Chapter Ten: Ecological Impacts of Tidal Restriction

Salt marshes are very productive ecosystems, providing a rich food base and habitat for resident and migratory shellfish as well as finfish and birds (Portnoy and Soukup, 1988). Fifty percent of the nation's coastal wetlands have been lost and even more have been significantly impacted (Roman et al., 1995a). 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). Mosquito abatement, due to diking and drainage, is reported but undocumented; agricultural development never materialized. Meanwhile, native habitat has been lost and freshwater wetland and upland plant species have invaded the diked areas.

Problem History

Research by the National Park Service since 1980 has documented that restricted seawater flow into salt marshes dramatically changes plant and wildlife habitat (Soukup and Portnoy, 1986). 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. Additionally, decomposing salt marsh peat, left after the marsh is drained, periodically releases toxic levels of acids and aluminum, resulting in massive fish kills (Soukup and Portnoy, 1986). Constant summertime oxygen stress (Portnoy, 1991), from lack of tidal flushing, reduces both fish and invertebrate numbers as well as diversity in both diked and drained wetlands. Even temporary tidal restriction reduces the vigor of the salt marsh community (Portnoy and Valiela, 1997). In drained salt marsh soils, acidification and metal mobilization increase and nutrients become less available. In waterlogged salt marsh soils, sulfide toxicity reduces plant production.

Restoration of salt marshes provides resource managers with a valuable tool for maintaining and enhancing coastal zone habitat diversity (Roman et al., 1995a). Numerous studies in other regions have shown that degraded coastal wetlands and small estuaries can be successfully restored. Hydrologic modeling is one method used to predict tide height levels and tidal flooding elevations that can occur as a result of salt marsh restoration. Roman et al. (1995a) used this method to predict the effects of dike and tide gate removal at Herring River in Wellfleet and Hatches Harbor in Provincetown. Hydrologic modeling combined with research and interagency planning since 1986 has resulted in an ongoing project to restore up to 90 acres of salt marsh at Hatches Harbor and to provide flood protection for the town's airport built in the floodplain.

The Challenge

Restore wetlands and satisfy the needs of existing development in those floodplains where building has occurred since historic diking.

Herring River Restoration

The history of anthropogenic alterations to the Herring River system has been well documented by the Cape Cod National Seashore scientific staff who have completed extensive research on past and proposed management of the Herring River system (Portnoy and Reynolds, 1997). The Herring River (Figure 10.1) was diked completely at its mouth by 1910 primarily to reduce the breeding ground for salt marsh mosquitoes (*Aedes sollicitans; A. cantator*). While salt hay production and fisheries productivity decreased, the mosquitos remained a nuisance. As a further attempt to eradicate the mosquitos, drainage ditches were dug in the marsh behind the dike structure. By the mid-1930s, the Herring River's mainstream, now flowing with fresh water, was channelized and straightened. A golf course and two residential dwellings were constructed in the floodplain. The wetland became dominated by freshwater vegetation and upland shrubs and trees. In 1982, the National Park Service began research that examined salt marsh restoration alternatives. In 1984, the Massachusetts Department of Environmental Protection gained control of the flood gates from the town of Wellfleet in order to enforce an Order of Conditions set by the local Conservation Commission on the dike's reconstruction during the mid-1970s. Ownership and maintenance of the dike and flood gates are retained by the town.

The National Park Service showed that serious water quality problems existed due to diking and reduced tidal flushing of the salt marshes. Problems included surface water acidification (Soukup and Portnoy, 1986) and oxygen depletion (Portnoy, 1991a) that led to massive fish kills and the persistence of abundant mosquito populations (Portnoy, 1984). In 1980, the dissolution of sulfurous compounds from the old salt marsh deposits and consequent acidification of the Herring River and tributaries by oxidized sulfur (sulfuric acid) caused a massive eel kill (Soukup and Portnoy, 1986). Aluminum leached from native clay was elevated to lethal levels.

