



Chapter Eleven: Summary of Recommended Water Resources Management Program

Introduction

Cape Cod National Seashore represents a nearly unique departure from the rest of the National Park System in that it was established after the area had been settled for more than 300 years. The manner and timing of the National Seashore's creation has resulted in the greater challenges for this park. The opportunity to set aside wilderness or to assume responsibility for a large private holding was not an option for the National Seashore. Consequently, there is an ongoing difficulty with sorting out historical jurisdictions in ways that preserve the mandate of the National Seashore. A thorough review of those jurisdictional interests and historical precedents combined with improved communication is inherent in many of this plan's tasks.

The history of environmental research and management at the National Seashore has provided an exemplary resource, but the National Seashore is both fragile and complex. Increased understanding of the complexity and sensitivity of the ecosystem are critical to wise management of the seashore environment. Therefore, a second and major thrust is to maintain and expand the knowledge of National Seashore water resources.

Since the National Seashore is neither wilderness nor exclusively recreational, the park must be a responsible combination of the two that optimizes both needs. Therefore, another important piece of the plan is to improve access to the information on the National Seashore's natural environment; to formalize communication channels among the many stewards of Cape Cod; and, to create innovative ways for people to understand more about the National Seashore environment.

Ground water is the lifeblood of many living things on the Cape, but water withdrawals and water quality impacts threaten the natural and human environment. While much is known, more study is needed to assess the consequences of current or future development, particularly for maintaining adequate water quality for human consumption or adequate water quantity and quality for surface water resources. Many of the tasks identified in this report propose ways to improve our understanding of the interaction between the water resources of Cape Cod and their continued, even increased, human use.

The National Seashore has a responsibility in common with other Cape water users to conserve water to the best of its ability. Further, the National Seashore, in its role as an environmental protector and educator, has a responsibility to lead the way in development, use and demonstration of water conservation techniques. Recommended actions to improve existing practices are detailed in this report.

Connected with ground water issues, non-point source pollution from individual systems, largely septic systems, and atmospheric deposition threaten ground and surface water quality. Some of the proposed

management is concerned with enhancing and refining monitoring, particularly for atmospheric deposition problems. The majority of the effort concerns improving ways to manage nutrients from individual septic systems and understanding the impacts on National Seashore kettle ponds. Some issues relate to the proximity of septic systems to water resources. Also, many of the systems are older and not in compliance with current technology. Some systems are used seasonally by temporary residents and so are unable to function as cleanly or efficiently. Other issues relate to the response of the ponds to varied nutrient inputs.

The plan identifies two areas with regard to potential major contamination. The first involves historic landfills in the vicinity of the National Seashore. Proposed action focuses on understanding the continuing pollution from those landfills and their impact on surface and ground waters. The second concerns heightened preparation for and awareness of potential toxic contamination from National Seashore or private facilities and operations.

Recreational impacts continue to threaten the water quality of the 20 kettle ponds in the National Seashore. The preservation of water quality is complicated by the sometimes conflicting management aims of towns, state agencies and the National Park Service, along with differing needs of permanent and temporary residents. Proposed measures include improving communication between agencies; improving the flow of information to both permanent and seasonal residents along with creating a process for feedback; and, developing a feasible plan that, coupled with water quality monitoring, will reduce or eliminate deleterious human impacts from recreation.

The National Seashore is a leader in the effort to restore the natural tidal environment of estuaries, reversing many decades of well-intentioned but environmentally damaging efforts to drain and alter these systems. In the process of restoration, there are many issues regarding how these systems originally functioned; how best to arrive at restored systems that resemble the original systems as closely as possible; and, how to make the transition in an environmentally safe and culturally sensitive manner. A number of specific tasks are outlined that continue the restoration process already begun at the National Seashore.

In sum, this Water Resources Management Plan updates the previous effort of 1981, identifies priority areas for continued research, management and outreach for the next 10 years, and suggests a number of specific projects and activities that either will help complete the knowledge base, respond to critical issues or enhance the role of the National Seashore in preservation, recreation, and research. The following table briefly lists those projects that are recommended. More detailed descriptions of proposed projects follow these summary tables and are referenced to the chapter where background information is presented.

