectives of the monitoring program, and to complement and capitalize on other environmental quality monitoring programs that are also providing data. In many cases where other programs have already been collecting data, these programs can provide insight into where to site the real-time monitoring station to maximize the benefit to all parties. For instance, in the MYSound project, previous involvement and consultation with EPA and Connecticut DEP indicated that a primary pollution concern was hypoxia in western Long Island Sound, particularly during the summer months. It was also known that Connecticut DEP was regularly sampling water quality at set locations along the axis of Long Island Sound. Accordingly, the MYSound Western LIS Offshore Station was deployed at the Connecticut DEP Sampling Station “C1” just south of Greenwich, Connecticut, so that real-time data could supplement the longer term, intermittent Connecticut DEP measurements.

In some cases, the program sponsors specify the location criteria. For the MYSound project, EPA’s EMPACT program stipulated that the monitoring stations be located within or in the vicinity of the EMPACT Metropolitan Areas, and be relevant to environmental problems and stakeholder concerns in these areas.

Important considerations in siting the stations, beyond meeting the basic objectives of the monitoring effort, include environmental conditions, station security issues, and station permitting requirements. Each station should be configured to withstand the range of conditions expected to be encountered. Wind, waves, currents, and tidal range must all be taken into account.

The station should also be sited in a location that minimizes, to the extent possible, the risk of damage by passing vessels and vandalism. Two MYSound stations have been rendered inoperable from vessel collisions. For this reason, it is advisable to locate the station away from vessel traffic lanes and near prominent larger structures such as navigation buoys or offshore structures. Vandalism can be reduced if the station is located where it can be easily observed by the project team and local authorities, or if access to the area is limited.

With regard to permitting, any buoy or fixed structure placed in navigable waters must first be permitted by the Coast Guard, and usually the state marine regulatory agency as well (e.g., Connecticut DEP). It may also be necessary to obtain permission (or at least advice) from the local harbormaster when locating the station.

4.3 DETERMINING MONITORING STATION CONFIGURATION AND COMPONENTS

The next step in designing and implementing the monitoring network is to determine the station configuration for each of the stations. Each station must be deployed in the water column on a stable platform, which can be either a buoy, a fixed structure in the water, or an existing structure on the shoreline (e.g., an existing pier). Figure 4.3 shows a general schematic for an offshore buoy monitoring station. Figure 4.4 depicts a somewhat more detailed schematic for an inshore monitoring buoy.

Each station is equipped with a suite of sensors that sample the parameters of interest. The signal is transmitted to a signal processing and conditioning unit and captured by a datalogger (Figure 4.5). For the temperature (T), salinity (S), and dissolved oxygen (DO) measurements on MYSound stations, the sensor

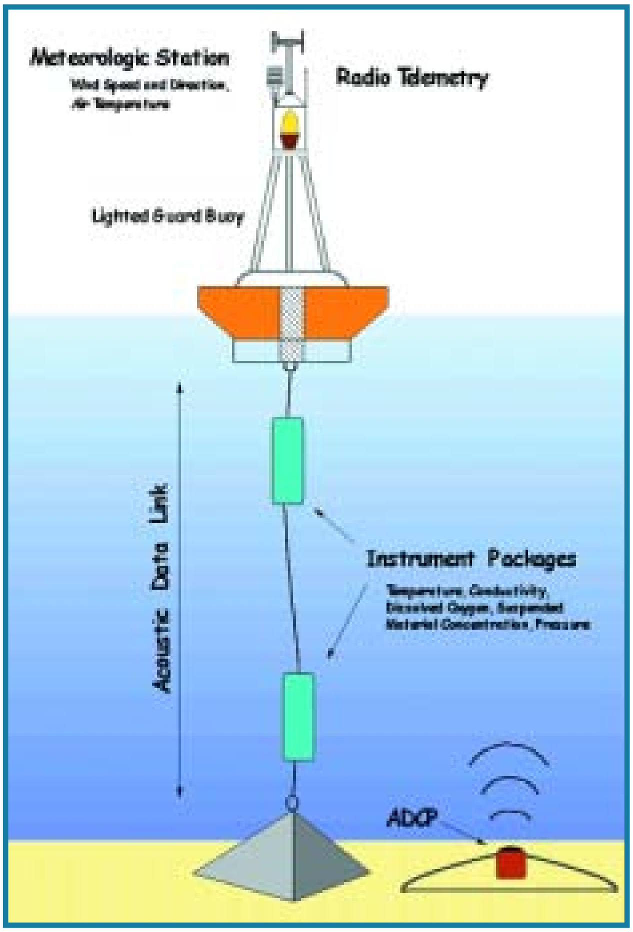


Figure 4.3. General schematic of an offshore buoy monitoring station

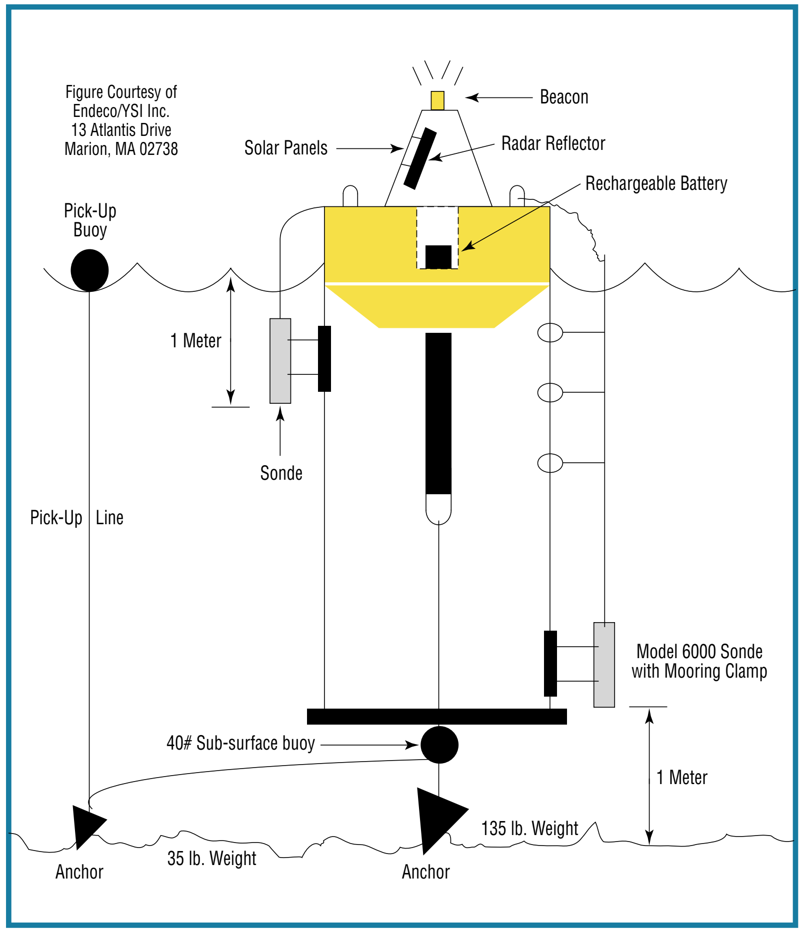


Figure 4.4. Detailed schematic of an inshore/harbor buoy monitoring station

and data processing capability are incorporated in one unit called a sonde. In some cases, the datalogger may be located at the station where it is retrieved periodically for processing. Another option is to transmit the data back to shore for processing either by a hard link (transmission wire) or a telemetry link (e.g. radio, cell phone or satellite communications link). MYSound stations have used both means of data capture. For example, on the Eastern LIS Station, T, S, and DO data are telemetered directly to shore, with backup datalogger capture at the buoy. Electrical power must also be provided by a shoreside power connection (where available), or by batteries and solar panels.

The platform type is dictated mainly by the desired location of the station and the availability of existing structures. For more exposed, offshore locations where existing structures are not available, a larger oceanographic buoy hull is required, such as the one shown in Figure 4.6. These buoys may be a meter or more in diameter and 2 to 3 meters in height, and may weigh 500 to 1000 lbs. or more. Their advantage is that they are rugged and stable even in offshore environments, but are costly and require a larger vessel and lifting device to deploy and service. These platforms can be purchased from an oceanographic equipment company, or can sometimes be acquired at reduced cost from oceanographic research institutions. The Gilman Corporation manufactures the larger buoy hulls (Model G2000) deployed in the MYSound network.

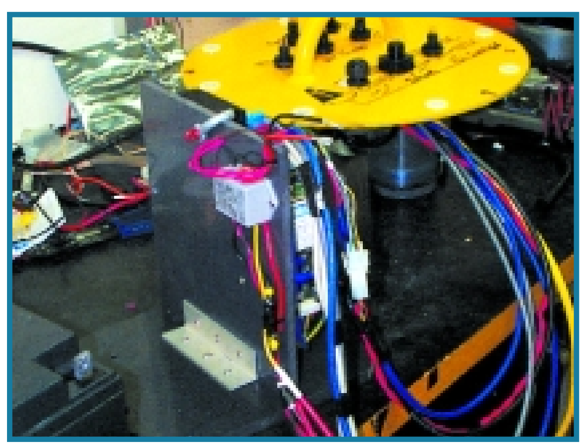


Figure 4.5. Datalogger for an offshore monitoring buoy

For more protected inshore and harbor locations, a smaller buoy hull can be employed, such as the one shown in Figure 4.7, which is deployed in the lower Thames River. Although these buoys are restricted to lighter payloads and less severe environmental conditions, they are cheaper and easier to deploy, and can potentially be constructed in house if some expertise and fabrication machinery are available. Another viable option for protected inshore locations is to mount the monitoring station on an Aid to Navigation or a fixed platform, such as a pier, that extends out into the water. Figure 4.8 shows the platform for the Hempstead Harbor station, which is mounted on a Coast Guard Aid to Navigation. Such platforms provide a stable and secure platform for the station, and often can accommodate a larger amount of instrumentation than can a buoy. Figures 4.9 and 4.10 show the Bridgeport Harbor monitoring station deployed from a pier.

Figure 4.6. MYSound offshore monitoring station near West Greenwich, CT

The third consideration in developing the station configuration is selecting the specific sensors to be used. For general water quality monitoring purposes, multiple sensor, fully integrated packages (sondes) can be purchased from commercial companies. Such packages can be configured to include basic water quality sensors such as T, S, DO, chlorophyll *a*, and turbidity. The YSI 6920 Model (manufactured by YSI Inc.) is the sonde used on many of the MYSound stations. The unit is 18 inches long, 2.85 inches in diameter and weighs 4 pounds. The sonde is equipped with internal batteries, datalogger, and sufficient memory for short-term data storage. Figure 4.11 shows the YSI 6920 Sonde. The network also uses the slightly larger Model 6600.

Figure 4.7. MYSound inshore buoy monitoring station in the Thames River, New London, CT

Figure 4.8. Hempstead Harbor monitoring station deployed on a Coast Guard Aid to Navigation

Figure 4.9. The Bridgeport Harbor monitoring station deployed from a pier. Note solar panels on pier.

Figure 4.10. The Bridgeport Harbor sensor package suspended from a pier

The 6600 can measure the same parameters as the 6920, but it allows for a wider range of sensor types and longer deployment time due to increased battery and data memory capacity.

Other instruments have been tested or are being considered for use in the MYSound network. An optical backscatter sensor (manufactured by D&A Instrument Company) was used to measure water turbidity. This sensor provides information on the amount of suspended material in the water, which is indicative of sediment load and biological activity such as algae and plankton blooms. This sensor, along with the chlorophyll *a* sensor (YSI 6025), further provide an indication of the nutrient levels in the water column that promote photosynthetic activity.

Figure 4.11. YSI 6920 Sonde, deployed to measure T, S, and DO on most MYSound monitoring stations

Nitrogen sensors provide a more direct way of measuring nutrients. Several companies manufacture nitrogen sensors, but they are still somewhat in the prototype stage and are very expensive ($30,000 and up), precluding their routine deployment as part of the sensor array. MYSound has not deployed nitrogen sensors because of their complexity, cost, and reliability issues. However, these issues are gradually being resolved in the industry, and a viable sensor could be deployed in the near future if funding is available.

A specialty sensor deployed on the Thames River station was a surface oil spill sensor, manufactured by the Spectrogram Corporation, designed to detect oil spills. The sensor detects hydrocarbons on the water surface using a fluorometric sensor. The sensor package is 12 inches long, 9 inches wide, and 12 inches high and weighs 38 pounds. These specialty sensors can be deployed on selected stations where the monitoring or research priorities at the specific location justify the added expense and complexity.

Sensors that measure physical oceanographic parameters, such as current speed and direction, wave motion, and tidal elevation, can also be mounted on selected stations. These sensors are incorporated to provide data on water and pollutant transport, which affects the water quality parameter values and can explain the causes of parameter fluctuations. In addition, these oceanographic parameters can be used as input data to numerical models that predict larger-scale variations in water quality and pollutant levels. On selected MYSound stations, Acoustic Doppler Current Profilers (RDI Workhouse Model) record current velocity at various depths. The ADCP is mounted on the ocean bottom adjacent to the monitoring buoy and measures current velocity throughout the water column. For current measurements at a single point in the water column, a two-axis electromagnetic current meter (InterOcean S4 Model) has been employed. Although these data are captured at the monitoring site rather than being transmitted in real time, they provide valuable data for future water quality analysis.

Meteorological forcing is another important phenomenon affecting water quality. Winds and air temperature can dramatically alter the T, S, and DO distribution in the water column. For this reason, MYSound has installed meteorological sensor packages at selected locations in the Sound. Meteorological data collected by Meteorological Stations (Met Stations) include air temperature, barometric pressure, humidity, and wind speed and direction. Climatronics Corporation manufactures the Met Station sensor package used in the MYSound network.

Table 4.1 lists the full complement of sensors being used or considered for future deployment as part of MYSound project, along with the sensor specifications.

From the sensors, the data signal is transmitted to a datalogger capable of accepting a wide variety of inputs (i.e., analog, digital, RS232, SDI-12, etc.). The MYSound dataloggers are manufactured by Campbell Scientific Corporation. The entire system is powered by batteries, supplemented by solar panels. Data are then transmitted from the monitoring station to the shore-side receiving station via telemetry using a wireless spread spectrum modem manufactured by Free Wave Technologies.

Data from the MYSound monitoring stations are transmitted back to the central data collection computer system at Avery Point in a number of ways: 1) Data can be transmitted directly to a receiving antenna at Avery Point using radio telemetry, 2) Data can be transmitted by radio telemetry to a relay computer receiving station on shore in the vicinity of the buoy and from there periodically downloaded to the main computer at Avery Point via an Internet connection, or 3) Data can be sent from the monitoring station by cell phone communications link directly back to Avery Point. MYSound is also investigating the option of using satellite communications links.

Table 4.1 Sensor Systems Employed or Considered under the MYSound Project*

Parameter	Manufacturer and Model	Range	Accuracy
Water Temperature	YSI 6920	-5°C to + 45°C	± 0.15°C
Conductivity	YSI 6920	0 to 100 mS/cm	± 0.5% + 0.001 mS/cm
Dissolved Oxygen	YSI 6920	0 to 20 mg/L 20 to 50 mg/L	± 2%, max of 0.2 mg/L ± 6%
Photosynthetically Active Radiation (PAR)	Li-Cor LI-193		± 5%
Suspended Materials	Downing Optical Backscatter Sensor	mg/L to 10^2 gm/L	~ 5% of full scale
Chlorophyll *a*	YSI 6025	0 to 200 µg/L	
Surface Hydrocarbons	Spectrogram Ospra System	15 ppm threshold alarm	
Nitrate-Nitrogen	Valeport SUV-6		± 0.05% of full scale
Current Velocity (Single Depth)	InterOcean S4		
Current Velocity (Multiple Depth)	RDI Workhorse ADCP	0 to 1000 cm/sec	0.5% of measured, max of ± 0.5 cm/sec
Wind Speed	Climatronics WM III	0 to 55 m/sec	± 0.11 m/sec
Wind Direction	Climatronics WM III	0 to 360°	± 3°
Air Temperature and Relative Humidity	Climatronics WM III	-30°C to 50°C	± 0.15°C
Barometric Pressure	Climatronics WM III	600 mb to 1100 mb	± 1.5 mb

*MYSound has deployed all the sensors listed except those used to measure nitrate-nitrogen and chlorophyll *a*.

4.4 Monitoring Station Deployment and Maintenance

Once the monitoring station has been designed and configured, it must be transported to the monitoring site and deployed. The following section provides recommendations for these steps, based on the techniques for deployment and maintenance that MYSound used at most of its stations.

For smaller harbor buoys, deployment can be accomplished using a small workboat (20 to 25 ft). For larger offshore buoys, a larger research vessel should be used because it will have the necessary lifting apparatus to safely lower the buoy over the side, and because the buoy and associated mooring equipment are large and heavy (see Figure 4.12). In the initial deployment operation, it is better to have a larger vessel than might be absolutely required, both in the interest of safety and in the event that problems are encountered and the buoy must be immediately retrieved.

