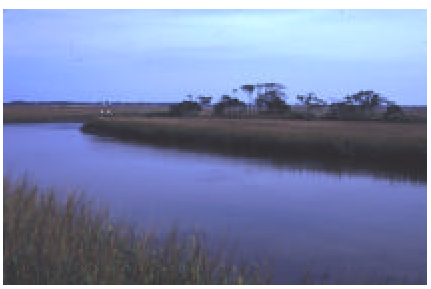
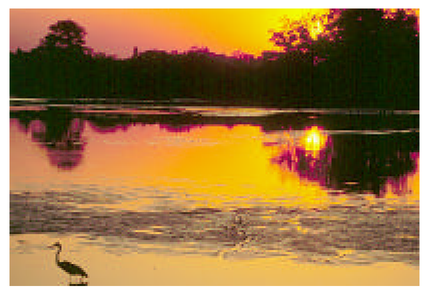
Polluted Runoff: Lessons Learned from the National Estuarine Research Reserve System





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National Ocean Service
Office of Ocean and Coastal Resource Management
Estuarine Reserves Division

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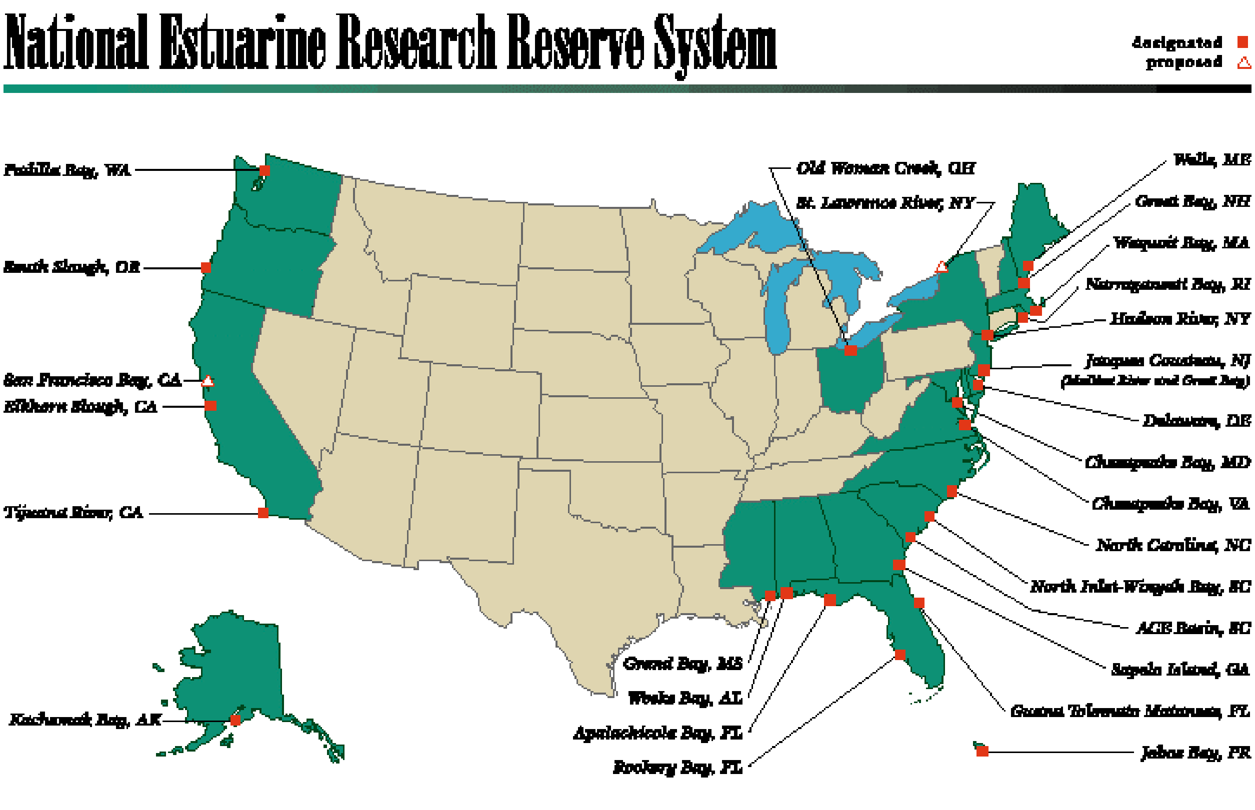
I. NERRS and the Clean Water Action Plan

The National Estuarine Research Reserve System is a network of 25 protected areas established to improve the health of the nation's estuaries and coastal habitats by developing and providing information that promotes informed resource management. The reserve system is a partnership between the National Oceanic and Atmospheric Administration and the coastal states. NOAA sets national priorities while various state agencies manage daily reserve operations. Through integrated research and education, reserves help communities develop strategies to deal successfully with coastal resource issues, such as non-point source pollution.



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In 1998, the National Clean Water Action Plan was assembled to provide a blueprint for coordinated action by local, state, tribal and federal governments to protect and restore the nation's water resources. The plan outlines four key tools to be used to achieve its goals—

- a watershed approach,
- strong federal and state standards,
- natural resource stewardship and
- informed citizens and officials.

The plan identifies a multitude of key actions that are to be undertaken and assigns agencies to those actions. The plan specifically identifies the reserve system as responsible for a program that will "broadly share lessons learned" from the activities of the system. This item is part of a larger action addressing the development and support of state, tribal and local governments and organizations to provide technical assistance and information to local decision makers in coastal areas.

Additionally, the plan identifies the development of a "multi-agency Coastal Research Strategy," to be completed in 1999, and a plan for a coordinated monitoring of coastal waters (2000). These efforts will lead to a comprehensive report to the public on the condition of the nation's coastal waters. Reserve system activities will contribute to the information base for the strategy, and current and future activities have an ongoing role to play in research and monitoring.