Current Projects

| Issues Addressed | Problem Summary | Project Statements |
|--|---|--|
| Water Resource Characteristics | Baseline surveys of many basic characteristics of the biotic and abiotic water resource environment are incomplete or outdated. | <ul style="list-style-type: none"> • Inventory freshwater and anadromous fish • Northern diamondback terrapin study • Synthesize existing wetland plant inventory data • Map the interdunal wetlands • Monitor the water quality of the interdunal wetlands |
| Human Environment | Water resources education is a critical part of maintaining the quality of water resources in the National Seashore. | |
| Ground Water Withdrawal | Ground water is the principal source of fresh water for Cape Cod, but it is threatened by increased water withdrawal, septic effluent, and contamination. | <ul style="list-style-type: none"> • Assess ecological effects of ground water withdrawal at vernal pond and kettle pond littoral zones. |
| Water Resource Contamination Non-Point Sources | The relatively permeable nature of Cape Cod soils to nutrients and the almost total reliance on private septic systems combine to pose a serious threat to the water quality of ground water, fresh water and estuarine resources. Other contaminant sources are atmospheric deposition, road runoff, and surface runoff. | <ul style="list-style-type: none"> • Monitor kettle pond water quality • Evaluate mercury contamination in aquatic environments • Study the paleo-limnology of kettle ponds • Continue National Atmospheric Deposition Plan monitoring |
| Confirmed and Potential Source Point Contamination Sites | Landfills, mostly uncapped, and associated septage lagoons threaten expanded contamination of the ground water. | |
| Cultural Impacts on Pond Water Quality and Biota | There is no integrated approach to recreational management of the 20 kettle ponds within the National Seashore boundary. | |

| | | |
|--|--|---|
| <p>Cape Cod National Seashore Infrastructure</p> | <p>An updated, formalized inventory of all park facilities and their associated water efficiency does not exist.</p> | |
| <p>Ecological Impacts of Tidal Restriction</p> | <p>Several major estuaries in the National Seashore have historically been diked to control mosquitos. A host of unanticipated impacts have occurred. Restoration of tidal flow seems desirable, but the consequences need to be fully explored.</p> | <ul style="list-style-type: none"> • Monitor Herring River dissolved oxygen • Develop Memorandum of Understanding with Cape Cod Mosquito Control Project • Monitor ecological changes resulting from tidal restoration in Herring River, Hatches Harbor, and the Pamet River • Coordinate planning and construction of enlarged culverts • Coordinate planning and construction of the Mill Creek dike • Monitor Nauset marsh |

Recommended Projects and Activities

The following projects are intended to address the major water resource management issues at Cape Cod National Seashore. They derive from a number of working meetings of Seashore scientific and management staff with university cooperators and local and state technical experts. They are intentionally listed in no particular priority order, reflecting the understanding that the relative importance of each project is likely to change over the expected 10-year life of this plan. In short, management should be adaptive, and more specifically, the full range of projects should be reviewed annually and selected to advance water resource management based upon the best and most current information.

The First 400 Days of the Water Management Program

Project Statement for Chapter One

The federal mandate of the National Seashore encompasses two conflicting goals of resource protection and public access. Cape Cod National Seashore must exist with the apparent contradiction between serving as a major attraction to people and protecting the National Seashore lands in as natural a condition as possible. These conflicting goals pervade a wide range of issues from beach access to ground water use. This conflict has become increasingly pertinent as Cape Cod has come under enormous development pressure in the past two decades. Most of that pressure has occurred on the upper Cape towns located west of Chatham in Barnstable County, but demographic trends suggest that the pressure will increase on the outer Cape (see Figure 1.2), in part because of the existence of Cape Cod National Seashore.

In recognition of these circumstances, the Cape Cod National Seashore Water Resources Management Plan must reconcile these opposing pressures by identifying alternatives and recommending actions that protect the water resources' characteristics.