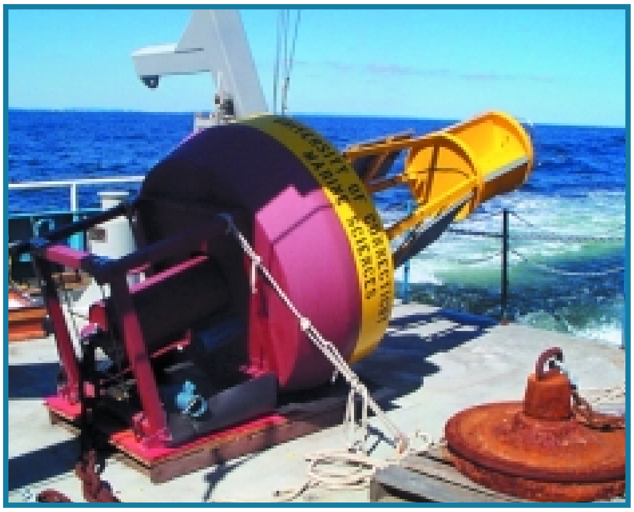


Figure 4.12. Buoy and mooring equipment for an offshore monitoring station arrayed on deck prior to deployment

After initial deployment, the monitoring system, including the buoy hull, sensors, dataloggers, batteries, telemetry electronics, and mooring hardware (anchors and mooring chains/cables) must be inspected and serviced at regular intervals. Major overhauls of the buoy and mooring system will probably require retrieval of the entire system (usually performed every one to two years).

For smaller inshore/harbor buoys, routine station servicing can be accomplished from a small workboat (see Figure 4.13).


Figure 4.13. Inshore/harbor monitoring buoy being deployed from a small work boat

MYSound has found that the maintenance intervals for the station platform and components will depend on the time of year (for example, biofouling intensifies in the summer), environmental conditions on site (wind, waves, and currents, which stress system components), and the overall reliability and ruggedness of the components. Sensor biofouling (the growth of marine organisms on the T, S, and DO sensors) usually determines the frequency of routine maintenance visits (see Figures 4.14 and 4.15). The monitoring system sensors must be inspected, cleaned, and calibrated at regular intervals (every two weeks in the summer, every month fall through spring) to clear fouling and ensure accuracy. Data not transmitted to shore via telemetry must be downloaded from the on-site dataloggers. Batteries must be checked and charged if necessary and solar panels must be cleaned. Periodically, the mooring system must be inspected for wear and fouling, and cleaned or replaced as necessary. Some of these functions can be accomplished from the maintenance vessel or by divers.

In MYSound's experience, volunteers or other non-technical personnel with a moderate level of training have been able to perform some of the routine maintenance functions required. These functions include sensor cleaning and calibration, data retrieval from the datalogger, battery replacement, and general inspection of the condition of the buoy. Training on basic sensor cleaning and calibration can often be obtained from the manufacturer. Other more complex maintenance functions, such as disassembly, troubleshooting, and repair of the datalogger and telemetry electronics, require a professional marine oceanographic technician or factory technical representative.


Figure 4.14. Biofouling on a YSI sensor package

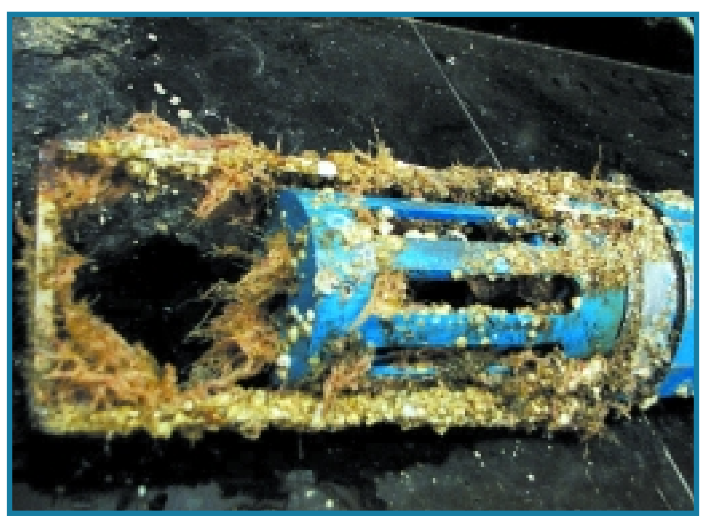


Figure 4.15. Sensor with heavy biofouling

4.5 DATA COMPILATION, SCREENING, AND PROCESSING

Once the data are acquired at the monitoring station and transmitted to the central computer network, they must be compiled, verified, and stored for further processing. The magnitude of this task depends largely on the volume of data that is acquired (number of stations, number of sensors, and sampling frequency of each sensor), and the level to which the data must be screened and processed prior to further dissemination and analysis. For a monitoring program the size of the MYSound program, several computers configured in a local network are required for data acquisition and processing (see Figure 4.16). Three central processing units (CPUs) support the MYSound project. As a rule, one desktop computer CPU and one monitor are used to process the data from one or two stations, housed in a suitable laboratory environment. For MYSound and programs of a similar size, a dedicated data manager must be assigned to screen and process the data and maintain the hardware and software of the system. Ideally, the computer manager will have excellent computer and data analysis skills as well as a background in marine science.

Figure 4.16. Computers at Avery Point for processing and storing the MYSound data

4.6 IMPLEMENTING A QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PROGRAM

Any time that environmental data are being collected, a program must be in place to ensure that the data are accurate and representive of the parameters being monitored at the station site. Steps must also be taken to ensure that the data being transmitted back to the data compilation and processing center are not being corrupted in the process. Three possible errors that will limit the value of the data may occur:

1) The value (e.g., concentration) of the parameter measured at the sensor is not representative of its value in the surrounding environment (that is, some phenomenon at the sensor causes an anomaly in the data).

2) The sensor records variations in the parameter, but because the sensor is malfunctioning, the values measured are inaccurate. The measurements obtained using a commercially available sensor suite are subject to errors caused by instruments drifting out of calibration or degradation of the sensor and/or sensor components (e.g., salt water contamination of electronics, biofouling of the sensor probe).

3) The sensor is functioning properly, but because of interference in the data telemetry, the values are corrupted with spurious signals being received with the valid data.

To detect malfunctions, inaccuracies, and spurious data, it is necessary to establish a Quality Control/Quality Assurance Program with QA/QC checks at three levels:

1) Measurements taken near the site, using either independent portable instruments used on site, or sample capture and laboratory analysis procedures, to ensure that the values measured by the sensor are representative of the overall conditions near the site and to ensure that the sensor is operating properly. MYSound primarily uses on-site checks with portable instruments for these QA/QC checks.

2) On-site calibration checks to ensure that the sensor is reading accurately.

3) Screening of the data as it is compiled and processed, which includes editing of data outliers (to ensure that the data are within preset ranges based on sensor sensitivity and known physical limits), statistical analysis and flagging of outliers (checks involve statistical analysis to ascertain that the data are within two to three standard deviations of a running mean), and comparison with field and supplemental data to detect spurious trends. Data that still do not fit set criteria are flagged and subject to the final level of quality control, in which the data are plotted and compared with other parameters (e.g., wind, historical, and any available third-party supplementary data) to determine the validity of the abnormality. If the data still fail this final check, a flag that describes the quality level (a number) is inserted in the archived database.

For the MYSound project, all levels of QA/QC are specified in detail in the MYSound Quality Assurance Plan, which was submitted to and approved by EPA at the beginning of the project.

4.7 DATA ARCHIVING AND DISSEMINATION

Once MYSound data have been transmitted and received into the primary data acquisition system and their quality checked, they are duplicated and archived onto a secondary system for storage. The database structure in its most basic form consists of space-delimited header fields with columnar parameter records in ASCII format. Data documentation is inherent within the header record of the database structure and in the time stamping of the individual parameter records. Records and documentation are supplemented by automatic progress logging of the incoming data.

The information management system includes a Pentium-based desktop computer with several high-capacity storage devices. Collection, management, and dissemination of the data involve both in-house custom programs written in a high-level language (e.g. FORTRAN, C), supplemented by off-the-shelf database management utilities including Microsoft ACCESS, PARADOX, and spreadsheets such as QUATRO and EXCEL. The storage devices allow for immediate backup and archiving of data for eventual end user access. System administrator requirements and duties will require in-depth knowledge of the system data, software management programs, and hardware infrastructure.

Basic data access in the MYSound network is implemented using standard TCP/IP protocols enabling HTTP, FTP, and TELENET capabilities. End users with Internet access are able to download data via any one of these protocols. The data elements include temperature, salinity, dissolved oxygen, current speed and direction, wind speed and direction, and air temperature. Security for end user data is implemented using several levels of user defined access and password protocols.

Implementing a Marine Water Quality Program: Key Points and Lessons Learned

- ***Number of stations:*** The number of stations in the network is determined largely by the funding and in-kind logistics support available. A basic monitoring station can cost between $15,000 and $30,000 per year, with annual maintenance costs from $5,000 to $10,000 per year. In a start-up program, two or three monitoring stations can be initially deployed to gauge the maintenance expense and workload.

- ***Location:*** Stations should be sited to address the objectives of the monitoring program, and to complement and capitalize on other environmental quality monitoring programs providing data. Extreme environmental conditions should be avoided (unless these are the focus of the monitoring effort) and stations should be sited to avoid damaged by passing vessels and vandalism.

- ***Configuration:*** Each station must be deployed in the water column on a stable platform (buoy, a fixed structure in the water, or an existing structure on the shoreline). The platform type is determined primarily by the desired location of the station and the availability of existing structures. For more exposed, offshore locations where existing structures are not available, a larger oceanographic buoy hull is required. For more protected inshore and harbor locations, a smaller buoy hull can be employed or the station can be mounted on a pier.

- ***Sensors:*** For general water quality monitoring purposes, multiple sensor, fully integrated packages (sondes) are recommended. Such packages can be configured to include basic water quality sensors such as T, S, DO, chlorophyll *a*, and turbidity. Specialty sensors can be added to measure other parameters of interest (e.g., nutrient concentration and hydrocarbons), but these will add to the cost and complexity of the stations. Oceanographic and meteorological sensors provide valuable information on the causes of water quality variations.

- ***Deployment:*** Smaller harbor buoys can be transported and deployed using a small workboat. For larger offshore buoys, a larger research vessel with the necessary lifting apparatus should be used.

- ***Maintenance:*** After initial deployment, the monitoring system including the buoy hull, sensors, dataloggers, batteries, telemetry electronics, and mooring hardware (anchors and mooring chains/cables) must be inspected and serviced at regular intervals. Major overhauls of the buoy and mooring system will probably require retrieval of the entire system (usually once a year). For smaller inshore/harbor buoys, routine station servicing can be accomplished from a small workboat. Volunteers with a moderate level of training can accomplish some of the routine calibration and maintenance functions; more complex maintenance functions require a professional marine oceanographic technician or factory technical representative.

- ***Data Compilation, Screening, and Processing:*** For a monitoring program the size of the MYSound program, several computers configured in a local network are required for data acquisition and processing (as a rule, one CPU and monitor process data from one or two stations), and a dedicated data manager must be assigned to screen and process the data and maintain the hardware and software of the system.

- ***QA/QC:*** To detect malfunctions, inaccuracies, and spurious data, it is important to establish a Quality Control/Quality Assurance Program with QA/QC checks at three levels: measurements taken near the site, on-site calibration checks, and screening of the data as it is compiled and processed.

5 PRESENTING AND DISSEMINATING INFORMATION

This chapter presents information and guidance on how to present and disseminate marine water quality monitoring data to the program's intended audience. Section 5.1 describes the MYSound Web site as that project's primary means of information presentation and dissemination. Section 5.2 presents more detailed information about how the Web site was designed and implemented. Section 5.3 presents some alternative means of information dissemination that a program can use, including traditional published reports, dial-up telephone service, and public broadcasts.

5.1 OVERVIEW OF THE MYSOUND WEB SITE

The marine water quality data collected by MYSound can be accessed and downloaded directly from the University of Connecticut data acquisition and storage computers at Avery Point, as described in Chapter 4. This is acceptable for longer term data retrieval and analysis by environmental managers and researchers. However, the data in this form are of little use to other potential users such as marine operators, educators, and the public at large, and cannot be readily accessed in a timely fashion to assist in day-to-day decision-making. The MYSound team realized that to promote the public awareness and community tracking envisioned under the EMPACT program, a more comprehensive, timely, and user-friendly means of data and information presentation and dissemination was needed.

Fortunately, the Internet and the World Wide Web provide a highly effective mechanism for accomplishing this. Accordingly, the MYSound project Web site was established at *http://www.mysound.uconn.edu* to be the primary data and information medium for the project. The MYSound site was designed to provide real-time water quality data, as well as a wide range of supporting data and information in a variety of formats to serve various user groups. The general organization and hierarchy of the MYSound Web site is depicted in Figure 5.1.

FIGURE 5.1 GENERAL ORGANIZATION OF THE MYSOUND WEB SITE

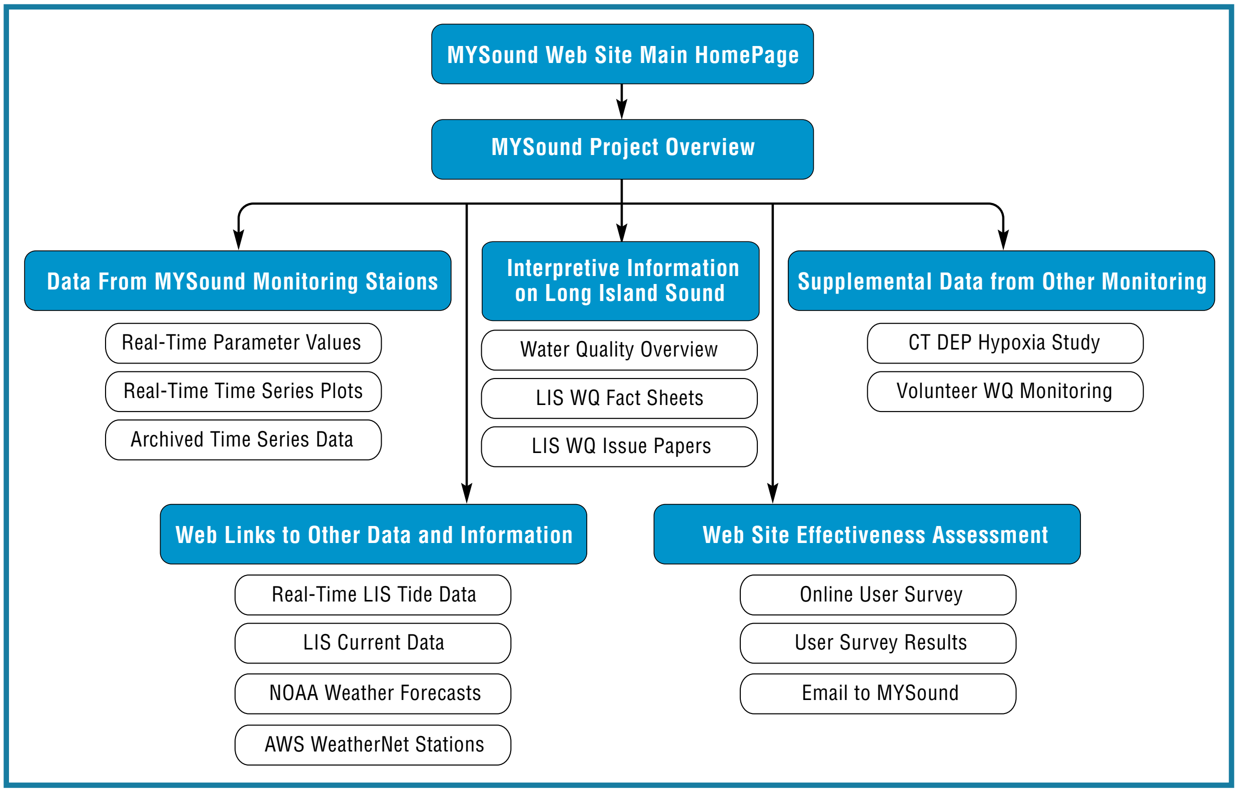
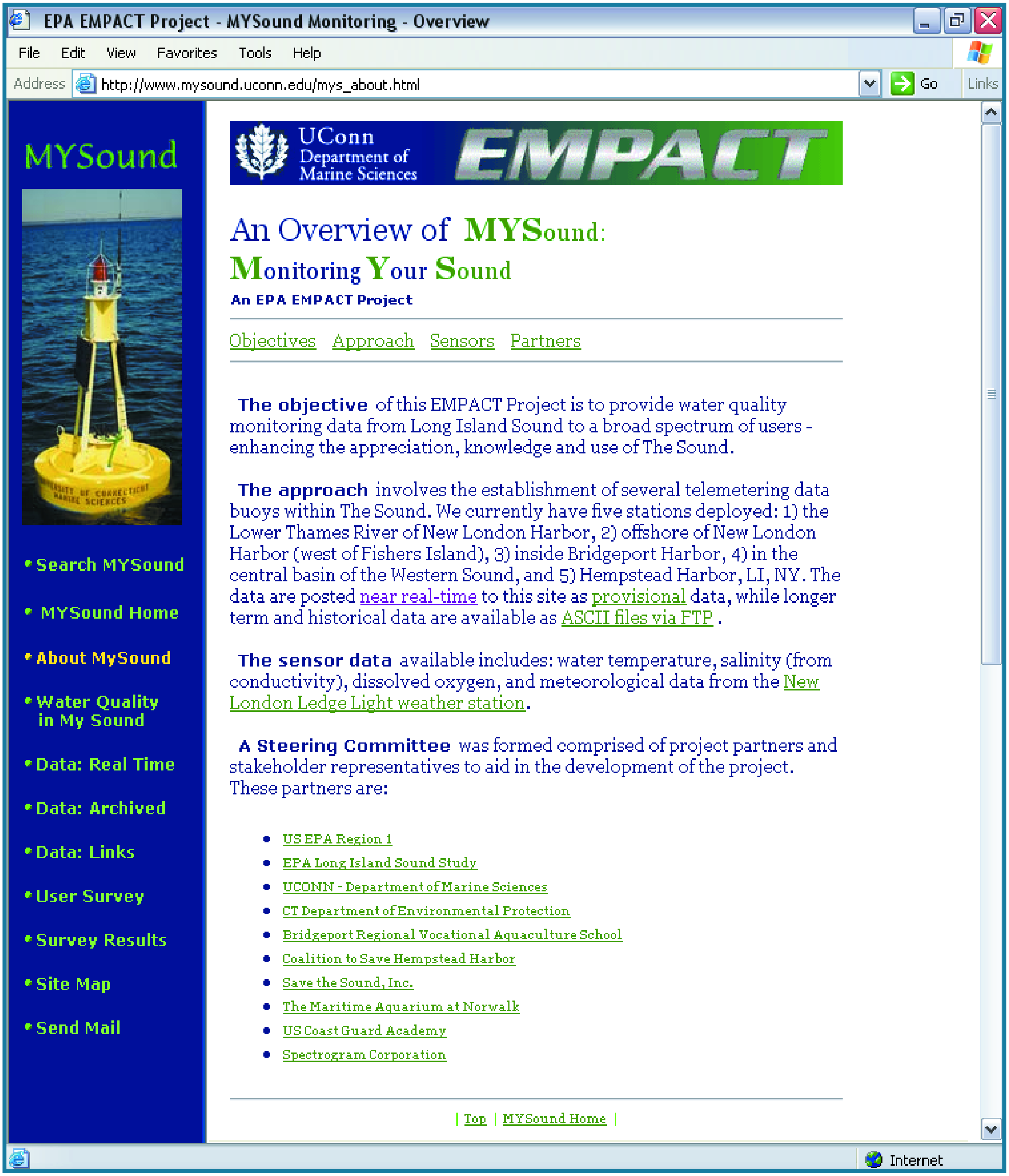