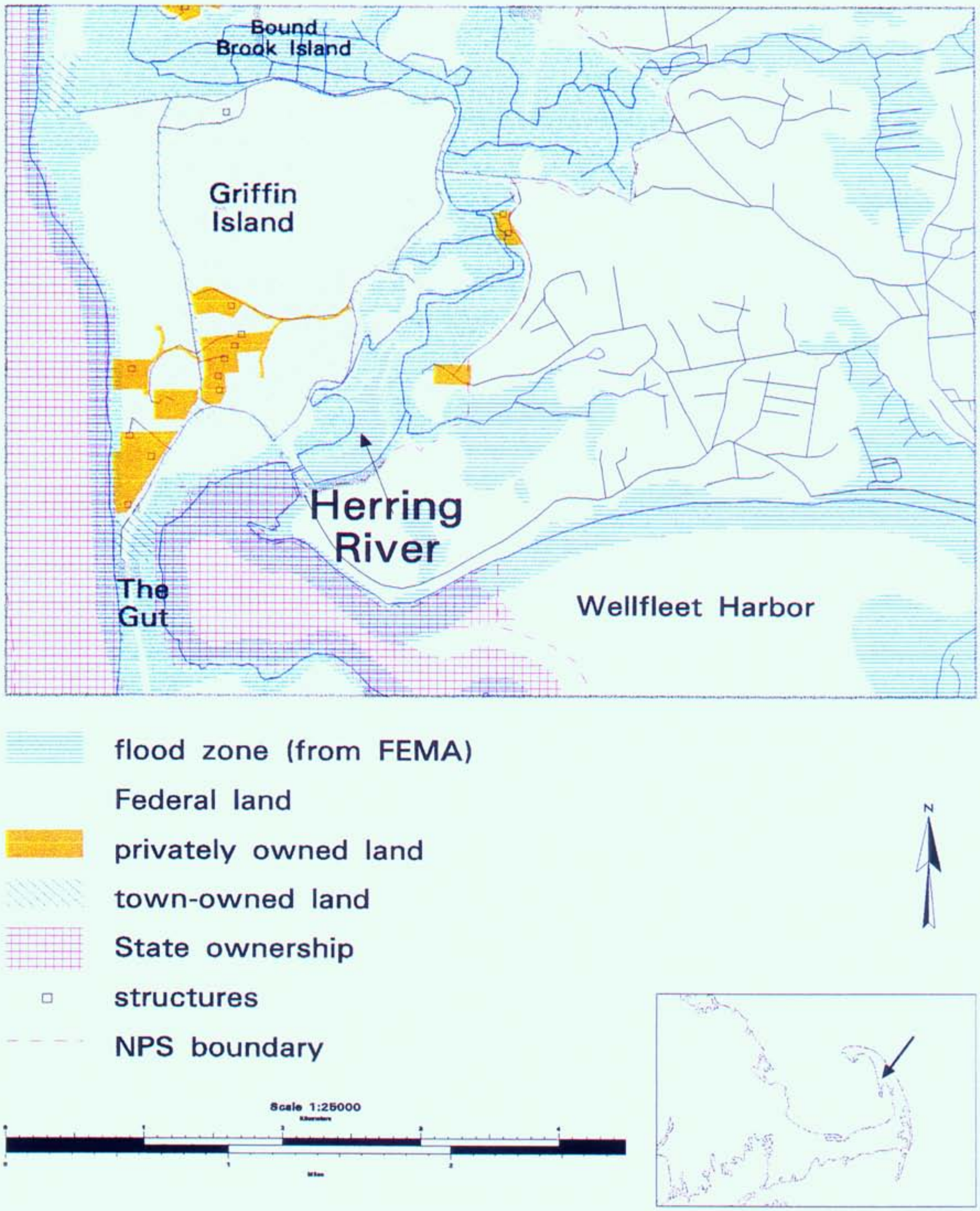
Reduced flushing of the Herring River has also caused oxygen stress and summertime oxygen depletions (Portnoy, 1991a). Starting in mid-May to early June, increased water temperature causes mid-day dissolved oxygen concentrations to decrease from 100 percent to 50 percent saturation levels. Total anoxia occurs during times of heavy precipitation, and resulting high flow contains proportionately more organic matter from the wetlands (Portnoy, 1991). These periods of high stream flow also stimulate juvenile herring to leave upstream natal ponds. If the stream is anoxic at the time of migration, massive fish kills ensue.