Jurisdictional Analysis

| Issues Addressed | Problem Summary | Project Statement |
|--|---|--|
| Resolution of jurisdictional conflicts | Management of the National Seashore generates conflicts within the National Park Service over the preservation and maintenance of the natural resources, and externally due to growth pressure from Cape towns and the region. There is local and state ownership and/or jurisdiction within the boundary, and their policies and regulations can differ from those of the National Seashore. | <p>1.1 Description of Policy Statement Regarding the Desired “Natural State” for Water Resources</p> <p>Review of founding legislation and experiences of other national parks with similar potential conflicts;</p> <p>Review of all policy and practice by the National Park Service and other agencies with jurisdiction of park resources;</p> <p>Develop an overarching policy statement that reconciles internal and external conflicts or proposes a means to achieve that goal.</p> |
| Integration of the efforts and interests of multiple agencies and consolidation of information | Many agencies, municipalities and non-profit organizations are active in various water resource activities, but coordinated effort is hampered by the lack of a structured forum in information exchange. | <p>1.2 Establish a Cooperative Program Committee</p> <p>1.3 Begin community extension work to involve residents and visitors in water resource protection</p> <p>1.4 Begin development of a comprehensive water resources database</p> |

Resource Characteristics Project Statements for Chapter Three

Much is known about the characteristics of the water resources of Cape Cod National Seashore, but its many habitats require continued inventory, monitoring, and research efforts that the past effort continue for those areas that have yet to receive sufficient attention. Also, both improvements in assessment techniques and a greater appreciation of the need for a holistic watershed view including assessment of external watershed influences require an ongoing base program to monitor and inventory watershed characteristics.

Water Resources Characterization

| Issue Addressed | Problem Summary | Project Statements |
|---|---|---|
| Baseline survey and monitoring of chemical, physical and biological characteristics | Baseline surveys of many basic characteristics of the biotic and abiotic water resource environment are incomplete or outdated. | <p>3.1 Inventory Aquatic Macrophytes</p> <p>3.2 Inventory Amphibian and Reptile Populations</p> <p>3.3 Study the Causes and Effects of Bullfrog Expansion</p> <p>3.4 Monitor Spotted Salamander Reproduction</p> <p>3.5 Wetland Plant Species Monitoring</p> <p>3.6 Inventory Kettle Pond Benthic Invertebrates</p> |

Swamps, Bogs, Freshwater Marshes, and Seasonally-flooded Wetlands

| Issues Addressed | Problem Summary | Project Statements |
|---|---|--|
| Location, characteristics and potential impacts to these habitats | Very little is known about the interdunal bogs and vernal ponds. Wetland mapping and classification is outdated. The impacts of water level change have not been evaluated. | <p>3.7 Update GIS Map of Wetlands</p> <p>3.8 Develop a Monitoring Program for Seasonally-flooded Dune Wetlands</p> <p>3.9 Develop Informational Display on the Interdunal Wetlands</p> <p>3.10 Historic Cranberry Bog Restoration</p> <p>3.11 Development of an Informational Display on the Role of Cranberry Bogs and their Use of Water</p> <p>3.12 Monitor Water Level Changes in Atlantic Cedar Swamps, Interdunal Ponds and Vernal Pools</p> |

The Human Environment

Project Statements for Chapter Four

Communication is a critical and necessary component of the Cape Cod National Seashore Water Resources Management Plan. To enhance the ability of all interested parties to communicate effectively, a comprehensive, objective database needs to be created and maintained. This database will not only provide important resource information useful for those entities (National Park Service, local communities and governments, the public) already interested and involved, but will provide a method to reach a broader audience. Open communication about water resources issues, supported by a comprehensive information database, will allow good decisions to be made in the process of guiding the National Seashore through the next decade.