With more than 20 years of research on estuarine issues, the reserve system is a long-standing contributor to the science of clean water. Research conducted in the reserves has contributed to the nation's ability to protect and restore water quality. In addition, education programs focus on complex environmental issues for a wide variety of audiences. The purpose of this report is to compile examples of these activities and experiences to allow their broad distribution and application.

II. NERRS Functions and Capabilities

A. Research

The reserve system provides an integrated program of research, education and resource stewardship. Since the designation of the first reserve 25 years ago, a significant amount of research on water quality issues has been fostered in response to the priorities of each reserve. In addition, system wide programs have been established.

1. System Wide Monitoring Program

The System Wide Monitoring Program (SWMP), initiated in 1995, provides standardized information on national estuarine environmental trends. The program was designed to fulfill two major goals—1) to support state-specific nonpoint source pollution control programs by establishing local networks of continuous water quality monitoring stations in representative protected estuarine ecosystems and 2) to develop a national database on environmental conditions in the reserves.

2. Graduate Research Fellowship Program

The Graduate Research Fellowship program was initiated in 1997. This program funds high quality research focused on improving coastal zone management and provides graduate students with hands-on training in conducting ecological monitoring. Research projects address coastal management issues that relate to—

- nonpoint source pollution,
- estuarine ecosystem restoration,
- biodiversity and effects of invasive species,
- sustaining estuarine ecosystems or
- socioeconomics of estuarine ecosystem management.

3. Cooperative Institute for Coastal and Estuarine Environmental Technology

The Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) is a national center for the development and application of innovative environmental technologies for monitoring, management and the prevention of contamination in estuaries and coastal waters. All CICEET projects must be conducted in one of the 25 National Estuarine Research Reserves. By utilizing the reserves as platforms for estuarine research, CICEET develops new environmental technologies and provides key users and decision makers with an opportunity to apply innovative techniques.

B. Education

The reserve system's national educational effort targets adult audiences who directly or indirectly make decisions that affect the nation's coastal areas. The Coastal Decision Maker Workshop series is the cornerstone of the national education effort. The program provides information about local and regional coastal resource issues to citizens, landowners, interest groups and government officials involved in coastal management.

In addition to Coastal Decision Maker Workshops, most reserves have strong K-12 programs, providing hands on experiences for students as well as teacher training and curricula that facilitate classroom involvement in estuarine issues.

Reserves also offer recreational education opportunities through interpretive facilities open to the public and through active participation programs that assist the reserves in carrying out their missions and duties.

C. Stewardship

Reserves are protected areas that promote coastal stewardship. However, federal designation as a National Estuarine Research Reserve does not impose additional land use restrictions. Many reserves provide for public recreational use, in addition to research and educational resources for local communities. These uses require that reserves establish and maintain facilities to accommodate them, such as interpretive centers, classrooms, parking and restrooms. Some reserves continue to conduct or allow agriculture, aquaculture and other pre-existing uses as a part of the management of the reserve. This has offered an opportunity for applied research. Techniques for addressing issues such as runoff and wastewater management, erosion management, wetlands and watershed restoration and agricultural practices are being investigated. These techniques are applied to land stewardship problems related to past and present human uses in a manner that maintains and enhances the natural character, resources and ecology of the reserves in the interest of long-term research.

III. The "Lessons Learned" by Reserves about Water Quality

Significant research has been conducted at National Estuarine Research Reserves into the sources, character and impacts of polluted runoff and into potential measures to control runoff and/or mitigate for its impacts. Estuaries are natural collectors of everything that moves with water. Because of this fact, estuaries are the product of and reflect the environmental conditions of the watersheds that feed into them.

It is a long known fact that the qualitative characteristics of water are directly impacted by human activities. However, prior to the 1970's the effects on the waters of general human use of the land were either—

- not recognized as having an adverse impact on water quality,
- below detectable levels with the technology available or
- masked by the impacts of large-scale point source discharges, such as sewers and factory waste disposal.

When Congress set an objective "to restore and maintain the chemical, physical and biological integrity of the Nation's waters" (33 USC, Sec 1251(a)) it was widely believed that the water quality problem facing the nation would be solved by controlling the highly visible and direct (point) sources of pollution. As these point sources came under control, the contribution of "nonpoint" sources became increasingly evident.

It is also noteworthy that the 1970 population of the United States was just over 200 million people, while today it approaches 280 million. This means that land is used more intensively, whether it is for the production of food and fiber; for the location of homes, business and industry; or for recreational activities.

“Pollution” is sometimes difficult to define. Clearly, there are specific chemicals that, if discharged to the water, have a direct adverse effect on aquatic life. Other substances may occur naturally but have adverse consequences as a result of changes in concentration, or quantity, within an aquatic system. Still others are not notably harmful to the aquatic system, but render water, fish or shellfish unfit for human use. While some of the effects of nonpoint pollution on the nation’s waters are evident, the specific causes and potential cures are much more difficult to discern. Sometimes, the effects are not readily apparent, but over time, have significant impact on the health of the receiving water body or its uses. Carefully conducted, scientific research is the key to understanding the problems and finding viable solutions. The reserves have been conducting research into these issues for many years.

A. Findings on Sources of Runoff Pollution

1. Residential and Recreational Uses

With the growth in the nation’s population, residential development has increased significantly, especially in coastal areas. Often, new residential developments use septic systems for sewage disposal. On a national level, 38 percent of new residential developments use septic systems, and coastal and recreational development septic system usage is probably higher. A conventionally designed septic system functions by treating and dispersing wastewater through a subsurface drainfield. The performance of the system depends on the overall climate, seasonal weather, soil conditions or the use level of the system. Under ideal circumstances, the wastewater is evaporated and the nutrients and bacteria carried by the water are assimilated by the soil. In many circumstances, septic system flows, when combined with background soil moisture, exceed evaporation rates. When this occurs, wastewater percolates through the soil and becomes part of the ground water, flows directly to nearby surface water or flows to the surface and runs to surface water.