Figure 5.2 shows the MYSound Web site Home Page, which is the entry point reached upon accessing the site. This page provides information on *What's New* on the Web site and *Station Status* (which of the monitoring stations are currently up and running). It also provides access to the main functions of the Web site, as depicted in Figure 5.1, by clicking on the "hot buttons" located in the left hand margin.

Figure 5.2 MYSound Web Site Home Page

Figure 5.3 shows the MYSound project overview page *(About MYSound),* which provides a general description of the project objectives, approach, and activities. It also provides links to the Web sites of many of the participating project partners.

Figure 5.3 MYSound Web Site Overview Page



EPA EMPACT Project - MYSound Monitoring - Overview

File Edit View Favorites Tools Help

Address http://www.mysound.uconn.edu/mys_about.html

MYSound

- Search MYSound
- MYSound Home
- About MySound
- Water Quality in My Sound
- Data: Real Time
- Data: Archived
- Data: Links
- User Survey
- Survey Results
- Site Map
- Send Mail

UConn Department of Marine Sciences EMPACT

An Overview of MYSound: Monitoring Your Sound

An EPA EMPACT Project

Objectives Approach Sensors Partners

The objective of this EMPACT Project is to provide water quality monitoring data from Long Island Sound to a broad spectrum of users - enhancing the appreciation, knowledge and use of The Sound.

The approach involves the establishment of several telemetering data buoys within The Sound. We currently have five stations deployed: 1) the Lower Thames River of New London Harbor, 2) offshore of New London Harbor (west of Fishers Island), 3) inside Bridgeport Harbor, 4) in the central basin of the Western Sound, and 5) Hempstead Harbor, LI, NY. The data are posted near real-time to this site as provisional data, while longer term and historical data are available as ASCII files via FTP .

The sensor data available includes: water temperature, salinity (from conductivity), dissolved oxygen, and meteorological data from the New London Ledge Light weather station.

A Steering Committee was formed comprised of project partners and stakeholder representatives to aid in the development of the project. These partners are:

- US EPA Region 1
- EPA Long Island Sound Study
- UCONN - Department of Marine Sciences
- CT Department of Environmental Protection
- Bridgeport Regional Vocational Aquaculture School
- Coalition to Save Hempstead Harbor
- Save the Sound, Inc.
- The Maritime Aquarium at Norwalk
- US Coast Guard Academy
- Spectrogram Corporation

| Top | MYSound Home |

Internet

Figure 5.4 shows the Water Quality information page *(Water Quality in MYSound),* which provides access to general information that allows better understanding and interpretation of the water quality data contained at the Web site. This includes a number of topic summaries (Fact Sheets) in PDF format on Long Island Sound pollution topics and summaries on how human activities can be modified to become more "Sound friendly" to reduce water quality impacts. In addition, this page provides direct Web links (in the right-hand margin) to other reports on Long Island Sound issues.

Figure 5.4 MYSound Web Site Water Quality Information Page

Figure 5.5 shows the *Real-Time Observations* access page, the centerpiece of the MYSound site. From this page, the user can directly access the MYSound real-time monitoring stations by choosing a station from the scroll down menu or clicking directly on a station location on the Long Island Sound (LIS) location map. A "Station Status" button is also provided to quickly determine which stations are operating. Clicking on a particular station brings the user to the *Station Summary page* (Figure 5.6), which provides general information on the station's configuration, location (including a pull up chart), and parameters measured. It also provides access to the real-time data presentation panels by clicking on the "hot buttons" in the left-hand margin or using the scroll down menu. Direct access is also provided to the real-time data at the other stations in the MYSound network to allow quick comparison of the temperature, salinity, and dissolved oxygen data among various locations.

FIGURE 5.5 MYSOUND WEB PAGE—REAL-TIME OBSERVATIONS ACCESS PAGE

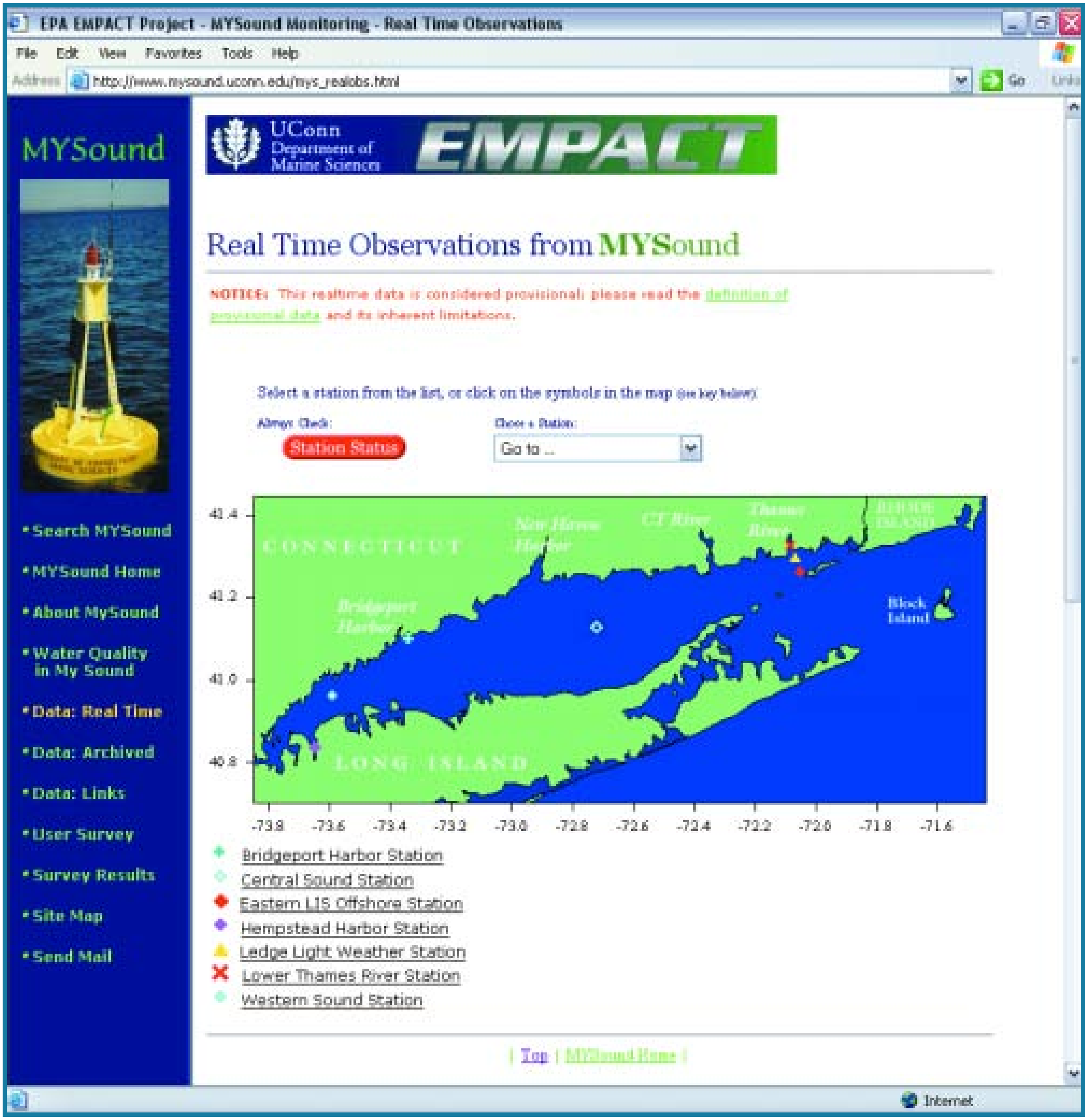
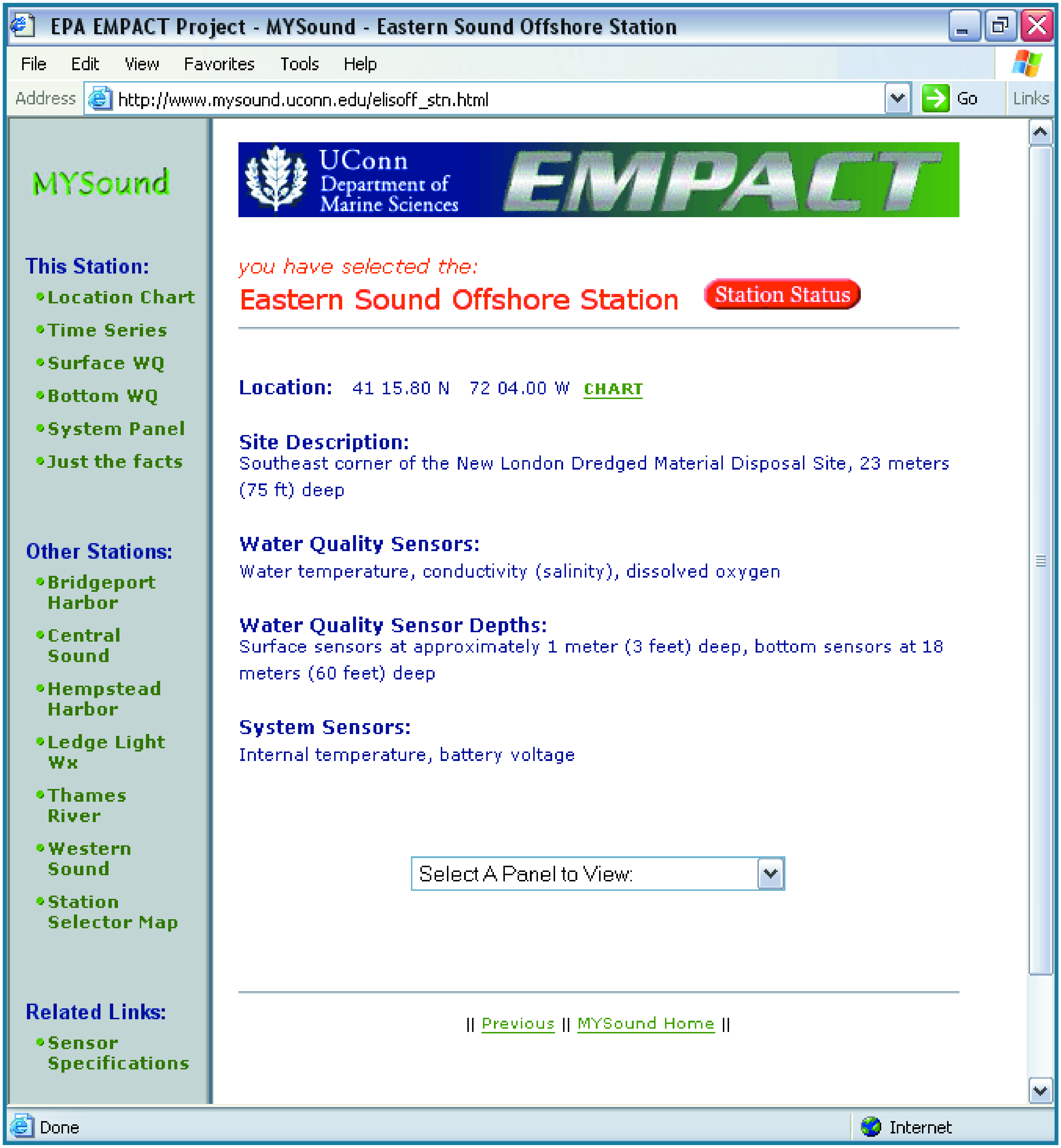
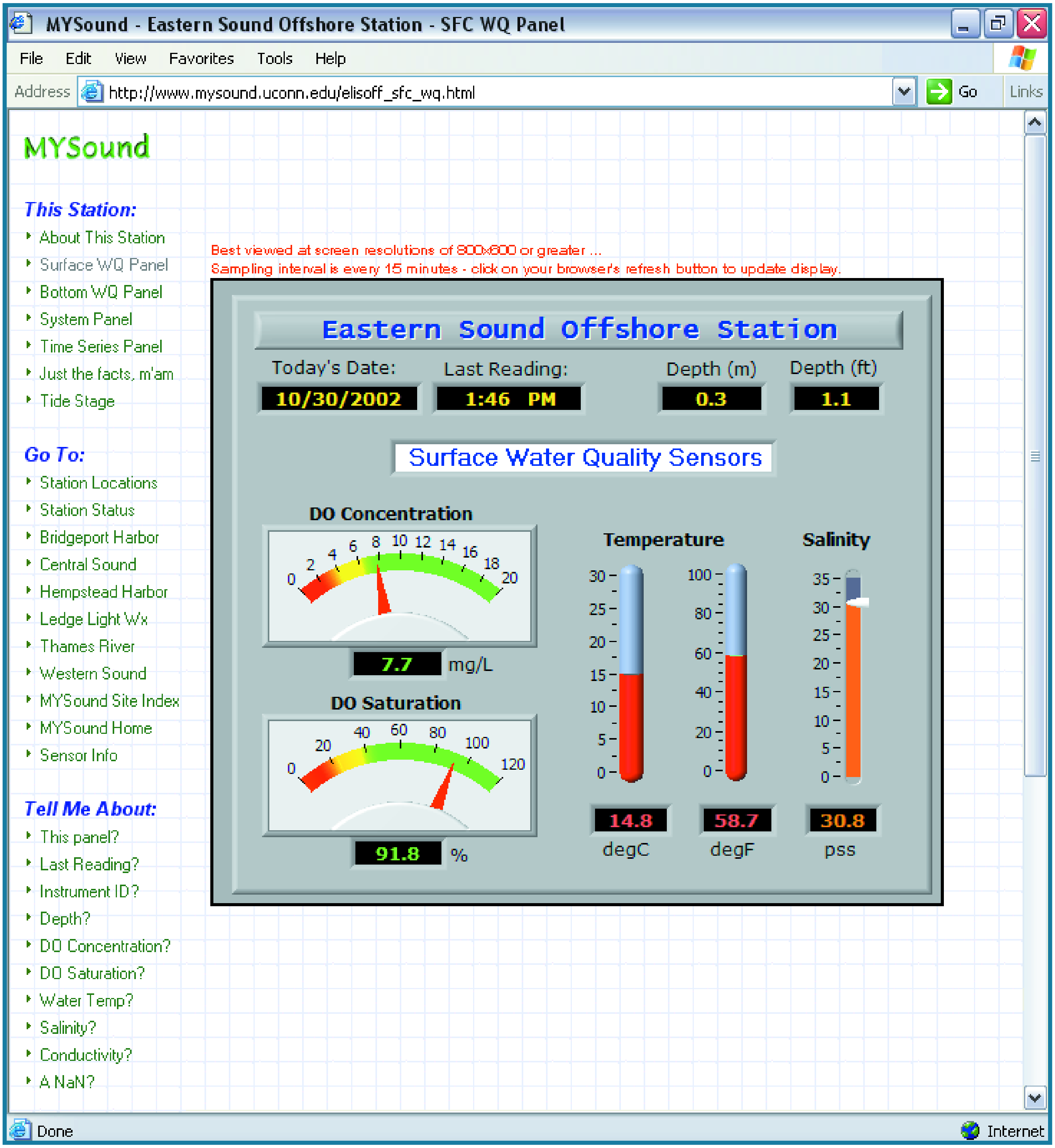


Figure 5.6 MYSound Web Page—Station Summary Page



Real-time data for each of the stations are presented in two ways. Real-time parameter readouts for surface and bottom sensors at each site are provided by the Surface and Bottom Data Panels (as shown in Figure 5.7), which give the current values of T, S, and DO for the particular sensor. The value of DO saturation is provided; this is the ratio of oxygen in the water column to the maximum amount of DO the water column can contain at the current temperature. The date, time, and depth of the readings are also provided.