Water Resources Information Database

| Issues Addressed | Problem Summary | Project Statement |
|--------------------------------|---|---|
| | There is no formalized database that provides updated, readily available monitoring information on water quality for the National Seashore. | <p>4.1 Develop a Water Resources Information Database</p> <p>Identify a database that is easy to use and is compatible with NPS information formats;</p> <p>Through the use of interns, enter the existing information into the database;</p> <p>Designate one person to update the database as information changes.</p> |
| Non-point source contamination | Adjacent development increases the potential degradation of park water resources. | <p>4.2 Periodically Map and Assess Adjacent Land Use</p> |

There is a good history of cooperation between the National Seashore, the public agencies and interest groups, but it is not perfect; cooperation usually develops as a reaction to perceived problems and focuses on conflict resolution rather than as a joint effort to anticipate and resolve problems before they become conflicts. Some conflicts do not get resolved and simply fester. The record of scientific inquiry concerning the resources of the National Seashore is quite good but not always intimately connected with the political conflict resolution process because various participants' opinions are formed and positions taken prior to the full dissemination of good science.

Technical Interagency Committee

| Issues Addressed | Problem Summary | Project Statement |
|------------------|---|--|
| | <p>There are no formalized links of communication between water resource stakeholder groups on the outer Cape and the National Park Service by which management is determined collaboratively and information is transferred regularly.</p> | <p>4.3 Develop Technical Interagency Committee</p> <p>Include representatives from the six towns, state agencies such as Coastal Zone Management, Department of Environmental Protection, Department of Environmental Management, Fisheries & Wildlife, regional agencies such as the Cape Cod Commission and local interest groups such as the Friends of the Seashore and Massachusetts Audubon;</p> <p>Develop a Memorandum of Understanding between all agencies that acknowledges the need for cooperative management efforts that complement each other;</p> <p>Create a technical committee as a subset of this group to focus on more technical issues including:</p> <ul style="list-style-type: none"> • an evaluation of zoning and healthy bylaws on the outer Cape as they relate to water resources; • water quality issues relating to septic systems; • landfills and their management • land use planning; • fertilizer use and landscaping alternatives; and, • cluster developments. |

From its inception, Cape residents have been incorporated in the land management process through what is referred to as the “Cape Cod Formula.” Despite the farsightedness of the Cape Cod Formula, conflicts still arise, many over water resources issues, and some of these have the potential to become precedent setting for future national park management. Full information exchange provides an opportunity to facilitate solutions to specific National Seashore problems and explore solutions to more general park issues.

Information Exchange with the Public

| Issues Addressed | Problem Summary | Project Statements |
|------------------|---|---|
| | <p>Currently, there are no formalized tools for communication between the public and National Park Service staff.</p> | <p>4.4 Publish a Newsletter</p> <p>Information on recent National Seashore research, information from the pond management committee, model home updates, articles from residents, articles from stakeholder organizations, and other information useful to both visitors and residents can be included in a newsletter.</p> <p>4.5 Develop an Interactive Web Page</p> <p>4.6 Create a Cape Cod Institute</p> <p>Patterned after the successful Yellowstone Institute.</p> |

Impacts to Ground Water Resources Project Statements from Chapter Five

Ground water is the principal source of fresh water for domestic, industrial and agricultural use on the lower Cape. In addition, the ground water resource supports freshwater ponds, wetlands, streams, and estuary environments, all of which represent a specific and important habitat for rare flora, fauna and fish spawning. The ground water quantity and quality are threatened by a variety of impacts such as increased water withdrawal, septic effluent, and contamination from landfills, leaking underground storage tanks, and urban runoff.