Research conducted at Waquoit Bay National Estuarine Research Reserve, in Massachusetts, has established a correlation between an increase in residential development using septic systems for sewage disposal in the watershed of the bay and an increase in nitrogen in the bay. The nitrogen transported to the bay was traced to groundwater and surface water runoff. Significant differences in nitrogen were found in areas with more residential development on the shoreline and in the immediate watershed. (9,16,17)

It has also been demonstrated that septic systems are one source of fecal coliform bacteria in estuarine waters in research conducted at the Chesapeake Bay–Virginia National Estuarine Research Reserve as well as other sites. (23)

2. Agricultural and Rural Land Uses

Modern agriculture has produced significantly greater crop yields through the application of nutrients and pesticides to farmlands. While this is of broad benefit to the nation in terms of food supply, an unintended secondary consequence is the transmission of these materials to surface and ground waters. Research conducted at Old Woman Creek National Estuarine Research Reserve, in Ohio, monitored water in the estuary for the presence of specific agricultural nutrients and pesticides. The study established that following storm events through the spring and summer months, concentrations of specific nutrients and herbicides present in the estuary increased. The increase was most dramatic following the first storm after spring planting. Some storm events were of sufficient strength to flush through the estuary into Lake Erie. Smaller storms were essentially contained by the estuary with the result that the nutrients and herbicides were also held in the estuary. (1)

Modern agriculture also favors confined animal feeding operations over dispersed grazing for both dairy and meat production. These facilities produce significant quantities of waste, which if not properly managed, can be carried by runoff. The animal waste is very high in both nutrients and bacteria. Research at Padilla Bay National Estuarine Research Reserve, in Washington state, indicated that water flowing from areas of the watershed with dairy operations had high concentrations of fecal coliforms and nutrients as well as turbidity. (17)

3. Urban and Industrial Findings

Substantial progress has been made in controlling major sources of pollution in urban areas, including transportation and industrial uses. While old sources have been controlled and new sources are closely regulated, the effects of past practices linger in the soils and on the streets that are in and around our urban areas. The effects of relatively minor sources are amplified by rapid urban area expansion. Over time, these by-products of urban life are transported to water bodies and accumulate.

Narragansett Bay, Rhode Island, was one of the first areas in the nation to feel the effects of industrialization. At the Narragansett Bay National Estuarine Research Reserve, studies were conducted to determine the historic deposition of certain heavy metals in the high and low marshes around Prudence Island. Analysis of this data indicates a direct correlation of the accumulation of copper, cadmium, zinc, silver and lead with the increase in population and industry in the watershed. Accumulation in the high marshes is less and appears to be primarily the result of direct deposition from the atmosphere while accumulation in the low marshes was both waterborne and air deposition. Uncharacteristic peaks in the metals in the low marshes indicate that they are re-mobilized by major storm events. (2)

Narragansett Bay Salt Marsh

A later study at the Narragansett Bay Reserve indicated that polycyclic aromatic hydrocarbons (PAHs) and polyclorinated biphenyls (PCBs) were being carried through the atmosphere and either deposited in rainfall directly on the site or deposited on the watershed and then transported to the estuary by runoff. These substances are by-products of transportation and a variety of industrial processes. (19, 21)

This research also found that atmospheric transmission accounted for 13 to 18 percent of the total input of nutrients (nitrogen compounds) to the bay and its watershed. Atmospheric nitrogen compounds are a by-product of combustion of fossil fuels and of other industrial processes. (21)

4. Erosion and Sedimentation Findings

Perhaps the most ubiquitous type of nonpoint pollutant is sediment. Erosion of the land's surface is a natural process. Wind and water have shaped and reshaped the Earth's surface from its beginning. In most circumstances, naturally occurring erosion is either a relatively slow process inhibited by the composition of the soils and the vegetative cover or is the result of relatively infrequent catastrophic events, such as earthquakes, landslides, floods or fire. Humans have altered the time scale of soil erosion significantly. Essentially, all land uses have an effect on erosion. In urban and suburban areas, substantial areas of hard surfaces that inhibit water infiltration characterize commercial, industrial and residential landscapes. Rainwater runoff from these areas is typically channeled to ditches and storm drains and is conveyed directly to streams. In areas without hard surfaces, much of the rain percolates into the soil and is stored and released gradually over time. Storm drains and ditches fed by hard surfaces direct a significantly increased volume of water to the streams in a short period of time following a rainfall event. This causes the streambanks to be scoured of loose material to a much greater extent than occurs with natural ground cover. It often means that during dry periods, the smaller streams dry out more quickly, inhibiting the growth of streamside vegetation that would reduce bank erosion. Construction and mining sites remove vegetation and loosen and move the soil, exposing it to being washed or blown away at a much greater rate than would otherwise occur. Some agricultural and forestry practices purposefully loosen the soil over large areas, allowing it to be moved by runoff and wind.

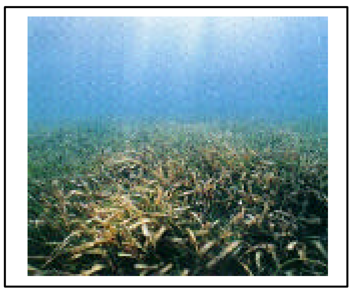
Research at several reserves has correlated sediment impacts with human activity. Core sample studies have indicated that deposition of sediment increased with the increased human land uses, and real time monitoring of water quality parameters has correlated sediment transport and turbidity with human activities in the watershed. (2,4,5,23,25)

These findings demonstrate the relationship between human activities on the land and direct and indirect effects on the character of water. As a general matter, nutrients, bacteriological contamination, heavy metals, pesticides and sediment can be traced back to sources on the land and the character of land uses in a watershed will be indicative of the character of contaminants found in rivers, streams and estuaries that drain and collect runoff from the land.