In July and August of both 1984 and 1985, the entire juvenile herring run was killed in the Herring River as a result of anoxic stream conditions (Portnoy and Soukup, 1988). A

Water Resources Management Plan

Figure 10.1: Herring River, Wellfleet
Cape Cod National Seashore

Sources: FEMA Flood Insurance Rate Maps, Federal land ownership records; 1991 aerials.



fish gate is now in place to prevent juvenile herring from entering the river during anoxic episodes (Portnoy et al., 1987). National Park Service staff monitor dissolved oxygen in the lower Herring River and install the fish gate when concentrations at midday decline to 3 ppm or less. There have been no major herring kills since this program was begun in 1986, despite almost annual oxygen depletions in the river.

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Despite dike construction, studies have found that the mosquito populations continue to thrive. On the Herring River, Portnoy (1984) found that acidification of the waters, caused by high sulfate, limited fish populations, natural predators of mosquitos. Thus, the stagnant water favored acid tolerant mosquitos. Portnoy (1984) concluded that by restoring the Herring tidal marsh, typical marsh-estuarine vegetation would increase, stream anoxia and acidification would decrease, and improved estuarine fish nursery habitat and shell fish populations would increase. Mosquito populations would actually decrease due to natural fish predation and enhanced tidal circulation. John Doane, Cape Cod Mosquito Control District, supports this conclusion and adds that for the past 20 years, the district has believed that it is easier to reduce mosquito populations in well flushed tidal marshes than in restricted systems (Doane, 1996, pers. comm., Cape Cod Mosquito Control District).

Roman et al. (1995a) stated that while restoration is an appropriate management tool for degraded salt marshes, there are several concerns that must be addressed before restoration can take place. One concern surrounding restored tidal flushing of the Herring River is salt water intrusion of private wells in the diked salt marsh. However, a U.S. Geological Survey investigation found that the freshwater lens at the very edge of the upland is 6.6 feet (20 m) thick and, therefore, projected tide height increases of 1.5 feet (0.5 m) after restoration would not impact wells outside of the floodplain (Fitterman and Dennehy, 1992). A second concern is flooding of a golf course and private homes within the floodplain. Nuttle (1992) showed that the golf course, which occupies a portion of the Herring River floodplain along a Mill Creek tributary, could be protected by rebuilding an old dike at the mouth of Mill Creek. However, protection of the two private homes is still an unresolved issue. A third concern is that restoration will initially generate a large pulse of nutrients, which may increase primary production and lower oxygen levels (Portnoy and Giblin, 1997a). Further, drained marshes exhibit significant subsidence as a result of increased decomposition of organic matter which, after restoration of tidal flushing, may result in flooding levels that yield more open water than intertidal salt marsh (Portnoy and Giblin, 1997b). To minimize these possible water quality problems, gradual restoration of tidal flow is recommended (Portnoy and Giblin, 1997a and 1997b). The tide height model and the mixing model were both used to predict changes in the Herring River system that would occur as a result of increased tidal flow

(Roman, 1987). The results of these two models allow all parties involved to evaluate and consider ecological and socioeconomic impacts (Roman, 1987; Roman et al., 1995a).

Hatches Harbor Restoration

Prior to 1930, Hatches Harbor was a productive 200 acre salt marsh and open water embayment. During the 1930s, the natural tidal regime of this embayment was altered by a newly constructed dike that isolated half of the estuary from the sea in an attempt to reduce salt marsh mosquito habitat (Figure 10.2). Subsequent to diking, a small airfield, now Provincetown Municipal Airport, was constructed on the floodplain above the dike. Flood protection for the airport became the primary role of the dike structure, and the dike was repaired three times for this purpose, in 1946, 1978 and 1984 (Portnoy, 1990a).

The 1987 major reconstruction of the dike prompted dialog between both airport and natural resource interests, who explored the possibility of salt marsh restoration. These discussions, facilitated by Massachussetts Coastal Zone Management, led to agreement that the dike structure provided more than adequate protection for the airport against flooding. Research by the National Park Service found that the salt marsh above the dike had become largely degraded, exhibiting a decline in natural salt marsh species and habitat for benthic fauna, fish, and native waterfowl. Research also showed that the reduction in sediment, normally imported to the marsh by flood tides, had led to the marsh subsidence, waterlogging, and plant stress. Two primary objectives became clear to all parties involved in the cooperative research: 1) restore the floodplain to salt marsh, and 2) protect the airport from flooding (Portnoy, 1990a).