Figure 5.7 Water Quality Data Panel



In *Time-Series Panel* (as shown in Figure 5.8) values for T, S, and DO are plotted over the previous 12 hours to show variations in the water quality parameters during this period. All sensors are displayed in the same panel to facilitate comparison of the changes in water quality parameters with depth. Current parameter readings for T, S, and DO are provided to the left of each time series plot. The time series plots are particularly valuable in determining the causes of fluctuations in the water quality parameters. For instance, a DO time series can be compared with time series of air temperature, wind speed, and tidal current velocity to determine if vertical mixing in the water column is caused by surface cooling, wind-driven mixing, or tidal flushing.

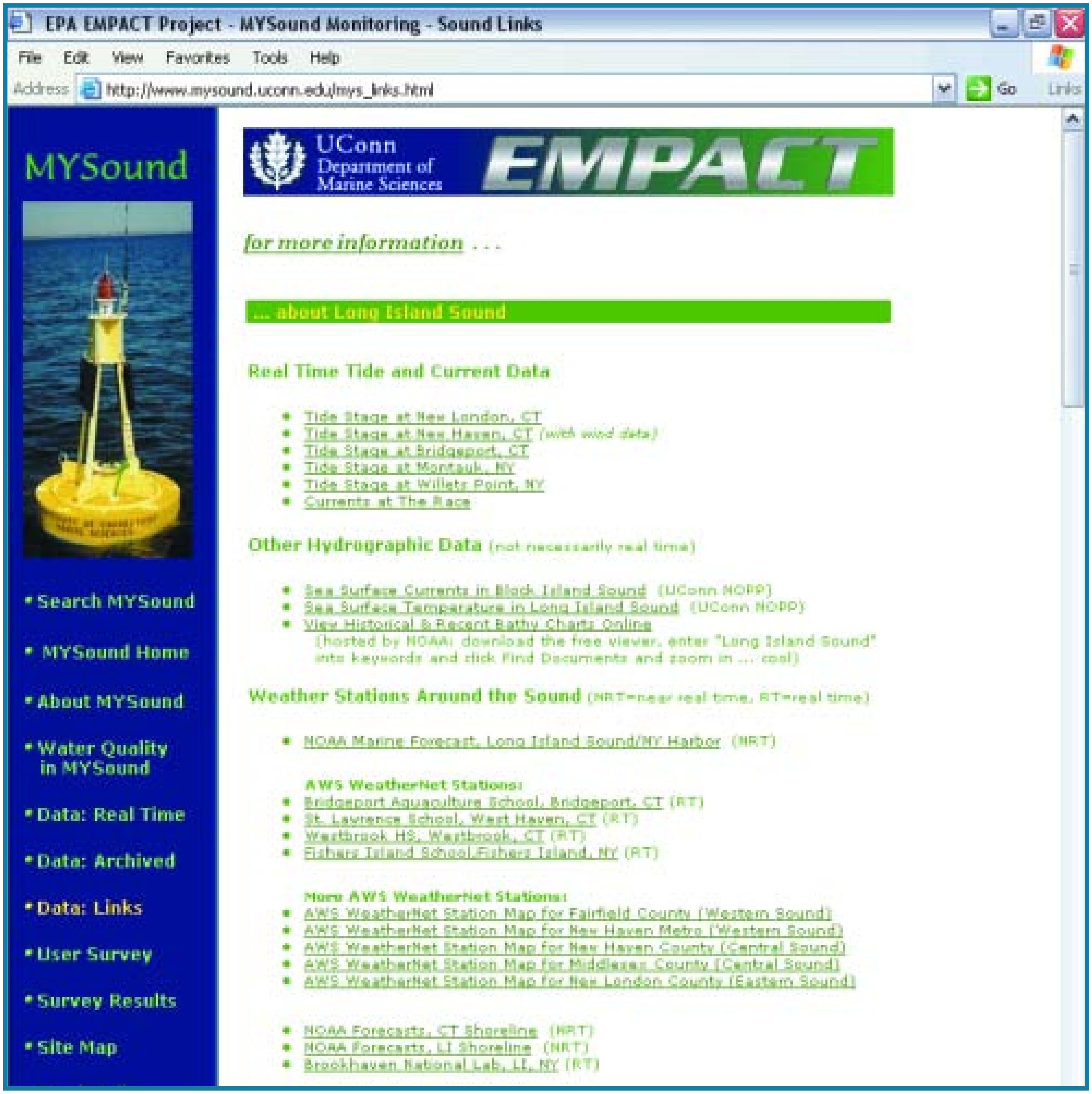
Figure 5.8 Water Quality Data Time—Series Panel

Figure 5.9 shows the *Archived Data* Web page, which allows access to archived data from the MYSound water quality monitoring stations at Bridgeport, Thames River, and Eastern Long Island Sound, the meteorological monitoring station at UConn Avery Point (which has been moved to Ledge Light), and the MYSound monitoring station at Hempstead Harbor (established by the Coalition to Save Hempstead Harbor). Archived data are also available from the volunteer water quality monitoring program for Bridgeport Harbor and Black Rock Harbor sponsored by Save the Sound. These files contain water quality data taken through sampling at various points around the harbor at set intervals throughout the year. These data are available in both ASCII format and CSV (Comma Separated Variable) format. Finally, the archives contain maps (GIF Maps) showing the results of the Connecticut DEP Summer Hypoxia Surveys for 1991 through 2001. These maps show the geographic extent and intensity of hypoxia in the Sound for each year.

Figure 5.9 Archived Data Web Page

Figure 5.10 shows the MYSound *Links* Page for accessing additional supplemental data and information from other Web sites. It includes links to NOAA real-time tide and current data at various points around the Sound, surface current and sea surface temperature data for Block Island Sound and Long Island Sound, and meteorological data from AWS WeatherNet stations located around the Sound. The Links page provides access to additional interpretive information on Long Island Sound natural history and water quality issues available from EPA, U.S. Geological Survey (USGS), and other agencies and institutions. Access is also provided to other marine data centers, water resources Web sites, and national marine science education Web sites.

Figure 5.10 MYSound Links Page



• Send Mail
Natural History of the Sound
• USGS Paper on Physical Processes in the Sound
• USGS Paper on Sedimentary Environments in the Sound
• About the Tidal Marshes of Long Island Sound
• Small animation showing glaciation and flooding of the Sound
Water Quality Issues in the Sound
• Branford River Project
• EPA Connecticut Beach Watch
• EPA Suffolk County, New York, Beach Watch
• EPA Nassau County, New York, Beach Watch
• Long Island Sound Study OnLine
• EPA Surf Your Watershed, CT
• EPA Surf Your Watershed, LI Shoreline
• NRDC 1998 Municipal Report Card for LI Sound
• NRDC 1999 Municipal Report Card Update
• SUNY, Stony Brook, MSRC Research on Long Island Sound
... about other Marine Data Centers
The Ocean Portal: A Global Directory of Ocean Data Sites
GoMOOS
GoMOOS: Gulf of Maine Ocean Observing System
COOL: Rutgers University Coastal Ocean Observing Lab
COAST: NY/NJ Coastal Ocean & Shore Trust - Virtual Estuary
COOS: U.S. COastal Observing System
^TOP
... about Water Resources
WaterWeb: A Database of Water Quality Site Links
WATER
EPA Student Center: EPA Site for Exploring Water
Water News
U.S. Water News: Online Newsletter (with archives) about Water
^TOP
... about Marine Education
BRIDGE
The Bridge: Resources for Teaching Marine Science
Jason Project: Ocean Expeditions Broadcast over the Web
Internet

Figure 5.11 shows the MYSound *User Survey Form,* a focused online user survey designed to capture essential data on user profiles and the perceived utility and effectiveness of the page. The strategy in designing the page was to keep it simple and brief to encourage Web site visitors to respond with at least some information. The survey contains only 10 multiple choice questions with a comments window for additional feedback beyond answering the 10 questions. It allows the MYSound project team to assess who is using the site and why they are accessing the site, and provides general impressions on the user-friendliness of the site and the overall usefulness of the information presented. Section 6.3 presents more information about the results of the user survey.

FIGURE 5.11 MYSOUND USER FEEDBACK SURVEY FORM ON THE NETWORK WEB SITE

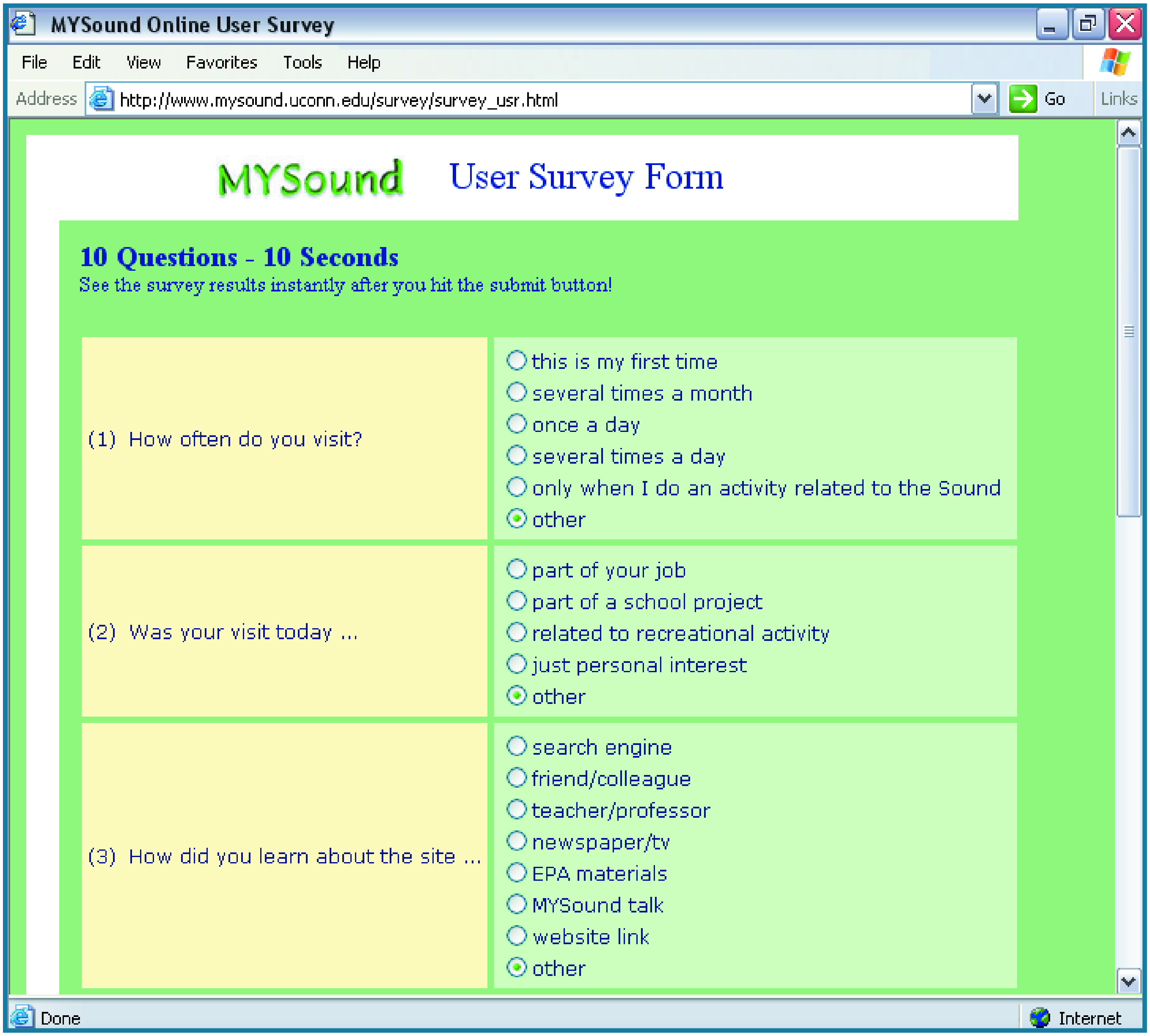
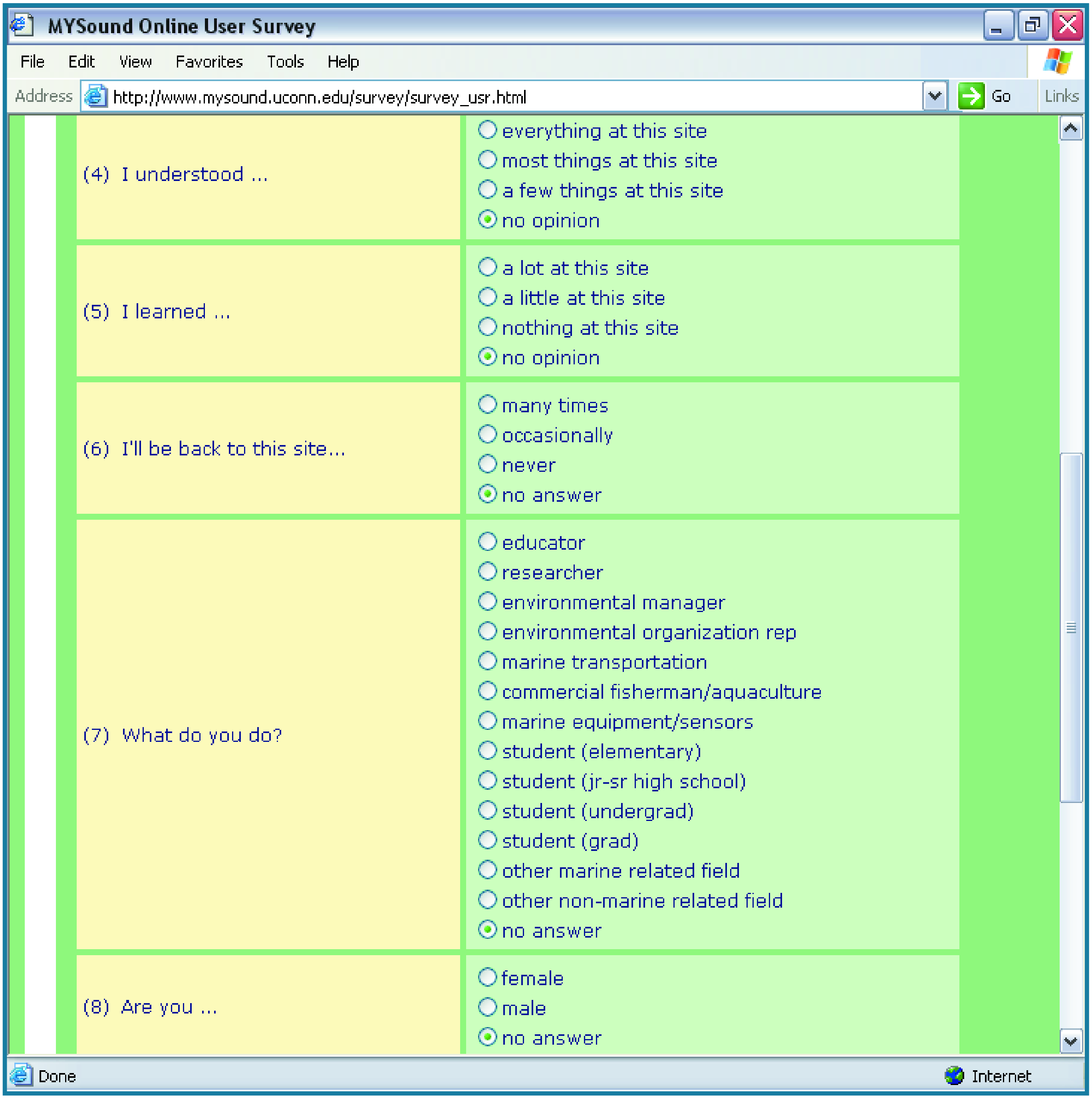


Figure 5.11 MYSound User Feedback Survey Form on the Network Web Site (continued)