B. Impacts of Runoff Pollution

The environment and productivity of a water body is based on a particular balance of characteristics. The precise balance varies with the weather and seasons, but occurs within a range dictated by the climate and attributes of the watershed. As noted in the previous section, human activities in the watershed change the character of the watershed, and thereby the character of the water bodies within the watershed. Initially, the change in the productivity or character of the water body may be minor and without notable effect. However, over time and with the increasing intensity of human uses, the balance is altered and the environment is affected. This is particularly true of substances such as nutrients, bacteria and sediments that are naturally occurring and necessary components of aquatic systems.

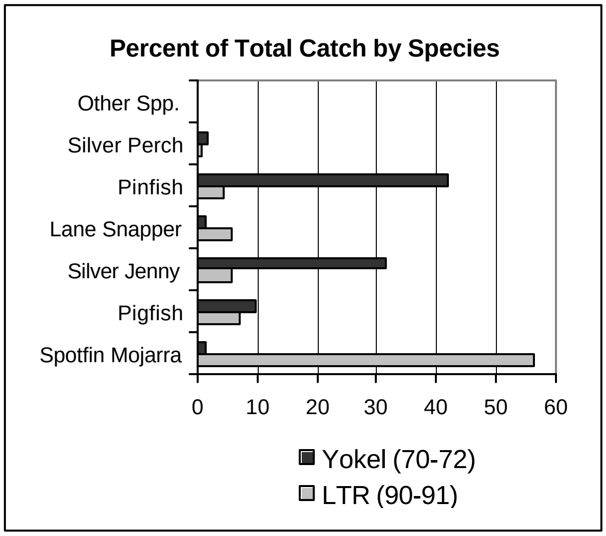
1. Seagrass as an Indicator



Seagrass grows in estuaries in intertidal and shallow subtidal areas where the bottom is sandy or muddy and sunlight penetrates sufficiently to support the plant's needs. Studies of healthy seagrass beds have demonstrated that they are a vital component of a healthy estuary because these beds provide food and shelter to a wide variety of lifeforms. Studies at Waquoit Bay Reserve, in Massachusetts; Rookery Bay Reserve, in Florida; and Padilla Bay Reserve, in Washington state, revealed that a wide variety of fish and shellfish depend on seagrasses at various life stages. Many of these species are part of food chains that extend to the ocean. Thus, the presence and productivity of seagrass in estuaries contributes to, and may be a critical link for, the health of offshore populations of fish and shellfish as well as the more immediate estuarine populations. (3,7,8,10,13,14)

In a study conducted at several National Estuarine Research Reserves along the East Coast, declining size and density of eelgrass beds has been documented. Eelgrass is a specific variety of seagrass. The study demonstrated that this trend was at least partly attributable to an increase in turbidity, resulting from sediment runoff to estuaries, which reduces light transmission through the water. Like terrestrial plants, eelgrass requires light to grow and be healthy. Increased algae growth has also been associated with eelgrass decline. Algae are normally part of the system, occupying a unique niche because of their ability to draw nutrients directly from the water. Algal growth is regulated, in part, by the availability of nutrients. The studies demonstrated that increased algae growth was due to increased concentrations of nutrients in the water, essentially, fertilizing the algae. Thick mats of algae developed, blocking light to the eelgrass. The study also determined that disease was a major contributor to eelgrass decline. The susceptibility of eelgrass to disease was greatly increased where lower light levels created greater stress on the plants. (12,15,18)

In another study at Waquoit Bay Reserve, in Massachusetts, rapid growth of algae in response to increased nutrients in the water also affects fish. Algae use oxygen from the water as it grows. The rapid growth of algae led to the consumption of available oxygen, which resulted in high mortality rates in fish and shellfish that also depend on the oxygen in the water. (16)



At Rookery Bay Reserve, in Florida, monitoring of fish species in the early 1970's and again in the early 1990's showed a sharp decline the Pinfish population. This decline was in directly related to the decline of seagrass beds resulting from changes in upland land use and water management practices. At the same time the Spotted Mojarra population dramatically increased. Spotted Mojarra are a species typically associated with sandy and muddy bottom areas.

2. A Coral Reef Example of Impacts of Sedimentation

A study of the coral reefs at Jobos Bay Reserve, in Puerto Rico, indicates that sedimentation has a devastating impact on the coral. Rapid agricultural and residential development in the reserve's watershed led to a dramatic increase in sediment being transported to the estuary. The first impact of the sediment identified in the study was reduced light availability to the coral due to the suspended sediment, also known as turbidity. Turbidity was found to reduce the area covered by coral and the diversity of coral on the reef because it reduces light penetration through the water and thus, the water depth in which some corals can grow. The second impact identified was that as the sediment settles out of the water, it covers the reef, killing certain corals. Finally, as the sediment spreads, areas for new colonization are reduced because the sediment is not a suitable substrate for coral attachment. Over a relative short period of time the extent of the reef was reduced from 40 percent to 3 percent of the study area, and the diversity of the reef was reduced from twenty species to less than five. (6)

3. Other Impacts

Other impacts of runoff pollution affect the use of an estuary without necessarily adversely affecting its productivity. For example, concentrations of bacteria from human waste can render shellfish unfit for human consumption without necessarily changing the basic character of the estuary or reducing shellfish populations.

