2 Project History, Purpose and Need

2.1 Historical Overview of Alterations to the Herring River System

The original Herring River estuary included about 1100 acres of saltmarsh (both high marsh and low marsh), intertidal flats, and open-water habitats. The river, its tributary streams, and the estuary into which they flow, form a prime example of a system that has suffered decades of extensive post-colonial hydrologic and consequent ecologic disturbance as a result of human activities (Portnoy & Reynolds 1997). Despite the blockage of tidal flooding in 1909, persistent nuisance mosquito problems prompted a wetland drainage program that accelerated in the 1930s. The tidal river and creeks were straightened and channelized, and the expansive bordering saltmarshes ditched in an effort to increase drainage. Dredge spoils were placed on the river's banks, further isolating the river's main channel from its floodplain. These actions were undertaken reportedly to create arable land and to control nuisance mosquitoes (Whitman & Howard 1906).

Wetland drainage made it possible to construct roads, which fragmented the river floodplain, a golf course (the Chequesset Yacht and Country Club, CYCC) and several residences on or very close to the original wetland. Several decades of observation and study were required before land managers and a significant portion of the broader public recognized the ecological damage that had occurred as a result of past actions.

2.1.1 The Chequesset Neck Road Dike

The Herring River passes under Chequesset Neck Road through an earthen dike, which was constructed in 1909 and rebuilt in 1974. The dike contains three six-foot wide openings as part of a cast-in-place reinforced concrete box culvert. Two culverts are equipped with top-hinged timber flap gates and one is equipped with a vertical lift sluice gate. The flap gates open outward to allow discharge of water to Wellfleet Harbor, while the sluice gate allows bi-directional flow (see Photo 3). The most recent formal inspection of the dike by a professional engineer to assess its physical condition occurred on November 17, 2003 (MacBroom 2003). The inspection also addressed the structure's suitability for sustaining higher flow velocities if the gates were more fully open.

Photo 3: Existing tide gates at Chequesset Neck Road

2.1.2 The modified river channel and ditched saltmarsh

The Herring River and its tidal floodplain have suffered significant human-induced

alterations. To increase the rate of river water flow to Wellfleet Harbor, segments of the river were straightened. Dredge spoils removed from the river bed were deposited on the river bank in many locations. In addition, saltmarsh habitats were ditched to enhance floodplain drainage.

Channelization and straightening of the tidal river cut off many creek meanders between High Toss Road and the present Route 6, significantly reducing the length of the river. In some places, old meanders are still evident and are hydraulically connected to the river main stem by culverts that pass under the river bank spoil pile.

2.2 Low-lying Roadways

Following dike construction roadways were built within the floodplain. Roads were built across streams and adjacent to and upon wetland areas. In addition to the information presented in the following sections that briefly discusses the roads that cross the Herring River, additional and more detailed information can be reviewed in Section 6.0 of this report and in the Low-lying Roadway Analysis Report (ENSR 2007). This report discusses all low-lying roads including those that cross streams in the other basins.

2.2.1 High Toss Road

High Toss Road crosses the Herring River approximately one mile upstream of the Chequesset Neck Road dike. This road (see Photo 4), is an unpaved, infrequently traveled, single-lane road that provides access from Pole Dike Road to Griffin Island. The road is only slightly higher than the adjacent wetlands. At the western end of the road, a tidally restrictive, 60-inch diameter, 24-foot long concrete culvert conveys the Herring River beneath the road.

Photo 4: High Toss Road

2.2.2 Bound Brook Island Road

Photo 5: Bound Brook Island Road crossing the Herring River

Bound Brook Island Road crosses the Herring River where the river changes from a north-south orientation to an east-west orientation. Much of this frequently traveled road between its intersections with Pole Dike Road and Old County Road is low-lying. A 60-inch concrete culvert (see Photo 5) conveys the Herring River beneath Bound Brook Island Road.

2.2.3 Pole Dike Road

This frequently traveled link between West Main Street and Bound Brook Island Road crosses Pole Dike Creek - a three foot diameter culvert. This culvert likely would restrict restored tidal flow; however, the decision on whether to include the Upper Pole Dike wetland in the tidal restoration project has been deferred pending more data on abutting private properties.