MYSound Online User Survey

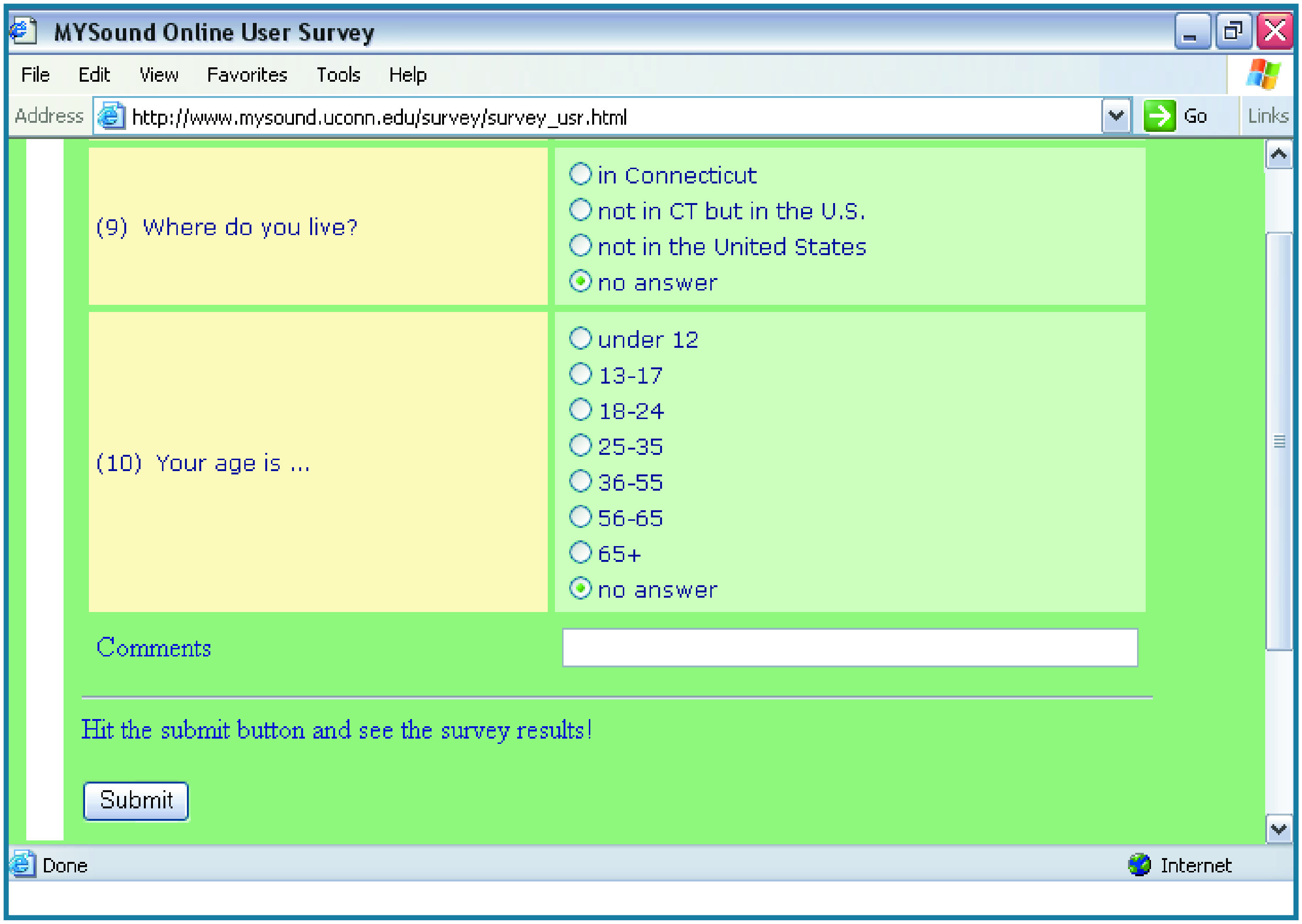
File Edit View Favorites Tools Help

Address http://www.mysound.uconn.edu/survey/survey_usr.html Go Links

(4) I understood ...	everything at this site most things at this site a few things at this site no opinion
(5) I learned ...	a lot at this site a little at this site nothing at this site no opinion
(6) I'll be back to this site...	many times occasionally never no answer
(7) What do you do?	educator researcher environmental manager environmental organization rep marine transportation commercial fisherman/aquaculture marine equipment/sensors student (elementary) student (jr-sr high school) student (undergrad) student (grad) other marine related field other non-marine related field no answer
(8) Are you ...	female male no answer

Done Internet

Figure 5.11 MYSound User Feedback Survey Form on the Network Web Site (continued)



5.2 Web Site Design and Implementation

The main pages of the MYSound Web site are housed on a server at the University of Connecticut's main campus in Storrs, Connecticut. These main pages were constructed using off-the-shelf HTML editing software. The data display panels are maintained on individual PCs at the Department of Marine Sciences building in Groton, Connecticut. The data panels were developed using National Instrument's LabVIEW, a commercially available software product developed to facilitate graphical presentation of quantitative data. Advertised advantages of this software package include:

- Strong integration with a wide variety of measurement devices
- Lower development costs through rapid development
- Powerful, built-in measurement analysis
- Compiled for faster performance
- Intuitive, industry-standard graphical development environment

The LabVIEW software has an integrated, network-ready component, which includes Web server capabilities. When a request is made for the data panel display from one of the main pages on the Storrs server, a command is sent to the appropriate PC to serve out a picture in JPEG format of the current data panel. The picture is static and must be manually updated by the browser user, preventing an overload on the LabVIEW Web servers. These PC-based data servers are connected to the main server at Storrs via a T1 line which is capable of carrying a large amount of Internet bandwidth (1.544 megabits/second) and is generally more reliable than a standard phone line.

More information on LabVIEW is available from the National Instruments Web site at *http://www.ni.com* (click on Products and Services and then Measurement and Automation Software).

The data servers running LabVIEW retrieve the data needed to update the panels from remote base stations every 15 minutes using the built in TCP/IP protocols of LabVIEW over a T1 line or cell modem connection. The LabVIEW routines for the MYSound site have been programmed to perform a first-order data quality review in which data outside the physical limits of the particular sensor are discarded. When the data are discarded, the routine posts a NaN (Not a Number) to the display panel, or just skips the point in the time series charts. All data are then written to an ASCII comma delimited file, which can be downloaded at a later time and subsequently reviewed before being posted to the MYSound archives for public use.

5.3 ALTERNATIVE INFORMATION DISSEMINATION APPROACHES

In addition to the MYSound Web site, several other mechanisms are being used or considered for data dissemination. The first is the more traditional approach for data dissemination and interpretation, which is publication in hard copy reports. Data from the MYSound monitoring stations are being made available for publication in reports of agencies and organizations such as the EPA Long Island Sound Study and the LIS Water Quality Monitoring Work Group (a coalition of government and NGO water quality monitoring programs which publishes an annual State of the Sound report). When published, these reports will be accessible from the MYSound site.

Other options include a direct telephone dial-up service or public broadcasts for individuals who need specific Long Island Sound marine environmental data but do not have immediate Internet access. An important user group in this category is the marine transportation community, as well as recreational boaters and fishermen. In the summer of 2002, a station was established in an offshore mid-Sound location to monitor wind, wave, and current conditions, as well as water quality parameters. This information is of great value to the mariner. MYSound will investigate the feasibility of implementing a dial-up telephone service, possibly available in 2003, that concisely conveys this weather and oceanographic data in a computer-generated voice message. This may be accomplished by passing information on to the National Oceanic and Atmospheric Administration/National Weather Service.

Presenting and Disseminating Information: Key Points and Lessons Learned

- **For a marine environmental monitoring program to be successful, the data must be effectively disseminated to user groups in a format that is both accessible and understandable. Internet technology has provided an ideal mechanism for accomplishing this. MYSound and other monitoring programs now have dedicated Web sites that serve this function. Important components of the MYSound Web site include:**
    - **Program information**
    - **Interpretive information on estuary ecology and pollution**
    - **Data presentation**
    - **Archived data inventory and access**
    - **Links to other Web sites**
    - **User survey**
    - **Contact E-mail for user feedback**
- **Software products and expertise for building the Web site are commercially available. However, a dedicated Webmaster with appropriate training is necessary to maintain the Web site.**
- **Although the MYSound Web site is the primary data and information dissemination mechanism, not everyone has access to the Internet. Data are also available in hard copy reports and technical papers, as well as by access to archived time-series data on request via FTP (as described in Section 4.7). Other possible data dissemination mechanisms include telephone dial-up services, and broadcasts via the local media.**

6 COMMUNICATION AND OUTREACH

This chapter presents the experience of MYSound in setting up and maintaining the communications and outreach component of a marine environmental monitoring program. This component is designed to cultivate interest in the monitoring network with potential partners and stakeholders, make the public aware of the monitoring program and its value, and solicit feedback from users about the usefulness of the program and how it could be improved. Section 6.1 provides tips on developing an outreach plan for the program, with a focus on working with partners, as well as determining target audiences, messages, and outreach tools. Section 6.2 describes the challenge of evaluating the success of the monitoring program.

Supplementary information about designing and implementing a communications program is available in the handbook *Communicators Guide for Federal, State, Regional, and Local Communicators* published by the Federal Communications Network *(http://www.fcn.gov)*. Guidance on communications and outreach for environmental projects is available through the EPA training program *Getting In Step—A Guide to Effective Outreach in Your Watershed (http://www.epa.gov/watertrain/gettinginstep)*. The following Web sites also provide more ideas about how to write clearly and effectively for a general audience:

- The National Partnership for Reinventing Government's Writing User-Friendly Documents, available at *http://www.plainlanguage.gov*
- The Web site of the American Bar Association has links to online style manuals, and grammar primers at *http://www.abanet.org/lpm/writing/styl.html*

6.1 DEVELOPING A COMMUNICATION AND OUTREACH PROGRAM

Communication is at the heart of MYSound's mission: to provide the public with real-time information on the water quality in Long Island Sound, and to educate the public about actions they can take to reduce pollution in the Sound. An effective communications and outreach program, therefore, has been key to the project's success. Some of the approaches and lessons learned in this area are described below.

6.1.1 PARTNERSHIPS IN OUTREACH AND EDUCATION

It can prove valuable in developing an outreach plan to invite other organizations to partner in planning and implementing the outreach effort. Partners can participate in planning, product development and review, and distribution. Partnerships can be valuable mechanisms for leveraging resources while enhancing the quality, credibility, and success of outreach efforts.

MYSound is a case in point. An important strategy in MYSound communications and outreach has been to leverage the communications and outreach activities of key MYSound stakeholders and partners. Key partners have included environmental and health agencies (EPA, Connecticut DEP, New York Department of Environmental Conservation [DEC], Suffolk County Health Department); educational institutions (Bridgeport Regional Vocational Aquaculture School in Bridgeport and The Sound School in New Haven); teaching aquaria (the Maritime Aquarium at Norwalk and the Mystic MarineLife Aquarium); and environmental NGOs (Save the Sound, the Coalition to Save Hempstead Harbor, and Connecticut Coastal Audubon Center). All of these agencies, institutions, and organizations have well-established communications and outreach programs of their own. Throughout the MYSound development process, the project team has integrated MYSound communications and outreach with the activities of these organizations. Some specific examples of these collaborative activities are described in Section 6.1.2.

6.1.2 MYSOUND AUDIENCE, MESSAGE, AND OUTREACH TOOLS

Broadly speaking, the target audience for the MYSound project is the general public, and particularly an environmentally concerned public, that is attempting to understand ecosystem health in Long Island Sound. This encompasses a diverse set of groups that use Long Island Sound for a variety of purposes; therefore, the MYSound message is presented in different formats and levels of technical complexity to reach these groups. (For example, the Web site includes information that is readily accessible to the non-scientist, while technical and scientific issues are addressed in greater depth at conferences for environmental managers and marine educators.) The same will likely be true for similar projects in estuarine waters near urban coastlines.

MYSound's key outreach tool is its Web site, but the project has also undertaken several other communications and outreach initiatives. These initiatives fall into three categories, each targeted to a particular stakeholder group: initiatives focusing on the scientific and technical community (including other EMPACT projects), initiatives focusing on the educational community, and initiatives focusing on interested citizens and the public at large

6.1.2.1 INITIATIVES FOCUSING ON THE SCIENTIFIC AND TECHNICAL COMMUNITY

Outreach initiatives focusing on the scientific and technical community have consisted largely of presentations at workshops and conferences, publication of articles in conference proceedings, and participation in technical working groups dealing with marine water quality monitoring. For instance, the MYSound project team has made presentations on the project at several EMPACT National Conferences in Washington, Baltimore, Minneapolis-St. Paul, and Boston; at the 2000 Long Island Sound (LIS) Research Conference in Stamford; at the Oceans 2000 Conference in Providence; and at the 2001 EMAP Conference in Pensacola. Figure 6.1 shows the MYSound poster presentation used at these conferences. The poster presentation includes the poster itself as well as a laptop presentation of the MYSound Web site (either a real-time or archived presentation). A customized poster presentation on the project was featured at the EPA's National Science Forum in Washington, DC in May 2002. MYSound Project Summaries were also distributed at these conferences. Technical papers and articles on the project have been published in the proceedings of the 2000 Oceans Conference, the 2000 Long Island Sound Research Conference, and the 2001 EMAP Conference. In addition, articles on the project were published in *Sea Technology* magazine, which subsequently led to the project being featured on the cover of the publication (see Figure 6.2), and in the Marine Technology Reporter published by the Massachusetts Ocean Technology Network. All of these efforts have given the project significant visibility on a regional and national level, and have facilitated networking activities.

Figure 6.1 MYSound poster presentation with MYSound Web site laptop demonstration and printed outreach material.

The MYSound project team also participated in a two-day workshop on Volunteer Marine Water Quality Monitoring sponsored by EPA and the Ocean Conservancy, and regularly participates in working groups dealing with LIS environmental issues, such as the LIS Water Quality Monitoring Working Group and the Science Advisory Committee of the Connecticut Coastal Audubon Center. This promotes awareness and interaction with local stakeholders and has led to the recruitment of additional project partners.

6.1.2.2 INITIATIVES FOCUSING ON THE EDUCATIONAL COMMUNITY

MYSound has undertaken initiatives focusing on the educational community to support marine science education, particularly at the junior high and high school level. Key educational partners in these efforts include the Bridgeport Regional Vocational Aquaculture School, the Sound School, and the Maritime Aquarium at Norwalk. These institutions are providing feedback on how the project can support marine education, and are assisting in the development of interpretive material targeting educators and students. Other initiatives under consideration include a series of guided Internet explorations that will lead students through marine environmental protection topical Web sites that discuss environmental problems and issues of importance in the Sound. MYSound is also investigating the possibility of developing a series of classroom exercises using Long Island Sound data to demonstrate various scientific concepts.

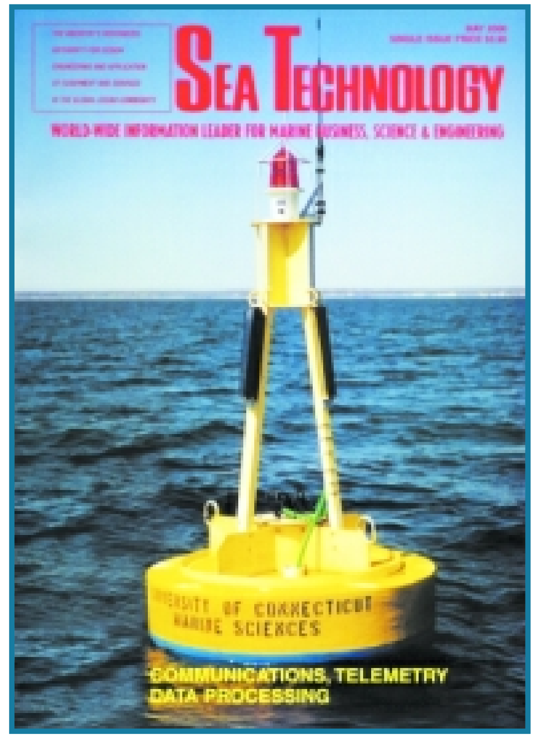


Figure 6.2 Cover of *Sea Technology* magazine featuring the MYSound monitoring buoy

In addition to providing educational material on the Web site, MYSound has established connections with educators in individual schools throughout the region by participating in the biannual Long Island Sound Educators Conference and the annual New York State Marine Educators Association (NYSMEA) Conference. The project team also helped organize a Marine Science Career Day at the University of Connecticut at Avery Point for students from the Bridgeport Regional Vocational Aquaculture School.

Perhaps the most significant networking initiative with educational stakeholders is the current effort to transfer operating responsibility for the Bridgeport harbor monitoring station, and future stations in New Haven and Norwalk harbor, to the three key educational stakeholders. This will not only provide hands-on experience for teachers and students in marine water quality monitoring, but also promote the future sustainability of these stations.

6.1.2.3 INITIATIVES FOCUSING ON THE GENERAL PUBLIC

In providing the real-time data and interpretive information to the public, MYSound recognizes that not all individuals are aware of the project or have direct access to the Internet. To promote public awareness of the project and provide for wider dissemination of MYSound data, the project has undertaken several citizen-targeted activities. The first is the publication of newspaper and newsletter articles on the project. Newspaper articles on the project, including two full-page feature articles, have been published in the New London Day, the Hartford Courant, Connecticut Post (Bridgeport), Stamford Advocate, and New York Times. In addition, articles on the project have been published in various regional newsletters such as the Sound Bites newsletter published by Save the Sound, Sound Outlook published by Connecticut DEP, and The Nor'easter published by New England Sea Grant.

MYSound has also developed a poster presentation for display and a brochure for distribution at public events focusing on Long Island Sound. Such events have included the annual Long Island Sound Watershed Alliance Conference and the Long Island Sound Day program held at the Mystic MarineLife Aquarium. The brochure is included in Appendix B.