Chemical contaminants may not have direct consequences but nonetheless, adversely impact the health of the estuary and human uses of it. A study of mercury accumulation conducted at Old Woman Creek Reserve, in Ohio, found that while levels of mercury in the water and sediment were well below criteria for contaminated sites, the mercury accumulated through the food chain. Animals with a long life span and near the top of the food chain, like catfish and great blue heron, had significant accumulations of mercury. (11)

C. Findings on Restoration, Remediation and Management

Having recognized that human activity on the land may negatively impact important aquatic resources, we have a choice. We can accept the loss of resources or we can find ways to manage our activities so that the negative consequences are eliminated or minimized. In adopting the Clean Water Act, the nation made the choice that we would not accept the losses. Point sources of pollution have been substantially controlled by the application of technology to waste water from factories and sewage treatment facilities to assure that whatever is discharged is clean. Polluted rainwater runoff presents a whole range of new problems. Each watershed and each property presents a unique set of circumstances. The changes required to achieve clean water involve some change from essentially everyone living in the watershed. Research conducted within the reserve system has looked at issues involved in land management techniques that reduce or eliminate the flow of pollutants from the land.

1. Agricultural Land Management

The Padilla Bay National Estuarine Research Reserve, in Washington state, encompasses a shallow estuary, cut off from the Skagit River, which formed it. The estuary receives much of its freshwater from a relatively small watershed of residential, industrial, timber and agricultural lands. Surface water enters the bay through a series of sloughs and ditches that drain the flat, low-elevation farmland, which was diked in the late 1800s. Not only is Padilla Bay bordered by drained, diked cropland to the south and east, but also more than half of its 23,000-acre watershed is in high-intensity, row crop agriculture. Agriculture is a major industry in the fertile Skagit River delta. Researchers at Padilla Bay Reserve are interested in the effects of agricultural practices on water quality and ecosystem health in the bay, and hope to address long-term solutions to these problems using the reserve and adjacent farmland as a research site.

Padilla Bay Reserve is conducting a demonstration project designed to test agricultural conservation practices in a real-life laboratory. In 1993, a study was commissioned by the reserve to investigate the feasibility of a research/education program centered on a demonstration farm. The farm was purchased by the reserve in 1994, and Washington State University conducted the study that evaluated the environmental issues associated with commercial agriculture and proposed problem-solving strategies and educational methods. This new Padilla Demonstration Farm focuses on the causes and effects of agricultural nonpoint pollution. It is an ideal site for research and education on this issue because it is representative of the typical reclaimed tidelands of the delta and it is highly visible to the public. The farmers continue to farm, but do so in conjunction with federal, state and local water quality activities. Leading farmers from the watershed and adjacent areas participate in planning the practices to be demonstrated or tested on the farm and help interpret and assess the results and feasibility. The participation of these farmers hastens the transfer of lessons learned on the Padilla Demonstration Farm to adoption on commercial farms in the area.

The reserve initially approached the project from the standpoint of water quality and estuarine resource management. However, the list of issues now includes water quantity, residential use of hazardous products, nonpoint source pollution from row crop agriculture, forestry practices, farmland protection and on-site impacts of nutrient loading, pesticide use and drainage practices. Recent projects have focused on winter farming practices that may reduce movement of sediments from the farms to the drainage ditches, sloughs and Padilla Bay.

Current and future work on the Padilla Bay demonstration farm includes establishment of sites for annual water quality and quantity measurement both on- and off-site; development of a hydrologic model and design solutions to address drainage impacts on the demonstration farm and surrounding farmlands; establishment of conservation practices on the demonstration farm, including use of cover crops and buffer zones; and development of promotional/educational information about the demonstration farm for presentation to the public and special interest groups.

Old Woman Creek National Estuarine Research Reserve, in Ohio, is actively involved with local landowners and resource managers in precision farming and stream bank stabilization projects to reduce nonpoint source pollution of surface and groundwater. The Erie Soil and Water Conservation District assists with implementation of the precision farming demonstration project. The project introduced local farmers to the rapidly evolving technology and equipment associated with precision farming. In addition, farmers received information and data from soil test results enabling them to reduce pollution of local waterways by using less chemicals on crop fields.

Ten farmers participated in the project, allowing their fields to be gridded, sampled, and mapped. Using global positioning equipment to gather local data, field staff collected soil samples from gridded fields at a density of one sample per three-acre plot. Soils data collection and mapping were completed for 750 acres of farmland in two consecutive years. Fertility maps for each field were generated and included analysis of organic matter, phosphorus, potassium, magnesium, calcium, pH and other elements. This information is used by farmers to develop customized chemical application plans for each field resulting in decreased polluted runoff from those fields into area waterways.

As a result of this demonstration project, several farmers purchased equipment, software or precision farming services from local dealers. Information is used to prescribe new seed and chemical applications for plots. The reserve uses its ongoing long-term water quality monitoring program to measure the effectiveness of precision farming and other best management practices. Improved water quality and reduced turbidity resulted from precision farming in Old Woman Creek.

In addition, the anchoring of evergreen trees horizontally along 350 feet of eroding stream banks is allowing silt and sand to be deposited along stream banks. Deposited material provides a source of seeds for trees and other plants, whose roots further stabilize banks and provide habitat for fish and wildlife.

Precision farming has allowed farmers in the United States to reduce their application of nitrogen fertilizer and save money without decreasing yield. Additionally, buffer strips stabilized stream banks and reduced soil erosion. The processes of precision farming and stream bank stabilization hold great promise for reducing polluted runoff from fields.