2.3 Private Residences

A few residences have been developed on lands at elevations below the historic river floodplain elevation in the decades following dike construction. Building on low-lying lands was possible as a consequence of tidal restriction and other river floodplain drainage efforts. Evaluations have been conducted on the two such private properties that contain structures below the elevation of the spring high tide elevation (5.1 feet NAVD 88), documenting the existing conditions and considering alternatives that could be implemented to address these conditions under the restored tidal regimes (ENSR 2005 and ENSR 2007).

2.4 Chequesset Yacht and Country Club

The Chequesset Yacht and Country Club (CYCC) is a semi-private, nine-hole golf course constructed between 1929 and 1933. Since that period, CYCC has filled small areas of lowland on their property in order to extend the length of certain fairways and accommodate additional tee box areas; however, the course has remained in its original configuration since construction.

Photo 6: Low-lying portion of CYCC

The property currently occupies approximately 106 acres of land that abut a portion of the Wellfleet Harbor shoreline to the south, CCNS lands to the west and northwest, and private properties to the east and northeast. Land elevations on the property range from below mean sea level and approximately 60 feet. Despite a relatively large amount of upland habitat on the property, much of the golf course (portions of five of the nine fairways) was constructed at low elevations in the river floodplain adjacent to Mill Creek (see Photo 6). Despite diking of the floodplain, these lands have remained subject to saturated soil conditions, shallow inundation, and occasionally surface-water flooding due to heavy precipitation, seasonally high groundwater elevations, high-tide events in Herring River, and the presence of fine-textured soils (i.e. decomposed salt-marsh peat and marine clay). The CYCC contains both terrestrial and palustrine habitats including freshwater-dominant wetland areas, a portion of Mill Creek, man-made channels and impoundments, a very small saltmarsh area, and pitch pine–oak forest. A plan and environmental evaluation for course reconfiguration has

been prepared on behalf of the CYCC that discuss existing site conditions and the planned project, which is linked to the Herring River restoration project (Horsley Witten Group and Howard Mauer Design 2006).

2.5 Dike Deterioration and Subsequent Management Decisions

By the 1960s, structural deterioration caused some of the tidegates to rust in an open position. As a result, tidal range and salinity in the Herring River increased (Moody 1974) and shellfish began to recolonize above the dike (Snow 1975). However increased tidal range in the river also caused periodic flooding of the CYCC and other properties during storm tides.

As the Town considered dike repairs, estuary and saltmarsh restoration advocates, including the then recently formed Association for the Preservation of Cape Cod (APCC), appealed to the Town to replace the dike with a bridge to promote estuary restoration (Portnoy 2007). Nevertheless, in 1971 the Town of Wellfleet voted to allocate $37,500 towards repair of the damaged dike. In 1973, the Conservation Commission issued an Order of Conditions approving the project, but included a condition requiring that the structure allow tidal water levels matching those seen prior to dike repair in order to achieve saltmarsh restoration. They further required that the new dike accommodate anadromous fish passage. Amid controversy, the State rebuilt the dike in 1974 (see Photo 7).

Photo 7: Dike reconstruction in 1974

Following dike reconstruction, APCC-sponsored observers began collecting data and reporting on water levels and salinity (Moody 1974) and plant community composition (Snow 1975) in areas upstream of the dike. Tide height monitoring showed that the new dike's gate opening was too small to achieve the tide heights prescribed in the Order of Conditions. Local fishermen complained that siltation had increased and shellfish had declined since the new dike was built (Tangvik 1979). As a result, the APCC objected to the Massachusetts Department of Public Works for not allowing sufficient flow through the dike. However, the sluice gate openings remained at six inches (i.e. a six-inch high opening in the gates). In 1977, the State Attorney General ordered the Town of Wellfleet to transfer control of the dike to the Department of Natural Resources (now the Department of Environmental Protection, DEP) so that increased tidal flow could be attained in the interest of restoration (Portnoy 2007).

In 1980, a large die-off of American eels (*Anguilla rostrata*) focused attention on the poor water quality conditions in the Herring River. The Division of Marine Fisheries and the

National Park Service identified the cause of the eel kill to be high acidity and aluminum toxicity in turn caused by diking and marsh drainage. These water-quality problems would eventually (October 2003) cause DEP to list Herring River as "impaired" under the federal Clean Water Act Section 303(d), for low pH and high metal concentrations.