A third mechanism for reaching the public that was developed and tested as part of the project was a computer-based public access kiosk that allowed public access to the MYSound Web site. Such a kiosk was implemented at the Maritime Aquarium at Norwalk. Although the kiosk did receive some attention by aquarium visitors, it proved somewhat too technical for many of the visitors and was not entirely self-promoting and self-explanatory (see “Lessons Learned” below). Therefore, it was discontinued in 2001 and plans for a similar kiosk at the Mystic MarineLife Aquarium were suspended.

Lessons Learned: MYSound’s Public Access Kiosk

In 1999, MYSound set up a kiosk at Norwalk’s Maritime Aquarium to provide direct public access to the project Web site. In retrospect, MYSound has judged that it was not successful because it lacked the explanation and sequencing that would have made it attractive to the broad audience visiting the aquarium. In addition, it was a stand-alone exhibit not tied to any of the more visible aquarium exhibits. A better approach would have been to offer a simplified exhibit that showed temperature, salinity, and DO from an offshore monitoring station, and that also described how these parameters affect species distribution and vitality. Such a kiosk could be incorporated directly into the Long Island Sound fish species exhibit at the aquarium to emphasize the connection between water quality and species health/diversity. In summary, MYSound learned that kiosk exhibits should be simple and focused on a particular theme or concept to be popular in a public venue.

6.2 PERFORMANCE EVALUATION AND PUBLIC FEEDBACK

Another important aspect of any marine environmental monitoring program is capturing information on the utility and effectiveness of the program and making adjustments and enhancements based on this feedback. In the MYSound project, this is accomplished through the online user survey at the MYSound Web site (See Figure 5.11), and through continuous user feedback through the Web site E-mail connection to the Webmaster.

Figure 6.3 shows the current cumulative results of the MYSound User survey. As of 11/11/02, 495 individuals had responded to the survey. The demographics of the user community and information on how they perceive the usefulness and user-friendliness are shown in the form of percent distribution bar graphs for the number of individuals recording each response. The survey indicates, for instance, that 52% of the responders were accessing the site for the first time. Responders learned of the site through a variety of mechanisms including search engines, friends and colleagues, newspapers and TV, and links from other Web sites. Most responders find the site both understandable and informative, and intend to return to the site. Of those responders indicating a specific occupation, most were educators, researchers, and environmental managers. Most responders live in Connecticut. Most responders are male (71%), and many responders are between the ages of 36 and 55 (44%).

As for E-mail feedback, Appendix C provides a sampling of the comments and suggestions received. Comments on the MYSound Web site have been generally favorable although not always providing great detail. The real-time weather data appears to be a particularly valuable piece of information for many users. The overall value of the Web site can be assessed by the fact that there are immediate inquiries from the public when the stations are off-line for repair.

Figure 6.3 Results of the MYSound User Feedback Survey Available at the MYSound Web Site

Visit Frequency

Response	Number	Percent	Graph
first time	256	52%	
several/month	101	20%	
1/day	26	5%	
several/day	29	6%	
related activity	46	9%	
other	37	7%	

Total Number of Responses: 495

Reason for Visit

Response	Number	Percent	Graph
job	98	20%	
school project	45	9%	
recreation	97	20%	
personal	222	45%	
other	33	7%	

Total Number of Responses: 495

How Site Found

Response	Number	Percent	Graph
search engine	69	14%	
friend/colleague	87	18%	
teacher/professor	23	5%	
newspaper/tv	82	17%	
EPA materials	25	5%	
MYSound talk	10	2%	
web link	102	21%	
other	97	20%	

Total Number of Responses: 495

Figure 6.3 Results of the MYSound User Feedback Survey Available at the MYSound Web Site (continued)

Understanding

Response	Number	Percent	Graph
everything	186	38%	
most things	198	40%	
few things	38	8%	
no opinion	73	15%	

Total Number of Responses: 495

Learning

Response	Number	Percent	Graph
a lot	226	46%	
a little	171	35%	
nothing	11	2%	
no opinion	87	18%	

Total Number of Responses: 495

Return Plans

Response	Number	Percent	Graph
many times	215	43%	
occasionally	219	44%	
never	11	2%	
no answer	50	10%	

Total Number of Responses: 495

Figure 6.3 Results of the MYSound User Feedback Survey Available at the MYSound Web Site (continued)

Occupation

Response	Number	Percent	Graph
educator	39	8%	
researcher	47	9%	
env manager	26	5%	
env organization	4	1%	
marine transport	13	3%	
fisherman/aquaculture	11	2%	
marine equip/sensors	3	1%	
elmentary student	3	1%	
jr-sr high student	28	6%	
undergrad student	26	5%	
grad student	11	2%	
other marine	53	11%	
other non-marine	140	28%	
no answer	91	18%	

Total Number of Responses: 495

Gender

Response	Number	Percent	Graph
female	113	23%	
male	351	71%	
no answer	31	6%	

Total Number of Responses: 495

Figure 6.3 Results of the MYSound User Feedback Survey Available at the MYSound Web Site (continued)

Location

Response	Number	Percent	Graph
CT	340	69%	
US	128	26%	
not in the US	3	1%	
no answer	24	5%	

Total Number of Responses: 495

Age

Response	Number	Percent	Graph
under 12	8	2%	
13-17	24	5%	
18-24	38	8%	
25-35	51	10%	
36-55	220	44%	
56-65	73	15%	
65+	24	5%	
no answer	57	12%	

Total Number of Responses: 495

MYSound Home

Communication and Outreach: Key Points and Lessons Learned

Because of the goals of the EMPACT Program, communication and outreach are at the heart of the MYSound mission: to provide the public with timely information on the water quality in Long Island Sound, and to educate the public about actions they can take to reduce pollution in the Sound. An effective communications and outreach program, therefore, is key to the project's success. In designing a communications and outreach program, several key points must be considered:

- An important strategy in designing and implementing the communications and outreach plan is to leverage against the communications and outreach activities of key stakeholders and partners.
- In formulating a communications and outreach plan for the monitoring program, several important questions must be addressed:
    - *What are the outreach goals?*
    - *Who are the target audiences?*
    - *What are the key messages and types of information to be delivered?*
    - *What outreach tools will be effective?*
- In addition to the monitoring project Web site, a number of communications and outreach tools were used in the MYSound project. These included:
    - Poster presentations at conferences and workshops
    - Hard copy brochures and project summaries
    - Articles on the project in marine environmental and technical periodicals and newsletters
    - Papers submitted to conferences and workshops that were subsequently published in the proceedings
    - Articles in local newspapers and news features on local television stations
    - An Internet-based kiosk at a regional aquarium
- Performance evaluation is a key component of any monitoring program. Two mechanisms successfully employed by MYSound are an online User Survey posted on the Web site, and E-mail feedback provided through the Web site.

7 FUTURE DIRECTIONS: ENHANCING AND SUSTAINING A MARINE WATER QUALITY MONITORING NETWORK

This chapter presents information about making a marine monitoring program sustainable in the long run, with an emphasis on the experience and explorations of the MYSound project in this area. Section 7.1 places the issue of sustainability for a specific program in the context of international, national, and local initiatives. Section 7.2 describes actions that MYSound is taking to enhance and expand its network, with an emphasis on the concept of "distributed stewardship." Section 7.3 focuses on future opportunities and initiatives that MYSound and other monitoring programs can consider to sustain this work into the future.

7.1 CHALLENGES AND OPPORTUNITIES FOR THE MYSOUND PROJECT

Establishing the MYSound network is a significant accomplishment, but maintaining and expanding it over time will be even more challenging. Sustainability is important for several reasons. First, implementing a regional, ecosystem-wide real-time monitoring network contributes to the national strategy and approach, described below, of providing longer term, multi-parameter environmental monitoring data. Second, the development of MYSound and other such monitoring programs represents a significant up-front investment of money and effort. This investment includes not only equipment, which is readily replaceable, but also expertise, experience, cooperation, and project visibility and momentum, which are not easily rebuilt. Finally, if the monitoring network becomes inactive due to lack of funding, a continuity gap in the data would occur, limiting the value of the data obtained before and after this monitoring gap.

EPA's EMPACT program provided the primary funding to initiate the MYSound project. This program-specific funding, while substantial, had a finite lifetime as EPA moves on to address other problems and issues. This is typical of most federally funded monitoring efforts (except for compliance monitoring, where the costs are borne largely by the municipalities and companies being monitored). The challenge in sustaining the MYSound effort is to develop a more diverse funding base by integrating the MYSound monitoring effort with other initiatives, and expanding the range of data and information disseminated to serve a wider group of users. It is hoped that these users can support the operation and maintenance of the network through direct funding and in-kind logistics support. Partnerships and leveraging of resources will be the key to success.

Coincidentally, a number of international and national initiatives are calling for partnerships in establishing and maintaining coastal marine monitoring networks like the MYSound network. On the international level, the world oceanographic community is moving steadily forward in implementing the concept of the Global Ocean Observing System (GOOS). GOOS is a global ocean monitoring network that acquires and disseminates data in near real time to support:

- Weather forecasts and climate predictions.
- Now-casting (providing information on current conditions) and forecasting for safe marine operations, mitigation of natural hazards, and national security.
- The detection and prediction of effects of human activities and climate change on marine ecosystems and living resources.

The system will assimilate data from in situ sensors mounted on a wide range of platforms (towed instrument packages, fixed moorings, drifters, autonomous underwater vehicles [AUVs] and remotely operated vehicles [ROVs]) and from aircraft and satellite remote sensors that transmit data in real time. Advanced data assimilation and modeling techniques will be used to analyze and synthesize the data into decision-making tools to support marine operations, environmental management, and basic research. It is envisioned that the coastal components of GOOS (C-GOOS) will be similar to MYSound in function and configuration. GOOS hopes to build on existing programs, including MYSound, to develop the global system.

On a national scale, enhanced long-term coastal monitoring efforts are called for in the Coastal Research and Monitoring Strategy developed under the Clean Water Action Plan (CWAP). In implementing this monitoring scheme the CWAP Coastal Strategy calls for expansion and enhancement of monitoring efforts by:

- Coordinating coastal monitoring and research activities to provide useful information on which to base coastal management decisions.
- Expanding federal coastal programs to focus on urgent issues (e.g. harmful algal blooms, shellfish mortality, habitat restoration).
- Building and expanding partnerships among federal, state, tribal, local, and business stakeholders to achieve clean water and public health goals in the coastal zone.

It should be noted that the Clean Water Action Plan stresses the importance of adopting a watershed approach in setting priorities and taking action to clean up rivers, lakes, and coastal waters. The plan also calls for collaborative effort on the part of government, industry and the public at large in sustaining water quality.

In addition to international and national programs, local monitoring efforts are expanding rapidly under the auspices of municipalities, colleges and universities, and volunteer water quality monitoring efforts sponsored by regional and local environmental NGOs. These efforts provide additional data on site-specific environmental trends and can be integrated into federal data sets if appropriate QA/QC protocols are followed. In addition, these local efforts represent a powerful constituency for the broader-scale federal and state monitoring programs.

Crucial to achieving long-term sustainability within the MYSound project will be achieving consistency with the longer term goals, objectives, and strategies of GOOS and the Clean Water Action Plan, and integrating with other marine environmental monitoring efforts on a national, regional, watershed, and local basis.

7.2 CURRENT ACTIONS TO EXPAND AND ENHANCE THE MYSOUND NETWORK

In 2001 and 2002, the MYSound project investigated the addition of several additional stations to the inshore portion of the MYSound network under the "distributed stewardship" concept. Under this concept, members of the MYSound project team at the University of Connecticut (UConn) will hand off the day-to-day maintenance of the inshore stations to the local partners (or in some cases a coalition of partners), while still maintaining the MYSound Web site and the offshore (mid-Sound) stations. The consensus of the MYSound partners was that they were amenable to the concept if funding were available to provide the basic inshore station equipment (buoy [if needed]), sensors, data processor, telemetry package, modem, etc.) as currently in place in Hempstead Harbor, Bridgeport Harbor, and the Thames River.

The MYSound team prepared several proposals outlining this concept and submitted them to the Long Island Sound Study Management Committee and the EMPACT program for consideration in 2001. In the fall of 2001 the project was able to acquire funding under the EMPACT Integration/Networking program.

In addition, the project was able to acquire some additional funding under the Long Island Sound Study to support the Web site and maintain the current offshore stations. This meant that while the future of MYSound had been uncertain in June 2001, the network now could be maintained and even expanded under the "distributed stewardship" concept in 2002 and 2003, as described in more detail in Section 7.2.2.

7.2.1 ENHANCEMENT OF THE OFFSHORE NETWORK TO SUPPORT ENVIRONMENTAL MANAGEMENT AND MARITIME OPERATIONS PLANNING

By the end of 2002, MYSound will have three oceanographic and two meteorological stations operational along the axis of the Sound with data displayed on the MYSound Web site. The oceanographic monitoring stations will be operating at the eastern Corps of Engineers dredged material disposal site off New London, at the midpoint of the Sound near New Haven (Central LIS station), and in the western Sound near Greenwich. Oceanographic parameters measured will be temperature, salinity, dissolved oxygen, and current speed and direction. A chlorophyll *a* and nutrient sensor may be added to one or more stations. The meteorological stations will be established on a Central Offshore LIS station in the vicinity of New Haven and in the Eastern Sound at New London Ledge Light. Meteorological parameters will include air temperature, humidity, barometric pressure, and wind speed and direction. At the Central LIS station, wave height will be measured as well. The temperature, salinity, dissolved oxygen, and nutrient data will be useful in interpreting long-term changes and trends in the Sound's water quality through correlation with Sound-wide water quality surveys conducted by EPA, Connecticut DEP, and New York DEC under the Long Island Sound Study.

7.2.2 EXPANSION OF THE INSHORE NETWORK AND INTEGRATION WITH WATERSHED, RIVER, AND HARBOR MONITORING EFFORTS

To increase outside involvement and expand the number of stations that can be supported, the project has developed and is testing the concept of "distributed stewardship" of the inshore stations. The MYSound project team will assemble and deploy the station, or facilitate the assembly and deployment of the station by a local agency or organization, but then that agency or organization (or a coalition of several agencies/organizations) will operate and maintain the station. The local entity will also be responsible for water quality sampling, possibly through a local municipal or volunteer water quality sampling program (such as those sponsored by Save the Sound, Inc.). The data telemetry links will be installed and maintained by the MYSound project team so that the data can be made available in real time on the MYSound Web site. The project team would also provide technical consultation and data interpretation support.
The incorporation of the Hempstead Harbor station into the network was MYSound's first attempt at distributed stewardship of a monitoring station and proved successful.

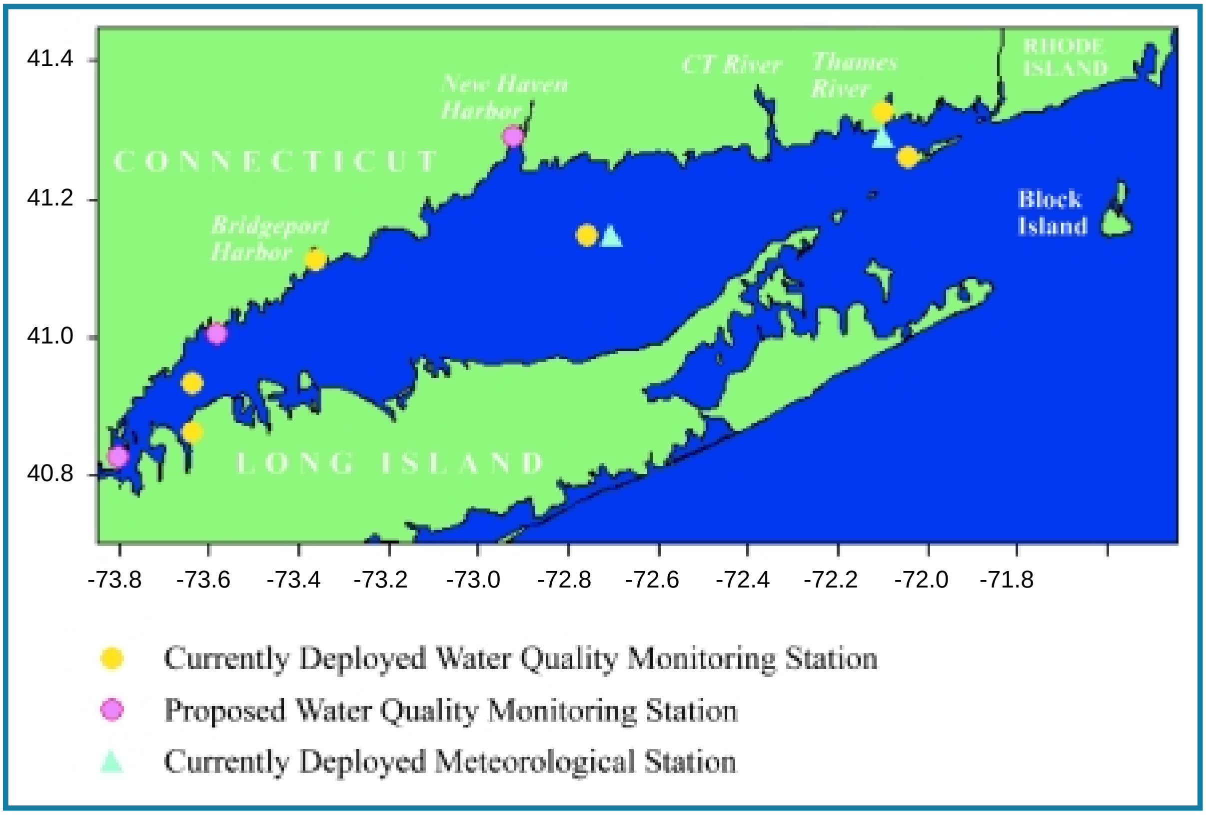
By the end of 2002, five "distributed stewardship" monitoring stations will be up and running along the Connecticut shoreline and on the coast of Long Island:

- New London Harbor (Thames River), already deployed.
- Bridgeport Harbor, already deployed.
- Hempstead Harbor, already deployed but currently offline due to a collision by a barge.
- Norwalk Harbor (Norwalk River), scheduled for deployment in fall 2002.
- New Haven Harbor, scheduled for deployment in spring 2003.