The Elkhorn Slough National Estuarine Research Reserve, in California, is located in a rich agricultural region that is hilly and has very sandy soils. As a result, the Elkhorn Slough suffers from two primary threats—high nutrient input entering the watershed from agricultural runoff and erosion on the steep, sandy upland slopes surrounding the watershed. The reserve, in cooperation with The Nature Conservancy and the Monterey County Agricultural Land Trust, purchased Azevedo Ranch with the intention of conducting research on sustainable agricultural practices.

Research studies on the East Coast show that vegetative buffer strips are effective at protecting water quality, but similar research is rare on the West Coast. The reserve, in cooperation with the University of California Santa Cruz, conducts research to determine whether native perennial grasses serve to restore native plant and animal diversity while simultaneously capturing both sediment and nutrients from adjacent conventional row-cropped agriculture. Approximately 26 percent of the Elkhorn Slough watershed is agricultural land with strawberries being the dominant product.

Buffer strips bordering Elkhorn Slough and draining directly to Monterey Bay within the Monterey Bay National Marine Sanctuary received one of three treatments—annual non-native grasses, perennial native grasses or an unseeded treatment of weedy volunteers. Sediment movement is measured as part of an erosion study, and nitrogen and phosphorus in soil, surface water, soil water, groundwater and vegetation are quantified. Researchers also looked at the mechanisms and processes involved in nitrogen transformation to understand how it changes and where it goes.

Preliminary results from the erosion study indicate that annual treatment was most effective in preventing erosion in the first year, whereas perennial grasses were more effective in the second and third years. Results from the groundwater study indicate a significant decrease in nitrogen concentration with an increase in buffer strip length. (26)

To promote implementation of buffer strips as a management strategy, it is clear that policy makers, growers, and other decision-makers in the region needed economic data. An extensive economic analysis was conducted to evaluate the costs and benefits of this strategy. The benefit to society by preventing environmental degradation was defined and quantified. Researchers are now working with the reserve and the Natural Resources Conservation District to build collaborations with growers in the watershed.

2. Residential and Commercial Land Management

The most prevalent management issue for Waquoit Bay National Estuarine Research Reserve, in Massachusetts, and similar shallow coastal embayments along the northern Atlantic Coast is an increase in nitrogen inputs from human activities in the watershed. Research at the reserve and elsewhere shows that residential and commercial development combined with highly permeable sandy soils increase the amount of nitrogen in the ground water and ultimately in coastal waters. In Waquoit Bay, these nutrients have led to increased growth of algae and plankton which leads to reduced concentrations of dissolved oxygen during certain times of the year when the algae and plankton growth is greatest. This results in reduced habitat quality for other plants and animals that had previously used the bay and thus reducing the number and diversity of plants and animals in the bay. The principal sources of nitrogen are fertilizers, acid rain and septic systems. Research showed that conventional septic systems contribute a significant percentage of the nitrogen in Waquoit Bay.

In 1991, reserve staff began investigating ways to reduce nitrogen input from septic tanks. The Massachusetts State health code, which regulates on-site wastewater treatment systems, at that time, discouraged approaches other than conventional tank and leach field on-site treatment. Reserve staff found that other states, however, allowed alternative systems. In 1992, the reserve held a conference that brought together Massachusetts state and local regulatory officials and officials from states that permitted alternative denitrifying systems, to examine the pros and cons of their use.

Following the conference, the statewide Ad Hoc Task Force for Decentralized Wastewater Treatment was created to explore land use concerns, financial challenges, technological problems and management approaches.

In late 1992, the reserve was designated as one of seven sites in the National On-site Demonstration Project (NODP) through EPA's Small Flows Clearinghouse. The purpose of NODP is to demonstrate and promote the use of on-site wastewater management programs as available alternatives to full-scale, centralized sewage systems for environmentally sensitive areas and small communities. The primary objective is to install proven innovative on-site systems in states that may not currently permit these designs in order to evaluate the appropriateness, effectiveness, and economy of their use. An additional objective is to educate communities about the management of on-site systems.

The Waquoit Bay Reserve held another conference in 1995 on the subject of managing small scale and alternative onsite wastewater systems. Since then a series of workshops have been held with attendance by local engineers, town and state officials and citizen activists.

The reserve continues to work to minimize nitrogen loading to coastal embayments. It is hoped that the demonstration projects, materials, and meetings will help others reduce the impacts of land use on their coastal resources.

3. Restoration Strategies

While most of the nations aquatic systems have been impacted by pollution, we know that the systems are resilient and with care, can be restored. The reserves have conducted research on restoration strategies.

At Elkhorn Slough National Estuarine Research Reserve, two hundred acres of wetlands that had been diked for agricultural use in the past were returned to tidal action. The land formerly had been used for pasturing dairy cattle for more than 40 years during which time the land had subsided up to three feet below the level of the adjacent marsh areas. Dikes were opened and channels excavated with the excess materials shaped into peninsulas and islands to provide a variety of elevations. Within two years, the wildlife species found on the site were comparable to those on adjacent marshes and colonization by marsh vegetation was occurring.

At South Slough Reserve, in Oregon, the Winchester Tidelands area historically consisted of highly productive estuarine channels, mudflats and salt marshes. These tidelands were diked and drained near the turn of the century for agricultural purposes. By the late 1960's agricultural interest in the area had greatly diminished, leaving the Winchester Tidelands fallow. Without constant maintenance of tidal gates and drainage culverts, limited tidal flooding began to creep back into the former tidal wetlands.

In 1992, South Slough Reserve staff worked with an advisory group consisting of nationally recognized experts in the fields of habitat restoration, estuarine ecology, hydrology, botany, and fisheries. The purpose of the group was to develop a plan to restore full estuarine habitat function to the Winchester Tidelands. The resulting Winchester Tidelands Restoration Project (WTRP) is designed to restore tidal wetland features that function to benefit anadromous fish, such as the regionally threatened coho salmon and cutthroat trout. Restored wetland features that benefit these fish include complex tide channels, salt marsh plant communities and freshwater stream channels. These areas provide places of refuge, food sources and nursery grounds.