Since both objectives are defined by land and surface elevations (Portnoy, 1990b), bathymetric mapping and tide height modeling studies were used to assess alternatives for restoration. Modeling showed that 90 acres of the floodplain within the 10 foot contour could be reflooded by semi-diurnal tides and restored to an inter-tidal salt marsh without impacts to the airport. Flooding of the salt marsh would occur via four concrete box culverts, each allowing ample tidal flow and flood protection to the airport. Airport landing system components located in two swales near the runways would receive added flood protection from earthen berms.

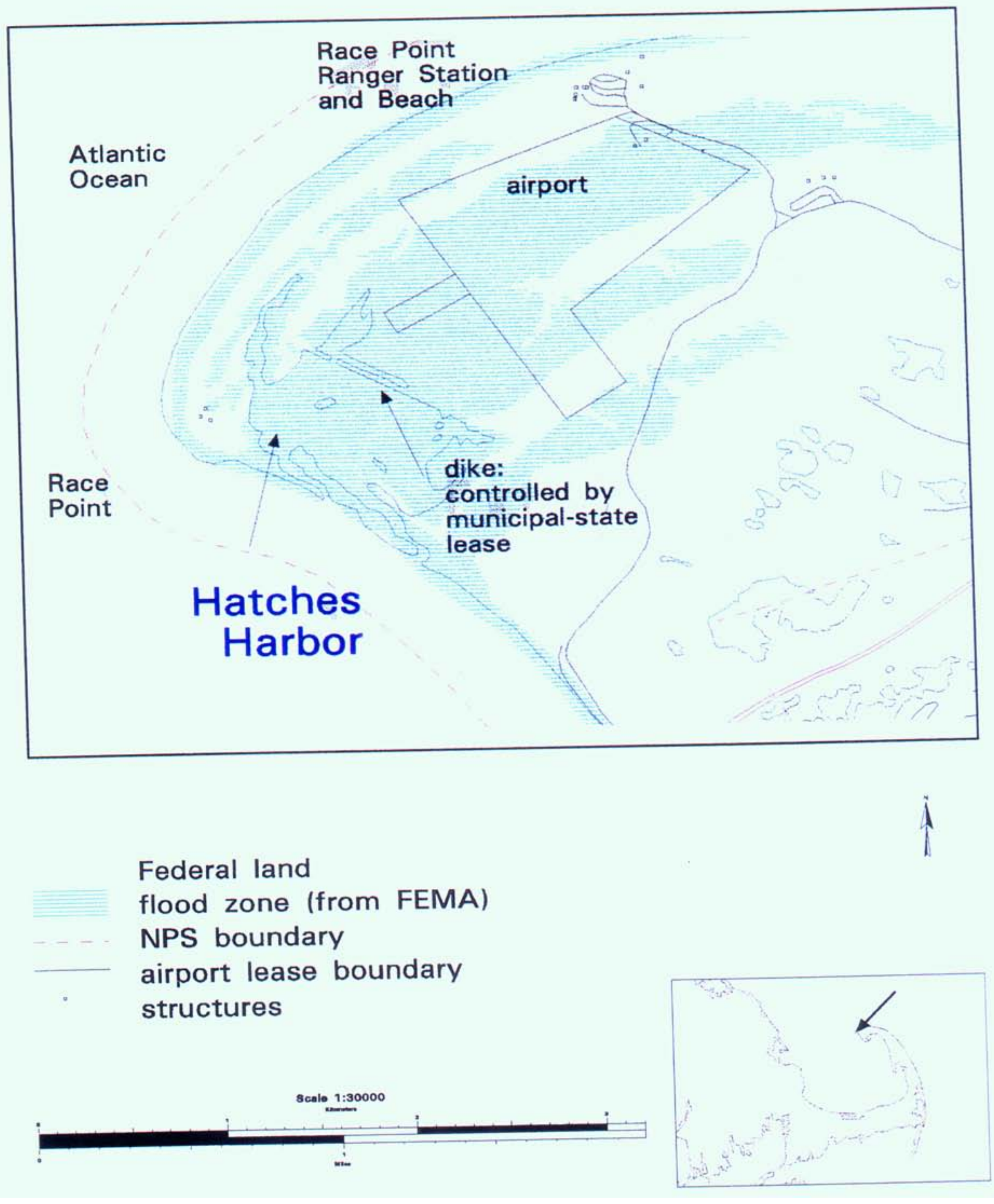
Numerous parties had an interest in the project, including FAA, MAC, Provincetown's Airport Commission, and others. As the baseholder for the dike, the Town of Provincetown agreed to be the project proponent. All restoration and monitoring efforts will be overseen by an operations oversight committee staffed by all parties.