Ground Water Models

| Issues Addressed | Problem Summary | Project Statements |
|---|---|--|
| <p>Ground water withdrawal</p> <p>Contamination sites</p> <p>Septic systems</p> | <p>Ground water models are of insufficient resolution to adequately estimate the local impacts of increased withdrawal. Prior work on water quality modeling has addressed only salt intrusion. Finer resolution models and a more comprehensive sampling network are needed for determining and predicting contamination flows and withdrawal impacts.</p> | <p>5.1 Conduct Comprehensive Fine Resolution Ground Water Modeling</p> <p>Analyze existing modeling efforts to determine: 1) areas of increased water quantity and quality data needs; and 2) the feasibility of using models for investigating local impacts and for evaluating the entire outer Cape ground water system. Design a cost-effective well network for finer resolution analysis;</p> <p>Implement refined well network system and collect additional information on outer Cape lithology, hydrology and ground water quality;</p> <p>Develop comprehensive outer Cape ground water model and sub-models targeted at specific local issues such as:</p> <ul style="list-style-type: none"> • locations for potential new well fields; • Pilgrim Lake impacts; • threat of contamination to Duck and Bennett ponds; • landfill contamination flows and impacts; and, • nitrate impacts on ground water quality. <p>5.2 Establish a Network of Water Table Monitoring Wells</p> |

Non-Point Source Pollution Project Statements for Chapter Six

Septic Systems

| Issues Addressed | Problem Summary | Project Statements |
|------------------|---|--|
| Septic systems | <p>The relatively permeable nature of Cape Cod soils to nutrients and the almost total reliance on private septic systems combine to pose a serious threat to the water quality of ground water, freshwater and estuarine resources. Given the seasonal use of many Cape Cod septic systems, alternative waste treatment technologies need to be researched and tested on a case study basis.</p> | <p>6.1 Review Alternative Methods of Wastewater Disposal</p> <ul style="list-style-type: none"> • alternative technologies for private septic systems; • cluster or package treatment plants for selected areas; and, • increased on-line sewerage. <p>6.2 Develop Case Studies of Improved or Alternative Systems</p> <p>6.3 Determine Nutrient Inputs from Shoreline Septic Systems</p> <p>6.4 Determine the Rate of Nutrient Attenuation with Distance</p> <p>6.5 Prioritize the Future of In-holdings Reverting to the National Seashore</p> |

Kettle Pond Nutrient Management

| Issues Addressed | Problem Summary | Project Statements |
|---|---|---|
| Impacts of eutrophication on pond water quality | A variety of eutrophication pressures threaten the 20 kettle ponds in the National Seashore; some are general to all the ponds and some are specific to individual ponds. Some basic monitoring has been conducted, but there has been no comprehensive effort to quantify the nutrient sources or likely impacts, and to develop cost-effective strategies for management. | <p>6.6 Develop Nutrient Budgets for the Kettle Ponds</p> <p>6.7 Review and Evaluate Existing Water Quality Monitoring Data</p> <p>6.8 Complete Specific Kettle Pond Management Plans and Develop a Comprehensive Kettle Pond Management Plan</p> <p>6.9 Develop a Nutrient Loading Risk Assessment for Changes in National Seashore Practice or Aquifer Water Quality</p> <p>6.10 Investigate the Cause of pH Changes in Ryder Pond</p> <p>6.11 Survey the Kettle Ponds for Invasive Species, Develop an Informational Program and Prepare a Response Plan</p> <p>6.12 Evaluate Feasibility of Remote Multi-parameter Data Logging</p> <p>6.13 Evaluate the Role of Aquatic Macrophytes in Permanently Sequestering Nutrients</p> |

Heavy Metal Impacts

| Issues Addressed | Problem Summary | Project Statements |
|--|--|---|
| Deposition and bioaccumulation of heavy metals, particularly mercury | Southeastern Massachusetts is highly impacted by atmospheric deposition that results in bioaccumulation of toxic metals, threatening human and environmental health. The high acidity of National Seashore ponds suggests this problem will be equally severe in the 20 kettle ponds with potential effects on the freshwater and estuarine biota. | <p>6.14 Monitor Mercury Deposition at Cape Cod NADP Site</p> <p>6.15 Evaluate Mercury Levels in Sediments of Freshwater Ponds</p> <p>6.16 Conduct Top Predator Fish Tissue Monitoring in Fresh and Estuarine Environments</p> <p>6.17 Evaluate Mercury Pathways and Management Alternatives</p> |

Confirmed and Potential Point-Source Contamination Sites Project Statements from Chapter Seven

Organic, inorganic, or biologic pollutants derived from landfills pose a serious threat to the integrity of clean drinking water supplies as well as rivers and estuaries. The intimate connection between ground water and surface water on the Cape compounds the difficulty of managing these problems, as does the permeability and generally poor contaminant adsorption characteristics of the sand and gravel aquifer.