During Phase I of the WTRP, restoration work was conducted at two sites within the Winchester Tidelands, both of which had experienced significant subsidence and ditch erosion. Portions of the agriculture dikes were removed, and the resulting material was redistributed over the marsh surface to re-establish the site's original elevations, tidal flushing, and tidal and freshwater channels utilized by salmon and other fish populations. All restored sites were monitored before and after tidal flushing was introduced to measure indicators of healthy marsh ecosystems, such as water quality, abundance of marsh grasses and fish species, and sedimentation and erosion rates.

The WTRP is now in its second phase. The ecological functions of four wetland sites are being restored. The resulting changes in productivity are being quantified and described, and experimental plots are being designed to examine different techniques for developing tidal channel habitat for salmon and other anadromous fish.


Winchester Tidelands Restoration Site

The WTRP is providing valuable information on the environmental benefits of restored wetlands that will aid regulators in estimating the value of wetland mitigation projects. Research conducted by scientists at the South Slough Reserve is also enhancing habitat for salmon and other depleted fisheries in the Pacific Northwest.

IV. How does NERRS "broadly share" these lessons?

Each site within the National Estuarine Research Reserve System is charged with developing a program that will link research results to better coastal management through education and outreach. The Coastal Zone Management Act calls for reserves to establish an education program that will "enhance public awareness and understanding of estuarine areas and provide suitable opportunities for public education and interpretation." The program's education and outreach programs provide a connection between the research and monitoring efforts and the decision makers, resource managers and users, educators and students and the general public that can apply the lessons learned now and in the future.

Each reserve's educational program is locally tailored to address issues of interest and concern in their vicinity and region. Because of the importance of water quality in estuaries, topics such as watershed management and nonpoint pollution are addressed by many of the programs. The programs also focus on increasing understanding of the basic functions and processes of estuaries and helping audiences to understand how everyday activities may impact their estuaries.

A. Coastal Decision Maker Workshops

The reserve system has developed a program to conduct workshops for people involved in the management of coastal areas. The program was funded as a system-wide effort in 1995. It grew out of the recognition that resource managers and users, community leaders, regulators, planners and consultants make decisions that effect coastal resources every day. These people are faced with complex, political, economic and scientific issues. The workshops provide science-based, up-to-date information on coastal management issues and options. They also offer an opportunity to discuss the issues outside of the often-polarized process associated with individual programs and projects.

Specific topics for the workshops are selected by each reserve, often in consultation with their state Coastal Management Program. Topic selection is based on needs assessments of target groups, current and emerging issues, availability of appropriate resource speakers and the ability of the reserve to demonstrate field implications related to the issue.

To date, the workshops have addressed a wide variety of issues including watershed management, shoreline protection, soil erosion processes, alternative wastewater treatment, public and private property rights, storm water management, groundwater and hydrology, protection of shellfish areas, nonpoint source pollution, nitrogen loading in coastal embayments and many others. Anecdotal information collected from participants indicates that information obtained in the workshops is valued, is used in decision making and has led to decisions that better protect coastal resources.

B. Estuary Net

Estuary-Net is a Web-based estuarine science education project that was developed by the 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 programs and the reserves to solve nonpoint source pollution problems in estuaries and their watersheds.

The Estuary-Net project supports partnerships that work to solve nonpoint source pollution problems in estuaries and watersheds through understanding the—

- upland influences that contribute to water quality,
- value of long-term data collection and data analysis,
- scientific process and its contribution to problem-solving,
- importance of telecommunications as a valuable networking tool and
- importance of estuaries.

The project has multiple components to assist citizen volunteer water quality monitors, and classroom teachers and students in understanding regional water quality issues. These components include information on; estuaries and estuarine ecology, water quality monitoring, data management and quality assurance, and curriculum materials. Complete information on the program can be obtained at http://inlet.geol.sc.edu/estnet.html

C. Other Education Programs

Most of the reserves offer a variety of classroom, laboratory and field based programs for kindergarten through high school education in cooperation with school districts in their region. These programs provide a range of opportunities for students to gain an understanding of estuaries, and the impacts of human activities on them. The students also experience scientific methods first hand. For example, a program at Waquoit Bay Reserve works with middle school students on the effects of land use on a pond near the school, and Sapelo Island Reserve works with the local high school to monitor beach accretion and erosion.

Reserves also offer teacher training programs and curriculum. For example Waquoit Bay NERR conducts training for adult basic education and English as a second language teachers using hands on watershed and groundwater concepts.

Information about these programs can be obtained by contacting the reserve education coordinators. (See Appendix A)

D. Public and Recreational Education


Waquoit Bay NERR Volunteers

The reserves also provide a variety of formal and informal opportunities for the public to learn about estuaries and the effect of human activities on them. Most of the reserves include interpretive centers that are open to the public and feature displays on local wildlife, reserve resources and water quality information.

Other activities include walks and hikes with interpretive information, wildlife viewing and photography, and annual public events, such as Coast Weeks and National Estuaries Day.

An example of these programs includes a recently upgraded interpretive center at Padilla Bay NERR. The new exhibits are colorful, fun and packed with facts about estuaries and how people have affected these fragile coastal habitats. They also show how people can help protect endangered salmon and the watersheds and estuaries near their homes.

Features of the new exhibits include:

- What are watersheds and why are they important?
- Avenues within a watershed that water travels through on its way to the estuary.
- An interactive exhibit entitled “Is Your Watershed Healthy?”
- The Greater Puget Sound watershed, and local watersheds.