A monitoring plan, consistent with the National Seashore's Inventory and Monitoring Program, has been developed. The 1996 Resources Management Plan project statement for Hatches Harbor salt marsh restoration (National Park Service, 1996b) outlines a plan for semi-annual monitoring of the estuarine system that includes analysis of hydrology and water quality, wetland vegetation, benthic macrofauna, shellfish, finfish, mosquitos, sedimentation, and migratory water birds. The first phase of pre-restoration monitoring under that plan has been completed.

Water Resources Management Plan

Figure 10.2: Hatches Harbor
Cape Cod National Seashore

Source: Provincetown airport lease documents; Federal land ownership records.



A description of this restoration project is not complete without a summary of the project's significance to the Town of Provincetown, National Seashore and the State of Massachusetts. Portnoy (1990a) describes the restoration of Hatches Harbor as "the largest single wetland restoration project in the history of Massachusetts."

The 10 year planning process behind the restoration proposal for Hatches Harbor is a significant multi-jurisdictional achievement among 11 different local, state, and federal agencies (Portnoy, 1990a). The Cape Cod National Seashore has placed this restoration project first on the park's priority list of resource management projects (National Park Service, 1996a).

Pamet River Restoration

Pamet Harbor (Figure 10.3), located on Cape Cod Bay, was once a viable commercial port that served a large fleet of local fishing vessels operating in the cod and mackerel industry (Giese and Mello, 1985). During the mid- 1800s, commercial fishing fleets were competing for space to anchor in Pamet Harbor, which could not accommodate all the vessels. As a result, the fishing industry declined and human population decreased. Remaining residents began to alter the Pamet in hopes of restoring and increasing the capacity of the harbor (Giese et al., 1985). From 1850 to 1930, significant alterations were made to the estuary system including diking and dredging. Wilder's Dike was built in 1869 to replace a rotting bridge across the mid-section of the Great Pamet and in 1950, a clapper valve and dike structure were built to accommodate the construction of Route 6 (Giese et al., 1993).