Having additional inshore stations in the various rivers, estuaries, and harbors throughout the Sound will provide valuable information on overall water quality status and trends, but also provide information on local water quality useful to municipalities, researchers, and NGOs on a site-specific basis. In the future, it would also be useful to establish monitoring stations further upstream in the major watersheds monitored within the MYSound project to document the watershed contributions to pollutants in the Sound.

Figure 7.1 shows the comprehensive array of water quality, oceanographic and meteorological monitoring stations throughout the Sound anticipated by the end of December 2002. Having these stations in place will set the stage for longer term development of the network as described in Section 7.3.

Figure 7.1 Map Showing the Location of MYSound Monitoring Stations Anticipated by December 2002



7.3 LONGER TERM OPPORTUNITIES TO EXPAND AND ENHANCE THE MYSOUND NETWORK

MYSound is actively pursuing several opportunities to collaborate with other organizations and agencies to expand and enhance the monitoring network. One such opportunity involves the NOAA Physical Oceanographic Real-Time System (PORTS) project *(http://co-ops.nos.noaa.gov/d_ports.html)*. The wind and water quality data acquired at the MYSound meteorological and oceanographic stations are of direct value to the maritime transportation industry, fishing vessels, and recreational boaters. In this regard, the MYSound offshore stations are similar in function to the stations deployed through PORTS, which also gather and disseminate, in real time, current, wind, and tide data in a number of port areas around the country. NOAA has established a PORTS Station in New Haven, which measures wind speed and direction and tide level. An excellent opportunity for integrating the MYSound and PORTS projects lies in cross-linking all of the MYSound offshore monitoring stations with the NOAA PORTS Web site to form a combined data source for Long Island Sound. It would also be desirable to establish wave sensors at the offshore MYSound sites to be available for commercial vessels, fishing boats, and recreational boaters. (A wave sensor and meteorological sensors are being added to the sensor array for the Central LIS Offshore station near New Haven; they may eventually be added to other stations if funding becomes available.) Access to these data could be obtained through the MYSound Web site, the NOAA PORTS site, or a dial-up telephone number.

MYSound is investigating collaboration with NOAA in expanding and supporting the offshore network. Such collaboration has already been initiated, in that NOAA provided the buoy hull for the Central Offshore LIS station. The meteorological and oceanographic data from the Central Offshore LIS buoy will be shared with NOAA. MYSound also has collaborated with NOAA in developing funding proposals for the MYSound project's offshore component.

The offshore oceanographic and meteorological data could also be used in hydrodynamic models to produce now-casts and forecasts of the current regime in the Sound for planning maritime transportation and predicting the transport of pollutants in the Sound. Several models are available (at UConn and elsewhere) that could be adapted to this application. Current vector maps could be provided over the Internet on the MYSound home page and could be downloaded by environmental managers and maritime users.

Satellite and aircraft remote sensing images of Long Island Sound are an additional data source that could be integrated with the MYSound real-time monitoring data. Remote sensing imagery can often help in explaining the scope and causes of phenomena that are detected in the real-time time series. They also facilitate visualization of circulation patterns and water property changes in the Sound on a seasonal basis.

If the "distributed stewardship" concept proves viable in the long term, it is likely that other local governments, educational institutions, and NGOs will seek to establish monitoring stations in their own estuaries, rivers, and harbors. Other collaborative inshore station and upstream watershed monitoring station possibilities include:

- A station in the Housatonic River Estuary at Milford Point in collaboration with the Connecticut Coastal Audubon Center and the Housatonic Valley Association.
- An upstream station in the Housatonic River Watershed in collaboration with Connecticut DEP, U.S. Geological Survey (USGS), and the Housatonic Valley Association.
- Two stations in the Connecticut River (an estuary station near Essex and an upstream station just below Hartford) in collaboration with the Connecticut River Museum, Connecticut DEP, and USGS.
- A station in the upper Thames River at Norwich in collaboration with Connecticut DEP, USGS, and the Thames River Basin Partnership.
- A station in the Pawcatuck River estuary in collaboration with the Connecticut DEP and Pawcatuck Watershed Partnership.
- Additional stations along the north coast of Long Island in collaboration with New York DEC, State University of New York (SUNY), municipalities, and local New York environmental NGOs.

The initial monitoring station deployments under MYSound focused on establishing static stations that would record environmental parameters at a specific location over a long period of time (one or more years). However, there are times when intensive real-time sampling may be required to provide supporting data for a specific research project or investigate the cause of a specific environmental problem (e.g. a Harmful Algal Bloom [HAB] or lobster die-off as experienced in LIS over the past year). To support this application, it would be ideal to have one or more monitoring stations that could be equipped with a tailored suite of sensors and rapidly deployed to provide the required data. An automated water sampling system could be included in the station for QA/QC. These "roving stations" could be deployed on several days' notice and remain on scene for a period of several days to several months. Because of their changing location, they would have to be operated and maintained by UConn. MYSound is exploring this option with EPA, Connecticut DEP, New York DEC, and university researchers interested in conducting studies around the Sound.

An important aspect of the MYSound project is providing a venue and test platforms for new water quality sensors and monitoring systems. As the system matures, MYSound will actively seek opportunities for the stations to serve as a sensor test-bed. MYSound will pursue this in collaboration with EPA and the Office of Naval Research (ONR), their research laboratories, and EPA's Environmental Technology Verification (ETV) Program, a government-industry consortium designed to test and verify the performance of new water monitoring technologies. A program will be investigated whereby prototype sensors would be solicited for testing. These sensors would be screened and pre-tested by EPA, ONR, and the ETV consortium as appropriate. Sensors and systems deemed to be applicable to coastal monitoring, and judged to be fully operational, would be tested in the field on MYSound stations. Federal funding will be sought to cover the cost of testing so that there is added incentive for sensor development companies to participate in the program.

Another important component of the MYSound project from its outset has been education and public outreach. MYSound will seek to expand this component by linking its efforts with those of other academic institutions and public outreach organizations. The project will work with the Bridgeport Regional Vocational Aquaculture School, the Sound School, and Project Oceanology to expand and refine the educational material available on the MYSound Web site. The project will also investigate the possibility of establishing a Long Island Sound topics lecture series that could be accessed through the Web site, as well as developing hands-on tutorials and exercises that use MYSound's real-time data to explain and demonstrate oceanographic and meteorological concepts.

MYSound also plans to intensify its efforts to network with other coastal marine environmental monitoring efforts in the Northeast and around the country and tie into the rapidly forming C-GOOS initiative. MYSound anticipates developing a proposal for an expanded MYSound network under the National Ocean Partnership Program or other major federal coastal monitoring programs. This effort will serve as a prototype for a large estuarine GOOS coastal monitoring component. MYSound plans to formulate this proposal as a joint effort with NOAA and EPA, Connecticut DEP and New York DEC, SUNY at Stonybrook, and several environmental NGOs around the Sound. Ultimately, the goal is to implement a comprehensive Long Island Sound Estuarine Observing System similar to the system established in Chesapeake Bay, and currently under development in the Gulf of Maine.

Finally, MYSound recognizes that to sustain and enhance the project, marketing and proposal writing are as important as equipment maintenance, data dissemination, and QA/QC. MYSound approaches project outreach and development as focused and continuous efforts, not just collateral activities undertaken at the end of each fiscal year. Communications and outreach material are kept up to date and disseminated to potential funding organizations. Pre-proposals and white papers on the project are prepared in advance so that they can be quickly modified and submitted as a proposal if a funding opportunity is identified.

Sustaining a Marine Water Quality Monitoring Network: Key Points and Lessons Learned

- **Sustainability is often a critical issue with regional or local marine environmental monitoring programs, since most programs are initiated with federal funding that provides support for one to five years. After that, the programs must become self-sustaining on a regional or local basis.**
- **The challenge in sustaining the MYSound effort is to develop a stable, ongoing source (or sources) of funding and in-kind support. To this end, MYSound is working to craft a strategic plan which it can promulgate to other agencies and organizations that may be interested in and capable of providing support; facilitate the development of partnerships to strengthen the project; and coordinate the development of a Sustainability Master Plan and specific proposals to obtain future support.**
- **Partnering with other agencies, institutions, and private organizations is the key to success. Partnering brings in fresh ideas and perspectives to the project, increases access to potential funding, and often provides in-kind support that can drastically reduce the need for direct annual funding. Potential MYSound partnerships that can broaden and strengthen the project include tying offshore stations to NOAA PORTS and expanding monitoring into watersheds in collaboration with upstream stakeholders. MYSound has found partnership opportunities through such activities as attending workshops and conferences and becoming involved in the programs of potential partners.**
- **Distributed stewardship provides the most promising approach in sustaining the local inshore and harbor stations. Through this approach, the MYSound project team at UConn will hand off the day-to-day maintenance of the inshore stations to the local partners (or in some cases a coalition of partners), while UConn maintains the MYSound Web site and the offshore (mid-Sound) stations. In addition, partners will seek their own maintenance funding from local stakeholders.**
- **The key to acquiring funding is maintaining a constant awareness of funding opportunities that may become available. This requires constant networking with potential funding agencies and organizations and being persistent in following up on funding leads. Rather than trying to fund the project under one large grant, it is often more feasible and expedient to define the project in several components and seek funding for each separately. This may require modifying the focus of the project somewhat, but this will not detract from the project as long as the overall goals are being met.**
- **Marketing and proposal writing are as important as equipment maintenance, data dissemination, and QA/QC. Project outreach and development must be focused and continuous, and not just collateral activities undertaken at the end of each fiscal year. Communications and outreach material must be kept up to date and disseminated to potential funding organizations. Pre-proposals and white papers on the project should be prepared in advance so that they can be quickly modified and submitted as a proposal if a funding opportunity is identified.**

APPENDIX A: GLOSSARY

A

Acid: A solution that is a proton (H^+) donor and has a pH less than 7 on a scale of 0-14. The lower the pH the greater the acidity of the solution.

Acidity: A measure of how acid a solution may be. A solution with a pH of less than 7.0 is considered acidic. Solutions with a pH of less than 4.5 contain acidity (due to strong inorganic acids), while a solution having a pH greater than 8.3 contains no acidity.

Algae: Simple single-celled, colonial, or multi-celled, aquatic plants. Aquatic algae are (mostly) microscopic plants that contain chlorophyll and grow by photosynthesis, and lack roots and stems (non-vascular), and leaves. They absorb nutrients (carbon dioxide, nitrate, ammonium, phosphate and micronutrients) from the water or sediments, add oxygen to the water, and are usually the major source of organic matter at the base of the food web in water bodies. Freely suspended forms are called *phytoplankton;* forms attached to rocks, stems, twigs, and bottom sediments are called periphyton.

Algal blooms: Excessive growths of algae caused by excessive nutrient loading.

Alkalinity: Acid neutralizing or buffering capacity of water; a measure of the ability of water to resist changes in pH caused by the addition of acids; in natural waters it is due primarily to the presence of bicarbonates, carbonates and to a much lesser extent occasionally borates, silicates, and phosphates. It is expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate) or as microequivalents per liter (ueq/l) where 20 ueq/l = 1 mg/l of $CaCO_3$. A solution having a pH below about 5 contains no alkalinity.

Anoxia: Condition of being without dissolved oxygen (O_2).

Anoxic: Completely lacking in oxygen.

Anthropogenic: Caused by human activity.

Aquaculture: The cultivation of the natural produce of water, such as fish and shellfish.

Attenuation: Decrease.

B

Base: A substance which accepts protons (H^+) and has a pH greater than 7 on a scale of 0-14; also referred to as an alkaline substance.

Basin: Geographic land area draining into a lake or river; also referred to as *drainage basin* or watershed.

Bathymetry: Measurement of the depth of large bodies of water.

Biofouling: The deterioration of instrumentation when it becomes covered with organisms such as bacteria, algae, or fungi.

Biochemical Oxygen Demand (BOD): A measure of the amount of oxygen that organisms would require to decompose organic material in the water column and in chemical oxidation of inorganic matter.
A high BOD is indicative of high levels of pollution.

C

Carbon dioxide: A gas which is colorless and odorless; when dissolved in water it becomes carbonic acid; CO_2 is assimilated by plants for photosynthesis in the “dark” cycles of photosynthesis.

Chlorophyll *a*: A green pigment in phytoplankton that transforms light energy into chemical energy in photosynthesis.

Conductivity: A measure of water's ability to conduct an electrical current based on its ion content. It is a good estimator of the amount of total dissolved solids or total dissolved ions in water.

Convection Currents: Air or water movement caused by changes in density or thermal (temperature) gradients.

D

Decomposition: The breakdown of organic matter by bacteria and fungi.

Density: The mass of a substance or organism per unit volume (kg/cubic meter; grams/liter).

Diffusion: The movement of a substance from an area of high concentration to an area of low concentration. Turbulent diffusion, or mixing, results from atmospheric motions (wind) diffusing water, vapor, heat, and other chemical components by exchanging parcels called eddies between regions in space in apparent random fashion. Molecular diffusion, which operates in stagnant zones, such as at the bottom sediment-water boundary in a deep lake, occurs much, much more slowly and so is important only on a very small scale such as right at the bottom.

Dissolved Oxygen (DO or O_2): The concentration of free (not chemically combined) molecular oxygen (a gas) dissolved in water, usually expressed in milligrams per liter, parts per million, or percent of saturation. Adequate concentrations of dissolved oxygen are necessary for the life of fish and other aquatic organisms and the prevention of offensive odors. DO levels are considered the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life. Levels above 5 milligrams per liter (mg O_2/L) are considered optimal and most fish cannot survive for prolonged periods at levels below 3 mg O_2/L. Levels below 1 mg O_2/L are often referred to as *hypoxic* and when O_2 is totally absent *anoxic* (often called anaerobic which technically means *without air*).

Dissolved Solids Concentration: The total mass of dissolved mineral constituents or chemical compounds in water; they form the residue that remains after evaporation and drying. Often referred to as the *total dissolved solids* (TDS) concentration or dissolved ion concentration. In seawater or brackish water this is approximated by the salinity of the water. All of these parameters are estimated by the electrical conductivity (EC).

E

Ecosystem: All of the interacting organisms in a defined space in association with their interrelated physical and chemical environment.

Estuary: A semi-enclosed coastal body of water that has free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage.

Eutrophication: The process by which a water body is enriched by nutrients (usually phospohorus and nitrogen) which leads to excessive plant growth.

Evaporation: The process of converting liquid to vapor.

F

Food chain: The transfer of food energy from plants through herbivores to carnivores. An example: insect-fish-bear or the sequence of algae being eaten by zooplankton (grazers; herbivores) which in turn are eaten by small fish (planktivores; predators) which are then eaten by larger fish (piscivores; fish eating predators) and eventually by people or other predators (fish-eating birds, mammals, and reptiles).

G

H

Hydrogen: Colorless, odorless and tasteless gas; combines with oxygen to form water.

Hypoxia: Low dissolved oxygen levels.

I

Impervious surfaces: Land surfaces such as roads, parking lots, buildings, etc that prevent rainwater from soaking into the soil. The water increases in velocity causing more erosion; it warms causing potential heat stress for downstream trout; it picks up roadway contaminants; and the loss of vegetation removes a “sink” for dissolved nutrients—plant uptake.

Indicator bacteria: Microorganisms whose presence indicates that fecal contamination has occurred.

Inorganic: Substances of mineral, not carbon origin.

Ion: An electrically charged particle.

J

K

L

Land use: The primary or primary and secondary uses of land, such as cropland, woodland, pastureland, forest, water (lakes, wetlands, streams), etc. The description of a particular land use should convey the dominant character of a geographic area and establish the dominant types of human activities which are prevalent in each region.

M

N

Nonpoint source: Diffuse source of pollutant(s); not discharged from a pipe; associated with land use such as agriculture or contaminated groundwater flow or on-site septic systems.

Nutrient loading: Discharging of nutrients from the watershed (basin) into a receiving water body; expressed usually as mass per unit area per unit time (kg/ha/yr or lbs/acre/year).

O

Organic: Substances which contain carbon atoms and carbon-carbon bonds.

Outliers: Data points that lie outside of the normal range of data. Ideally, outliers must be determined by a statistical test before they can be removed from a data set.

Oxygen: An odorless, colorless gas; combines with hydrogen to form water (H_2O); essential for aerobic respiration.

Oxygen Solubility: The ability of oxygen gas to dissolve into water.

P

Parameter: Whatever it is you measure; a particular physical, chemical, or biological property that is being measured.