- What are estuaries and why are they important.
- A computer tour of other estuaries around the U.S.
- How humans have changed estuaries over time.
- A focus on Padilla Bay: 3-D model, habitats, tides, people;
- Tide In/Tide Out: An interactive tour of the hidden and not-so-hidden worlds of the estuary.
- Food chains/webs in the estuary.
- Eelgrass and why it's important; and
- How animals adapt to changing conditions in the estuary.

V. Where do we go from here?

The Clean Water Action Plan recognized that the NERRS provide valuable services in understanding and addressing the challenge of cleaning up the nation's waters. While continuation of the work currently conducted at the reserves obviously is important, it also is appropriate that the NERRS give consideration to new and expanded activities and services that it is well qualified to perform. The following is a compilation of activities or services that the system is currently considering.

A. Technical Training

The need for expanded educational programming oriented toward providing useful, current information on coastal issues to coastal decision makers has been identified as a critical need by coastal programs and NERRS. While the Coastal Decision Maker Workshops have provided a mechanism to address this need, a much larger effort is desired. The National Estuarine Research Reserve System has developed a "Coastal Training Initiative" designed to build upon the Decision-maker Workshop experience. The initiative will increase the reach and depth of training programs in the reserve system. The program calls for the reserves, working closely with the state Coastal Management Programs, Sea Grant and other partners, to develop a permanent forum for outreach and training for a wide range of audiences involved in coastal management and resource use.

B. System-wide Monitoring Program

The System-wide Monitoring Program collects data using standard methods at all reserves. Currently, parameters related to water quality are measured at all reserves and made available over the Internet through the Centralized Data Management Office. (http://inlet.geol.sc.edu/cdmohome.html). This data is valuable in assessing and describing trends and in making management decisions. Future plans call for expanding the monitoring program to include weather; biological indicators, such as habitat change and eutrophication; and land use change analysis. Addition of these components will enhance the value of the SWMP for conducting comparative research, will increase our understanding of estuarine processes and systems and will provide valuable information for education programs.

C. Habitat Restoration Science Initiative

On a national basis, most environmental programs focus on preventing further harm to the environment or removing damaging substances or activities. The assumption is that natural processes would restore the habitat. It has become increasingly clear, however, that in some circumstances it is necessary to actively intervene if a fully productive environment is desired. Also, as a result of changing economics, demographics and other social factors, land that was formerly productive for agriculture, industry or other uses, is no longer suited to such uses. This presents opportunities to restore or recreate some or all of the environmental values that such sites previously provided.

As living laboratories, the reserves are ideal settings to investigate the restoration and protection of estuarine and coastal habitat. The estuaries, which constitute a national network of protected areas, tend to be more pristine, and therefore useful as long-term scientific reference sites for understanding estuarine ecosystems and comparing them with other more degraded habitats. Moreover, most reserves also have habitat that has been lost, damaged, or altered over time. Within reserve boundaries and watersheds, one can find wetlands historically converted to agricultural lands; coastal hydrography disrupted by roads, dikes, and other man-made structures; native forest and meadow species replaced by invasive, non-indigenous species; beaches and dunes used for commercial or recreational purposes; and habitat damaged by accidental spills or groundings.

Because of their federally protected status, biogeographic diversity, on-site facilities, long-term monitoring programs and data, and professional staff capabilities in science and education, NERRS are excellent platforms for advancing the "science" of restoration, staging demonstration restoration projects, and monitoring their long-term success. To date, the majority of reserves have engaged in restoration science and have planned or conducted small to medium-scale restoration projects (.5 - 250 acres). They have investigated both engineering and natural approaches to restore areas to approximate natural, unaltered conditions. Several reserves are demonstrating leadership in restoration science in their estuaries and communities. For example, the Wells (Maine) Reserve is playing a lead role in salt marsh restoration in the Gulf of Maine. Some of the reserves must first address water quality issues and/or restore hydrologic regimes (i.e. sheet flow, tidal exchange, and freshwater drainage) before they can actually restore terrestrial and aquatic native plant communities and achieve successful faunal and ecological recovery.

In 1999, the NERRS initiated the process to develop a NERRS Restoration Science Strategy. The preliminary focus of the national strategy is:

To provide the scientific basis and technical expertise to restore, enhance and maintain estuarine ecosystems. There is an emphasis on eveloping and transferring effective standardized techniques to identify, prioritize, restore, and monitor degraded or lost coastal habitat. Success will require a partnered approach, education and community involvement components, regional coordination, and additional resources.

Conclusion

The work of addressing nonpoint pollution has really just begun. It is clear that the things we do on the land have direct and indirect effects on the streams, rivers, lakes, estuaries and oceans. Management measures can be developed that reduce or eliminate the adverse effects of our land-side activities. With clean water, restoration of productive aquatic environments is feasible. However, there is no ‘one size fits all’ solution. Each watershed has a unique set of physical, cultural and economic characteristics. This means that each watershed will require individual consideration of the sources, impacts and appropriate solutions and participation by the residents, users and managers of the watersheds in making decisions and implementing programs.

As locally based and managed organizations within a nationwide system, the NERRS are well positioned to conduct appropriate scientific research on sources, impacts and solutions. This report provides examples of research conducted by the reserves that is broadly applicable such as demonstrating linkages between land based activities and water quality and demonstrating the impacts of water quality changes on aquatic habitats. Other projects cited, such as restoration related programs or agricultural management techniques may be more specific to a particular setting but provide useful information and methods that are applicable in other settings.

The information gathered through research is essential to good decision making about water quality issues but will not by itself result in clean water. Whole communities need to understand the issues in their watersheds, to have the information necessary to consider alternatives and to make decisions, large and small. The educational programs conducted by the reserves enhance community understanding of these complex issues and provide information and examples that are applicable locally and throughout the nation.

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Appendix A

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