Landfills are among the five most serious threats to ground water quality in the U.S. (Noake, 1989). In Massachusetts, leachate contamination of ground water from landfills has been responsible for private well contamination in at least nine communities (Massachusetts Department of Environmental Quality Engineering, 1988). On the Cape, pollutants related to landfill leachate are also considered a threat to ground water supplies (Janik, 1987). A 1996 report (ATP Environmental, 1995) documents that the Eastham Municipal Landfill is directly responsible for contaminating private drinking water supplies within its vicinity.

There are five landfills (now closed) located on the outer Cape (Figure 7.1), all of which have the potential to impact the surface water resources within the National Seashore (Table 7.1). The Provincetown and Truro landfills are located inside the National Seashore boundary. Wellfleet's landfill abuts the National Seashore boundary, and the two others in Orleans and Eastham are in close proximity to the National Seashore. All landfills have monitoring wells, and the contaminant plume for each site has been mapped and discussed in various reports (Cambareri et al., 1989 a, b; Frolich, 1991; Urish et al., 1991; Urish et al., 1993; Winkler, 1994). According to these reports, some surface waters both inside and outside of the National Seashore boundaries may have been impacted.

Landfill Impact Evaluation

| Issues Addressed | Problem Summary | Project Statements |
|--|--|--|
| Movement and impact of landfill contaminant plumes on surface and ground water resources | Five landfills, mostly uncapped, and associated septage lagoons threaten expanded contamination of the ground water and may provide excess nutrients or toxic substances to nearby ponds, streams and estuaries. | <p>7.1 Continue Landfill Plume Monitoring</p> <p>7.2 Review and Evaluate the Study Design of Past Plume Monitoring</p> <p>7.3 Review the Literature on Landfill Capping and Recommend the Best Technique</p> <p>7.4 Assess Contaminant Discharge into Surface Waters</p> <p>7.5 Create a Forum for Dialogue on Contamination Issues</p> |

Hazardous Waste

| Issues Addressed | Problem Summary | Project Statements |
|--|---|--|
| <p>Potential impact on water resources from hazardous waste spills</p> | <p>Hazardous waste spillage may occur from large sources or small but significant sources that will impact both surface and ground water resources.</p> | <p>7.6 Hazardous Waste Spill Preparation</p> <p>Add information on private homes as well as septic systems within the National Seashore, and conduct an inventory of the park infrastructure. Conduct an inventory (i.e., gather existing information from towns and/or owners) of septic systems and storage tanks on homes located on or near surface water resources. Place storage tanks into a GIS data layer -- code by their age and the risk they present to water resources;</p> <p>Develop an outreach program primarily for homes that are NPS-owned and privately occupied to help homeowners understand water resource issues. Evaluate each property using criteria that relates to its potential impacts to surface and ground water quality. Use this evaluation in the decision making process for management of these homes if they are NPS-owned and occupied;</p> <p>Prepare an emergency response plan for spills or leakages of contaminants specific to the National Seashore.</p> |

Cultural Impacts on Pond Water Quality Project Statements for Chapter Eight

Perhaps more than any other park in the National Park System, the Cape Cod National Seashore has an inherent conflict between natural preservation, historical preservation, recreational use and the long-standing and presently burgeoning needs and desires of visitors and residents. In addition, much of the resource to be managed is not solely under the jurisdiction of the National Park Service. While this affects all water resource management activities in the National Seashore, it is an especially difficult issue for the management of the kettle ponds.