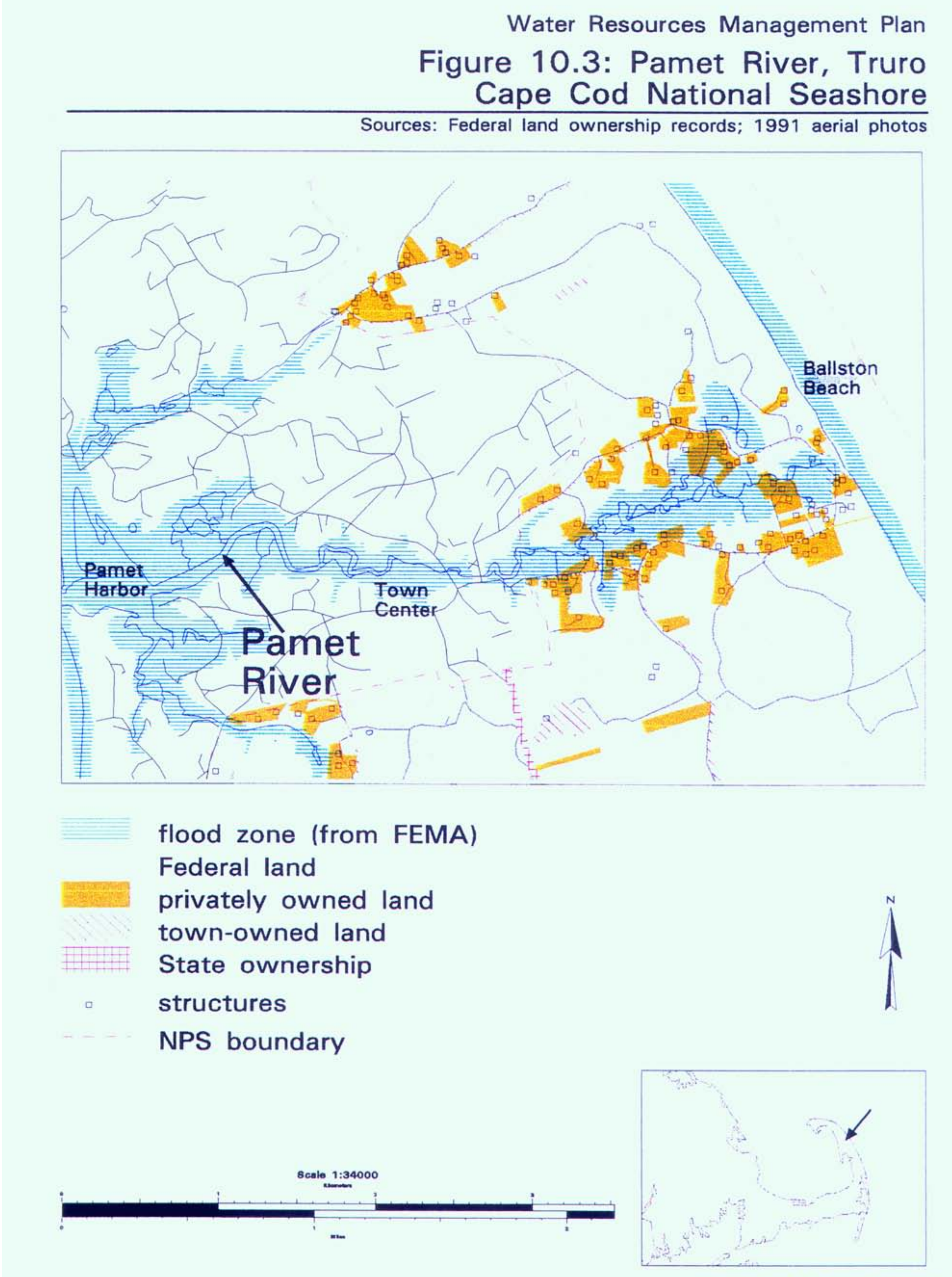
The alterations of the Pamet have divided the river into two distinct hydrological sections, the upper Pamet and the lower Pamet (Livingston, 1996). East of the tide gate located just west of Route 6, the upper Pamet is freshwater (Figure 10.3) with a watershed encompassing approximately 192 acres. Many upland species of salt- intolerant plants have invaded the area. Ground water discharge from the Pamet and Chequesset lenses, as well as precipitation are continuously recharging this section of the Pamet. The upper Pamet flows slowly west and enters into the lower Pamet, a saltmarsh estuary (National Park Service, 1986).

Restoring tidal flow to the Pamet River has many beneficial effects including increased natural flushing in the estuary which would in turn improve water quality, maintain habitat diversity, and balance sediment loads in the Pamet River Valley.

The lower Pamet is an intertidal estuary, greatly stressed by past alterations that have reduced natural tidal circulation and in turn increased shoaling and sedimentation (Giese et al., 1993). Tidal channel beds, except for the outermost section of the inlet channel, are higher than the mean low tide in Cape Cod Bay (Livingston, 1996).

Restoring tidal flow to the upper Pamet River would provide many benefits including increased natural flushing in the estuary which would in turn improve water quality, maintain habitat diversity, and balance sediment loads in the Pamet

River Valley (National ParkService, 1986).



Additionally, restoration of natural flows would allow the salt marsh to regain a state of equilibrium between sea level and wetlands elevations in the upper Pamet at Ballston Beach.