Pathogens: Disease-causing organisms.

pH scale: A scale used to determine the alkaline or acidic nature of a substance. The scale ranges from 1-14 with 1 being the most acidic and 14 the most basic. Pure water is neutral with a pH of 7.

Phosphorus: Key nutrient influencing plant growth in lakes. Soluble reactive phosphorus (PO_4^{-3}) is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

Photosynthesis: The process by which green plants convert carbon dioxide (CO_2) dissolved in water to sugars and oxygen using sunlight for energy. Photosynthesis is essential in producing a lake's food base, and is an important source of oxygen for many lakes.

Phytoplankton: Microscopic floating plants, mainly algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.

ppb: Part-per-billion; equivalent to a microgram per liter (ug/l).

ppm: Part-per-million; equivalent to a milligram per liter (mg/l).

Pressure (p): The force exerted per unit area.

Pycnocline: A separation between two layers of different densities.

Q

Quality Assurance/Quality Control (QA/QC): QA/QC procedures are used to ensure that data are accurate, precise, and consistent. QA/QC involves following established rules in the field and in the laboratory to ensure that samples are representative of the water being monitored, free from contamination, and analyzed following standard procedures.

R

S

Salinity: The amount of salts dissolved in water expressed in parts per thousand (ppt).

Sonde: A multiple sensor, fully integrated water quality monitoring instrument.

Stormwater discharge: Precipitation and snowmelt runoff from roadways, parking lots, roof drains that is collected in gutters and drains; a major source of nonpoint source pollution to water bodies.

Stratification: An effect where a substance or material is broken into distinct horizontal layers due to different characteristics such as density or temperature.

Stratified: Separated into distinct layers.

T

Telemetry: The science of automatic measurement and transmission of data by wire, radio, or other methods from remote sources.

Thermocline: An interface where temperature changes rapidly with depth.

Tidal flushing: The net transport for water (and sediments and contaminants) out of an estuary with tidal flow and river flow.

Total Dissolved Solids (TDS): The amount of dissolved substances, such as salts or minerals, in water remaining after evaporating the water and weighing the residue.

Trophic levels: The levels of nourishment within an ecological system (producers, consumers, scavengers, decomposers), describing how energy is transferred within food webs and chains.

Turbidity: A measure of water clarity (degree to which light is blocked because water is muddy or cloudy).

U

V

W

Water column: A conceptual column of water from surface to bottom sediments.

Water density: The ratio of water's mass to its volume; water is the most dense at four degrees Celsius.

Watershed: All land and water areas that drain toward a water body; also called drainage basin or water basin.

X

Y

Z

APPENDIX B: MYSOUND OUTREACH BROCHURE (OUTSIDE)

User Community

- Environmental Managers
- Marine Scientists
- Non-governmental Environmental Organizations
- K-12 and College Educators
- Maritime Transportation Industry
- Swimmers, Sailors, and Beachgoers
- Recreational Anglers and Boaters
- Commercial Fishing and Aquaculture
- Marine Instrumentation Developers

Project Partners

- U.S. EPA Region I
- EPA Long Island Sound Study
- UCONN Department of Marine Sciences
- Connecticut Department of Environmental Protection
- New York City Department of Environmental Protection
- Bridgeport Regional Vocational Aquaculture School
- The Sound School, New Haven
- Save the Sound, Inc.
- Maritime Aquarium at Norwalk
- Mystic Aquarium
- U.S. Coast Guard Academy
- Connecticut Sea Grant
- New York Sea Grant
- Spectrogram Corporation, North Haven
- Coalition to Save Hempstead Harbor

EPA

EPA Region 1

Long Island Sound Study

MYSound

The MYSound Project:
Monitoring the Ecological Health of Long Island Sound

EMPACT Program

U.S. Environmental Protection Agency
U.S. EPA Region I
EPA Long Island Sound Office
University of Connecticut

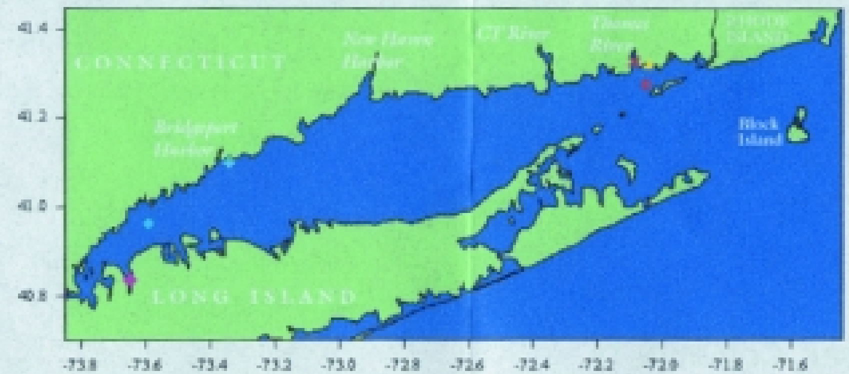
Environmental Monitoring for Public Access and Community Tracking (EMPACT) is an EPA program designed to work with communities to collect, manage and present environmental information. MYSound (Monitoring Your Sound) provides comprehensive, timely water quality data on Long Island Sound, its harbors and estuaries.

APPENDIX B: MYSOUND OUTREACH BROCHURE (INSIDE)

Activities

- Establish a network of marine water quality monitoring stations inshore and offshore of Bridgeport, New Haven and New London harbors
- Collect, analyze and integrate real-time data with other data sources
- Provide the composite data set to users on the World Wide Web in a format that can be assimilated by the user community
- Develop interpretive educational material for curriculum support, particularly on the K-12 level
- Promote public awareness to improve Long Island Sound's water quality and living resources

UConn Department of Marine Sciences **EMPACT**



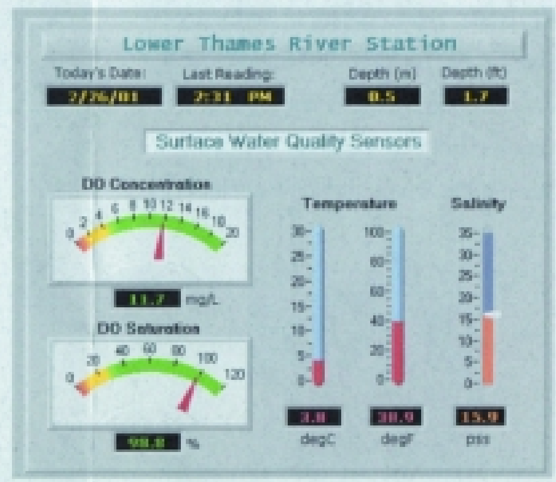
Monitoring Your Sound: www.mysound.uconn.edu

Environmental Parameters

Water Temperature
Conductivity/Salinity
Dissolved Oxygen
Current Speed and Direction
Meteorologic Data

Future Parameters

Nutrients/Nitrate
Chlorophyll A
Surface Hydrocarbons



APPENDIX C: SELECTED E-MAIL MESSAGES FROM MYSOUND USERS COMMENTING ON THE PROJECT WEB SITE

1999

***

This is a great site! Thanks for putting it up. I accessed it because I love the sound...spend my summer vacation on the sound and visit it whenever else I can. Also, I have recently become interested in certain minerals I find in sand deposits near the mouth of the CT river. I was hoping the site would show currents near the mouth of the river. My theory is that the minerals come down the river from somewhere. Knowing how the currents move would help me look for other sites where I could find (or NOT find) the minerals, to confirm my theory. I am not a scientist or a student or anything...just a curious, middle-aged "geology junkie" with a degree in English. Will your site eventually offer this information? If not, do you know of anywhere else I can get this information? Would the DEP have maps? Would NOAA have maps? I am, like, clue-less. Thanks, Katie

***

To Whom it May Concern,
This site is incredible! What a use of technology to transmit real time data about the sound posted in 15 minute intervals. I am a Sound enthusiast and boater and would like a little better information as to how real time data affects water quality. i.e. - An acceptable range of salinity is ### to ###, or O2 should be within a certain range etc.

***

Many thanks for sharing this valuable information. I am a local that fishes in the sound alot and always am interested in wind, water temp, currents(not tides), etc. I will share this great find with my friends.

I was out fishing last Friday and heard a couple of local charter captains chatting. One mentioned he checked out your site and thought it was neat. Just thought you should know.

***

I am a coastal researcher with Mass. Coastal Zone Management and I was very much pleased with your web site. We currently are monitoring via telemetry buoy systems, the lower Taunton River in Massachusetts and will be adding two additional buoys in the Upper Mount Hope Bay region of Narragansett Bay. We would like to get the data out on our web page (www.state.ma.us/czm/) in a manner similar to your format. Is this format available for adapting to our region? It would be nice if similar projects had similar formats. What are the types (or brands) of buoys you are using? sensors? We currently use a Endeco/YSI Environmental Monitoring Module with there sonde units.

Thanks in advance to any of the information you could provide.

2000

***

As a local mariner, it would be helpful to get readings such as wave height and wind speed and direction from your NL Dumping Grounds buoy.**

***

I am helping develop a site that monitors water quality and conditions for the local rivers. I saw your site and was wondering, what did you use to generate the gauges and meters? We want to do something similar and are looking at Macromedia Flash and Generator.

***

I am working on a water quality monitoring project on the Neuse River, and I happened to come across your MySound website, and I particularly liked the graphs you presented on the site.

I was wondering what you were using to graph your data. I know you are using YSI probes, so are you using standard YSI software, or something else? We are using RTDM, a package put out by Campbell, which I am looking to find an alternative for.

Thanks for your help, and I really like the way your site is set up.

***

I am a researcher at UNC at Chapel Hill, and I come up to Connecticut periodically to collect some estuarine animals. I love your MYSOUND website for its real time data on water temperature...and was wondering if you had archived some of that data for the past 3 years. It would help me out tremendously to see it.

***

Excellent site. Any way to access wind speed data for immediately preceding week (or other time period). This would be a useful feature on a continuing basis. The archived data is great but it's from too far back. I would very much like to obtain the hourly wind speed readings for Saturday, May 6 from 12 noon - 6 pm for Avery Point (or lower Thames.)

Thanks.

***

Thank you for the great resource you are providing. I just checked out the page and will definitely use it with my oceanography classes next year. I love the data displays, but was wondering if there is a way to get more data. I would love to be able to easily display seasonal or tidal changes in a single station or across stations. Is this data available? Thank you Mike

***

I am a graduate student at Pace University and I am completing a laboratory experiment to determine Nitrite concentration. I chose 2 locations in CT on the Long Island Sound and I am trying to get some reference information on what is the standard Nitrite(nitrogen) concentration.

Can you provide any assistance? I have been all over the world wide web looking up data and have found nothing. I would appreciate any help you can provide.

2001

***

Hi,
Anyway to put ups some webcams looking at the sound? I see Maine and Maryland have lots of websites showing the coast line. I even found an under water cam located in a lobster pot in Maine!

***

I have been looking at your MySound website, and that is how I found your email address. I am involved in the National Estuarine Research Reserve monitoring project, have been for a number of years. We have a system of YSI 6600 dataloggers that transmit data to a lab computer via a series of 1240 radios, antennas, etc. We have been trying to get someone to help us post this data on a website in real time, similarly to what you have done. The major stumbling block seems to be the type of file that is received by the lab computer. A binary file I believe. So I was wondering if you use the same type of software that we do, to collect and monitor the data and if so, was it difficult to interface it with the Campbell software. Or maybe you could put me in touch with someone who can help me send this effort in the right direction. Currently I am using the DOS version of Ecowatch to actually collect and display the data.

Thanks.

***

I'm a Television Meteorologist for News12 Connecticut in Norwalk and I just wanted to compliment all hands on the awesome MySound site!! I have been searching high and low for real-time local Long Island Sound water temp data to help in formulating my forecasts...... until now that is!!! I happened to find your site through the use of GOOGLE as a search engine! Again great job on not only the site, but the work that goes into maintaining those data collection points!!!

2002

***

Please advise if fish and/or seafood can be eaten from the Long Island Sound. I am especially concerned with lobsters and clams.

Thank you, and a big hug.

***

Hello,
I am doing a science project for school on water pollution. I was going to get samples of water fro different bodies of water, like the Long Island Sound, and set them to a lab to see if the samples contain e-coli. I would like to know before I do this project if you think that I will have a successful project (would I find *e-coli?*).
If you could please e mail me back any information involving this e mail or my topic it would be greatly appreciated.

Thank you

APPENDIX D: CASE STUDIES OF RELATED COASTAL MONITORING PROGRAMS

For the purpose of comparison with the MYSound program, the following short case studies of similar EMPACT programs may be of interest to the reader:

D.1 JEFFERSON PARISH—LOUISIANA PROJECT

Wetland loss along the Louisiana coastal zone is one of the state's most pressing environmental concerns. Although numerous factors have contributed to this loss, perhaps the most significant is the leveeing of the Mississippi River for flood control. Construction of the levy has blocked the river's historic spring overflows and thus impeded the rush of marsh-supporting fresh water, nutrients, and sediment to the coastal zone.

One of the strategies for reversing the recent loss of wetlands in coastal Louisiana is to partially restore some of the natural flow of fresh water into these ecosystems. One such project is the Davis Pond Freshwater Diversion Project, which will divert up to 80,000 gallons per second of river water into the Barataria Bay estuary. Some citizens, however, are concerned that the freshwater diversion will have a negative effect on the estuary. They are concerned about the effect that nutrient-rich river water may have on water quality (perhaps by causing harmful phytoplankton blooms).

The EMPACT project in Jefferson Parish has involved monitoring water quality before and after the fresh water diversion in order to assess its effect. The Jefferson Parish project supplies water quality data to the public nearly as quickly as they are collected. Data collection consists of automated time-series water sampling, manual field sampling of water, and remote sensing using satellites. The automated sampling procedure regularly checks water temperature, dissolved oxygen, conductance, pH, and turbidity. The manual field sampling tests salinity, pH, chlorophyll *a* levels, suspended matter, carbon levels, nutrient levels, and phytoplankton identification. The remote sensing instruments used in the Jefferson Parish project are the NOAA Advanced Very High Resolution Radiometer (AVHRR) and the Orbview-2 SeaWiFS ocean color sensor.

Results are primarily reported to the public through the Jefferson Parish Web site, accessible at *http://www.jeffparish.net/pages/index.cfm?DocID=1430*. The Jefferson Parish outreach strategy also involves other modes of communication, such as brochures, presentations at events, and television. The specific audiences targeted in these outreach efforts include:

- Commercial and recreational users of local bodies of water.
- Residents of communities that could be affected by water diversion (because of the potential for flooding).
- Louisiana citizens concerned about coastal erosion, hypoxia in the Gulf of Mexico, eutrophication, and algal blooms.

D.2 CHESAPEAKE BAY EMPACT PROJECT

The Chesapeake Bay is the largest estuary in the United States and one of the most productive in the world. Scientific and estuarine research conducted on the Bay between 1976 and 1983 pinpointed three problems requiring immediate attention: oversupply of nutrients, dwindling underwater Bay grasses, and toxic pollution. These findings led to the development of the Chesapeake Bay Monitoring Program in 1984, which monitors the overall health of the Bay through the collection of comprehensive data on physical, chemical, and biological characteristics throughout the year in the main-stem of the Bay and tributaries.

In conjunction with the Monitoring Program, the Chesapeake Bay EMPACT project was set up to provide timely information regarding water quality and its relationship to toxic dinoflagellate *(Pfiesteria piscicida)* outbreaks on the Pocomoke River. This project was meant to supplement data collected as part of the comprehensive *Pfiesteria* monitoring program that is integrated with water and living resource quality assessments through the broader Chesapeake Bay Monitoring Program. The EMPACT project enables people to learn more about Maryland's waterways and keep up-to-date with water quality and *Pfiesteria* issues. In 2000, the project was expanded to provide more comprehensive information about how water and habitat quality affect living resources.

After project staff installed YSI 6600 probes at monitoring locations, the following water quality data could be gathered in an ongoing, automated fashion: dissolved oxygen, fluorescence, pH, salinity, turbidity, and water temperature. Project staff manually measure the following water qualities parameters during weekly maintenance visits: chlorophyll *a*, nutrient levels (carbon, nitrogen, nitrates, phosphorus, and ammonium), and total suspended solids.

So that they may be accessed on the project Web site, monitoring data were first processed with various Visual Basic modules that format them properly and store them in a database. The project Web site allowed visitors to specify their own data parameters when viewing these data. The Web site was developed with two software applications that help produce user-defined graphs quickly. The first application, a Web application development tool, is called *Cold Fusion* (developed by Macromedia, Inc.). The second application, an add-on graphics server engine, is called *CFXGraphicsServer* (developed by TeraTech, Inc.).

The project was designed to enable scientists, stakeholders, and the general public to gain a greater understanding of how the tributaries of the Chesapeake Bay function. For example, the relationship between storm events and freshwater flows to the Pocomoke River is poorly understood because of its altered watershed hydrology. This is an important process to understand because of the likely linkage between runoff, nutrient loading, and *Pfiesteria* populations.

As of 2002, the Chesapeake Bay EMPACT program ended and was replaced with a Continuous Monitoring Program, which continues and extends many of the same efforts in Maryland's Chesapeake Bay and Atlantic Coastal Bays. The Continuous Monitoring Web site is located at *http://mddnr.chesapeakebay.net/newmontech/contmon/index.cfm*.

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