Kettle Pond Recreational Management Plan

| Issues Addressed | Problem Summary | Project Statement |
|---|---|---|
| <p>Recreational impacts to pond water quality</p> | <p>No plan currently exists that provides an integrated approach to the recreational management of all 20 kettle ponds within the National Seashore boundary.</p> | <p>8.1 Develop a Kettle Pond Recreational Management Plan</p> <p>Assemble a Pond Management committee consisting of all involved organizations;</p> <p>Review existing knowledge base and develop a plan for larger citizen involvement and problem identification, prioritization and solution implementation;</p> <p>Characterize problems and issues by surveying current recreational patterns, categorizing constraints to management, identify cause of impacts, and perform a rapid environmental impact analysis for each pond that highlights critical sites;</p> <p>Develop an appropriate outreach program for recreational plans:</p> <ul style="list-style-type: none"> • Prepare public outreach document that summarizes the plan and its intentions. • Organize a public meeting and lake management committees to work on volunteer activities such as monitoring, re-vegetation, etc.; <p>Research the feasibility of remediation, rationalization, and implementation of best management practices. Follow up with public meetings. Implement the plan and pursue monitoring after remediation. Re-adjust accordingly, and continue public participation.</p> |

Managing the Gull Pond Sluiceway

| Issues Addressed | Problem Summary | Project Statement |
|---|--|---|
| <p>Whether or not to continue the maintenance of the historical sluiceway between Gull and Higgins ponds due to concerns about water quality and alterations to Gull Pond's trophic structure</p> | <p>The National Park Service, and now a volunteer group, has historically maintained the Gull Pond sluiceway (established in the 1800s) to protect herring and their habitat and because the impacts from removal of the sluiceway are unknown. Whether to maintain the sluiceway between Gull and Higgins ponds is a complex question with potential impacts on the natural biota of the ponds, the introduced trout fishery in Gull Pond, and the anadromous herring run in the Herring River.</p> | <p>8.2 Managing the Gull Pond Sluiceway</p> <p>Gain an understanding of the ecological impact of the sluiceway by:</p> <ul style="list-style-type: none"> • determining a detailed nutrient budget for Gull Pond and the freshwater reach of the Herring River system; • determining the trophic structure of Gull Pond and the chain of ponds, river and estuary downstream; and, • completing a study which models the trophic structure and nutrient status of Gull Pond with and without river herring. |

Cape Cod National Seashore Infrastructure Project Statements for Chapter Nine

The Cape Cod National Seashore has three types of properties within its boundaries. One encompasses facilities owned by the National Park Service including houses, waste disposal systems, and storage tanks. Another is permitted homes within the National Seashore that are federally owned, but privately occupied. These homes have septic systems; some also have underground storage tanks. A number of these homes are located adjacent to ponds and marshes and will be turned over to the National Park Service for occupancy within a specified period of time. Finally, there are private improved properties or “in-holdings” that will always exist within the National Seashore, but will never fall under the ownership of the National Park Service unless donated or sold to the National Seashore. What the three types of properties have in common is that they exist and function within the National Seashore and have a potential impact on water resources. For this reason, it is important to inventory all properties within the park, regardless of ownership status.

Evaluate Current Infrastructure at the National Seashore

| Issues Addressed | Problem Summary | Project Statements |
|---------------------|--|---|
| Park infrastructure | An updated, formalized inventory of all park facilities and their efficiency does not exist. | <p>9.1 Update All Water-Related Facilities within the National Seashore and Monitor their Efficiency</p> <p>Meter all National Seashore facilities and use as a tool to evaluate different approaches to water conservation and wastewater minimization.</p> |

Model Home Case Study

| Issues Addressed | Problem Summary | Project Statements |
|---|--|---|
| <p>Ground water withdrawal</p> <p>Septic systems</p> <p>Park infrastructure</p> | <p>The National Seashore currently does not have a forum to combine park research with public education.</p> | <p>9.2 Use a National Seashore-owned Home(s) to Showcase a Living Laboratory for the Public</p> <p>The home(s) (possibly the Highlands Center, a former Air Force station that will become a center for exploring the arts and environmental understanding) may include:</p> <ul style="list-style-type: none"> • alternative septic system; • modern water conservation devices; • xeriscaping; • pervious outdoor surfaces; and, • rooftop rainfall collection; <p>Develop workshops for visiting schools and public groups. Cover:</p> <ul style="list-style-type: none"> • the importance of water on the outer Cape; • threats to the water resources on the Cape; • what the National Seashore is doing to prevent resource degradation; and, • what individuals can do to protect the resource; <p>Include model home activities in the newsletter;</p> <p>Monitor the results of various technologies and management practices, and place results in water research database.</p> |