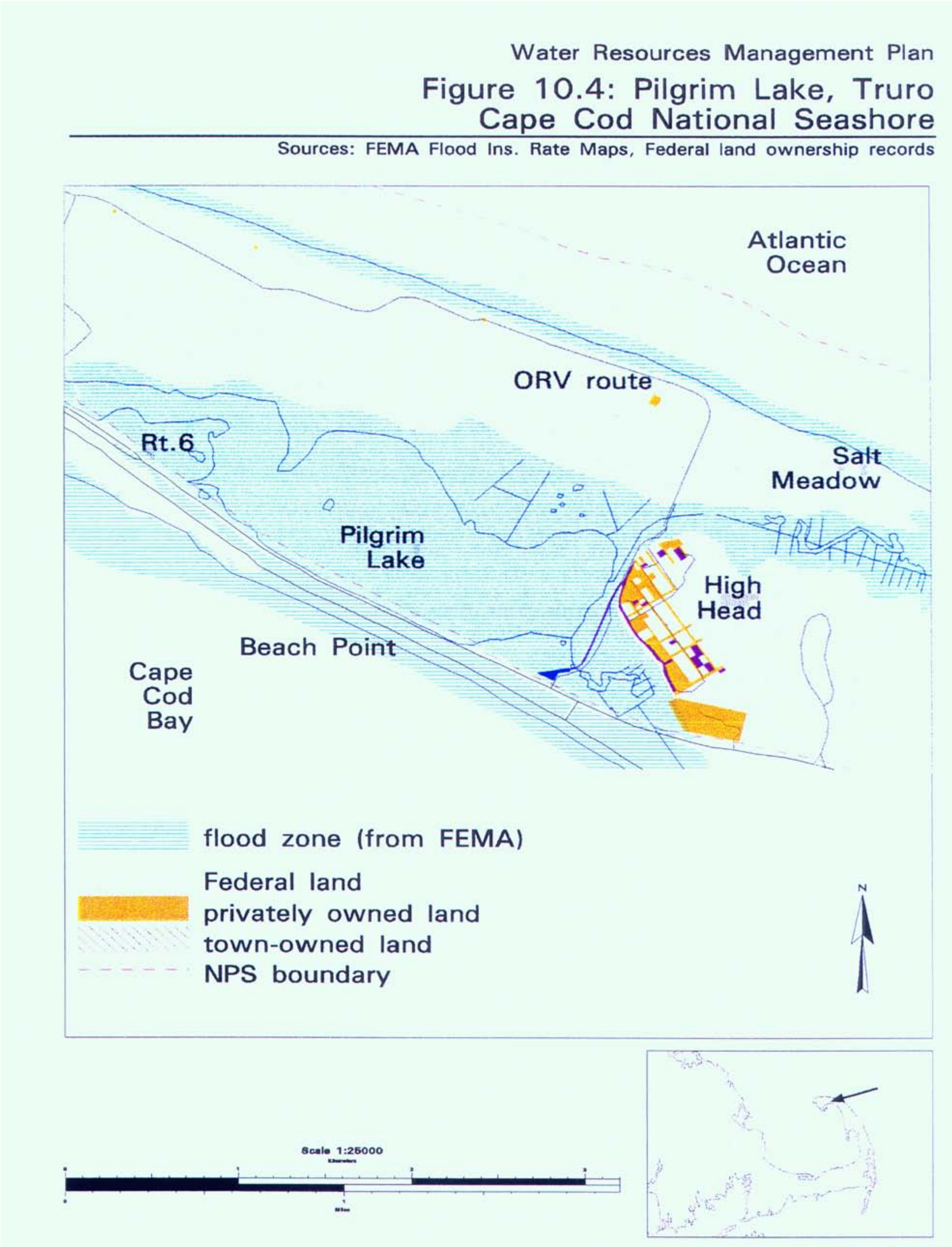
Currently, the upper Pamet River is vulnerable to storm overwashes at Ballston Beach, on the Atlantic Ocean side of the Cape and at the upstream end of the freshwater section of the Pamet River. Such an overwash could fill the upper, freshwater portion of the Pamet River with undiluted seawater, an extremely unusual situation for most river/estuarine systems. Further, because of the restriction of discharge imposed by Route 6 and Castle Road, saltwater cannot readily discharge to Cape Cod Bay. If an overwash were to occur in summer, present salt-intolerant vegetation would die. The U.S. Army Corps of Engineers and Cape Cod Commission are studying alternatives that address this concern, as well as the possibility of tidal restoration in the upper Pamet River.