Impacts of Estuary Tidal Restriction Project Statements for Chapter Ten

Most of the marshes within the Cape Cod National Seashore have been altered with dikes and/or tide gates and subsequently drained. This practice of “marsh reclamation,” started in the late 1600s, was meant to reduce mosquito populations, increase productive agricultural acreage, and improve roadways (Portnoy and Soukup, 1988). As a result, native habitat has been lost and freshwater wetland and upland plant species have invaded the diked areas. Salt marshes depend on sediment from the ocean in order to stay above sea level rise. Dike structures prevent this process from occurring, in turn causing the marshes to be vulnerable to flooding when dikes are breached. Decomposing salt marsh peat, left after a marsh is drained, periodically releases toxic levels of acids and aluminum, resulting in massive fish kills. Lack of tidal flushing also results in constant summertime oxygen stress, which reduces both fish and invertebrate numbers and diversity in both diked and drained wetlands.

Estuarine Habitat Restoration

| Issues Addressed | Problem Summary | Project Statements |
|---|---|--|
| <p>Restoration of natural tidal flushing to the Herring River</p> <p>General improvement and restoration of estuarine habitat</p> | <p>Considerable effort has already been expended to demonstrate the importance and feasibility of tidal restoration to diked estuaries in the National Seashore. Three areas are under consideration for tidal restoration. Each presents specific problems to be solved but together they present an ideal opportunity to improve the predictability of tidal restoration.</p> | <p>10.1 Topographic Survey and Hydrodynamic Modeling for Estuarine Habitat Restoration at Herring River, Wellfleet</p> <p>Design a restoration plan by:</p> <ul style="list-style-type: none"> • improving modeling of the dike removal effect by adding topographic and hydrologic evaluation and expanding the portion of the floodplain evaluated; • designing a tidal control structure that allows incremental restoration of tidal flow in the Herring River; and, • evaluating the flood storage capacity of the Mill Creek floodplain below the golf course fairway to size a pump-out system capable of preventing flooding of the golf course after a historic dike is rebuilt. <p>10.2 Monitoring of Planned Estuary Restorations</p> <p>Evaluate tidal restoration by comparing a restored system with both a natural system and a tidally restricted system using indices of biological integrity, hydrology, and chemistry;</p> <p>Through monitoring, determine the costs and benefits of restoration of tidal flushing.</p> |

Pilgrim Lake, formerly East Harbor, was closed off from Cape Cod Bay completely in 1868 with the construction of a dike structure meant to provide a travel corridor for cars and railroad. Since the construction of the dike, the waters of Pilgrim Lake have become brackish and eutrophic (Applebaum and Brinnekmeier, 1988). The eutrophic condition of the lake is believed to be the result of natural and human factors such as the shallow depth (2.5 ft in 1987), stirring of lake sediments by coastal winds, nutrient input from septic system effluent and animal feces, and saltwater intrusion from malfunctioning weir boards (Mitchell and Soukup, 1981). There are fairly consistent blue-green algal blooms and periodic outbreaks of midges (Chironomidae).

Pilgrim Lake Management

| Issues Addressed | Problem Summary | Project Statements |
|---|--|--|
| Eutrophication, sedimentation and midge control | Pilgrim Lake, originally a coastal embayment and now a landlocked, brackish, shallow basin experiences high levels of noxious algae, frequent outbreaks of midges under changed hydrologic regimes, and is rapidly filling in. | <p>10.3 Determine Bathymetry and Sedimentation Patterns in Pilgrim Lake</p> <p>10.4 Study Controls of Midge Production</p> <p>10.5 Evaluate the Cause of the Eutrophication Problem in Pilgrim Lake</p> |