Since the construction of the dike, the waters of Pilgrim Lake have become brackish and eutrophic.

Pilgrim Lake

Pilgrim Lake is a 344 acre coastal lagoon that once functioned as a tidal back barrier estuary and salt marsh system connected to Cape Cod Bay by an inlet at its western end (National Park Service, 1996c) (Figure 10.4). East Harbor, as it was once called, was closed off from Cape Cod Bay completely in 1868 with the construction of a dike meant to provide a travel corridor for cars and the railroad. Since the construction of the dike, the waters of Pilgrim Lake have become brackish and eutrophic (Applebaum and Brinnekmeyer, 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). The algae blooms occur in all seasons except winter and give the lake its blue-green color. High values of total phosphorus, and ammonia-nitrogen have been recorded (Mozgala, 1974). The source of these high values has not been determined but may be from organic bottom sediments, septic systems, and leaching from old salt marsh sediment. The nutrient supply from these sources nourishes a large algal population. The lake's surface elevation is believed to be a major factor in its functioning.

Lake level is determined by 1) the height of the water level control structure, located on the bay side of the lake and operated by the Cape Cod Mosquito Control Project, and 2) the opening of tide gates in the dike operated by the Massachusetts Division of Waterways (National Park Service, 1996c). The significance of the lake's water level to the ecological community was highlighted in 1968 when weir boards were removed from the water level control structure. After the boards were removed, there was a fish kill and massive outbreaks of midges, whose larvae live in lake bottom sediments (Portnoy, 1991b). After the 1968 episode, water depth, salinity levels, midge larval counts, dissolved oxygen, and nutrients were examined. Emery and Redfield (1969) compiled a


Water Resources Management Plan
Figure 10.4: Pilgrim Lake, Truro
Cape Cod National Seashore
Sources: FEMA Flood Ins. Rate Maps, Federal land ownership records
Atlantic Ocean
ORV route
Rt.6
Salt Meadow
Pilgrim Lake
High Head
Beach Point
Cape Cod Bay
flood zone (from FEMA)
Federal land
privately owned land
town-owned land
NPS boundary
N
Scale 1:25000

thorough set of data at this time; however, their study was not continued. The 1969 midge outbreaks were controlled with pesticides, a practice that is not acceptable to the National Park Service today.

The three major management concerns for Pilgrim Lake are sand deposition, eutrophication, and nuisance insects (National Park Service, 1996c). Sand deposition continues to decrease the depth of this already shallow lake. The extensive migrating dune system upwind of Pilgrim Lake may be partly responsible for the 1.5 foot (0.5 m) decrease in depth from 1948 to 1987. While past and present infilling rates have been poorly recorded, a 1987 assessment determined that the lake may fill in completely in 25 years (Applebaum and Brinnekmeyer, 1988).

Current Research

Research and Resource Management Projects-Fiscal Year 1996:

Salt Marsh Restoration Research/Planning: Herring River, Hatches Harbor, Pilgrim Lake

- Extend hydrodynamic modeling of expected tidal heights and salinities into the Herring River floodplain.
- Begin salt marsh restoration at Hatches Harbor and continue to monitor affected resources.
- Develop data compendium and research plan for Pilgrim Lake hydrology and aquatic ecology.

Pamet River Restoration/Hydrologic Cooperative Study

- Develop Pamet River restoration plan in cooperation with Town of Truro, Cape Cod Commission and U.S. Army Corps of Engineers.

Management Steps: Impacts of Diked Water Bodies
400 Days to 5 Years

Committee

Continue conversations regarding Herring River restoration. Develop a collective statement of management objectives for the wetland areas connected with the Herring River.

Education

Inform communities and private landowners of options regarding land trust donations and conservation restrictions on property that includes wetlands.

Data Management

Place all information, including monitoring data, related to the restoration projects in a central, easily retrievable database.

Research

Determine the relative importance of freshwater discharge from ground water and fresh surface waters versus tidal flushing from the ocean in maintaining the natural habitat and biota of estuaries.