Within a year of the eel kill the Park Service determined that the sluice gate opening did not provide the tide heights mandated in the 1973 Order of Conditions (Portnoy 1980, 1982). The dike's sluice gate was opened slightly to a 6.5-inch high opening to allow some additional tidal flow.

Under continuing pressure from the Department of Environmental Quality Engineering (now the Department of Environmental Protection) the Town increased the sluice gate opening to 20 inches in 1983. That same year, the NPS documented summertime oxygen depletions and river herring kills for the first time and subsequently took steps to protect river herring and avert kills by blocking their emigration from upstream ponds in order to prevent the fish from entering anoxic waters (Portnoy et al. 1987).

Despite these poor habitat conditions, concerns about increased mosquito production, among other issues, prevented a larger sluice gate opening. However, mosquito breeding research conducted from 1981 to 1984 by the NPS documented that the principal nuisance mosquitoes emerging from the diked river floodplain were freshwater and brackish species, not those from saltmarsh habitats (Portnoy 1984). In 1984 the sluice gate opening was increased to 24 inches and has remained at this setting since then.

In 1985, the State classified the river as "prohibited" due to bacterial contamination. Work by NPS researchers would eventually show the bacterial contamination to be another symptom of restricted tidal flow and reduced salinity (Portnoy & Allen 2006).

A series of studies through the late 1980s and early 1990s assessed the effects of tidal restoration in the Herring River on both natural resources and private and public infrastructure. In 1987, Rutgers University completed an evaluation of hydrologic alternatives for tidal restoration and predicted that beneficial ecological effects would result (Roman 1987). In 1990, a water budget study of the Mill Creek tributary described options for controlling flooding on the CYCC golf course (Nuttle 1990). In 1991, a US Geological Survey study determined that tidal restoration would not threaten private groundwater wells located near the river (Fitterman & Dennehy 1991).

In 2001, the NPS and the University of Rhode Island completed and presented hydrodynamic and salinity modeling to assess effects of dike opening or dike removal on tide heights, salinity, and sediment movement both seaward of the structure and on the entire floodplain above the dike (Spaulding and Grilli 2001). Additional modeling to evaluate a much wider dike opening was undertaken in 2005 (Spaulding and Grilli 2005). The NPS completed additional studies in 2003 addressing the potential for saltwater intrusion of wells (Masterson 2004, Martin 2004) and sediment re-suspension near shellfish

beds (Dougherty 2004) under modeled restoration alternatives. Also in 2001, the Wellfleet Conservation Commission voted to support estuarine restoration within the Herring River floodplain and formally requested assistance and funding to promote restoration from Massachusetts Coastal Zone Management's Wetland Restoration Program (WRP).

Numerous other local, state, and federal agencies and groups began more formal involvement and support for the project: among these were the NOAA Habitat Restoration Center, US Fish and Wildlife Service, Natural Resources Conservation Service, and The Nature Conservancy. More formal discussions and planning to address the reconfiguration of the golf course and associated funding needs began with the CYCC in 2004 and have been ongoing. In 2005 the Wellfleet Town Meeting approved $1.2 million of Land Bank funds for acquisition and open space protection of the low-lying portion of the CYCC lands. In 2005 the NPS and Town of Wellfleet completed a Memorandum of Understanding (MOU, see Appendix A) agreeing to work together on the project, and establishing the HRTC and Stakeholder Group to advance the project. The U.S. Senate Appropriations Committee secured $500,000 from the NOAA Coastal and Estuarine Land Conservation Program for the CYCC land acquisition shortly after the MOU was signed.

Over the past several years there has been growing momentum, supported by scientific and engineering studies, to bring this river restoration project to a reality.

2.6 Project Purpose and Need

As described in the previous section, and further supported by the information presented in Section 4.0 describing the existing environmental conditions, the ecological characteristics of the Herring River basin have suffered dramatically from tidal restriction, saltmarsh drainage efforts, and infrastructure development in the river floodplain. The restoration of the Herring River was proposed by APCC, NPS, and others more than 30 years ago. Currently, natural resource protection agencies, conservation organizations, municipal agencies, and the public understand the important need for coastal resource restoration and now broadly support this concept for the Herring River. The following sections present the case for tidal restoration of the river system.

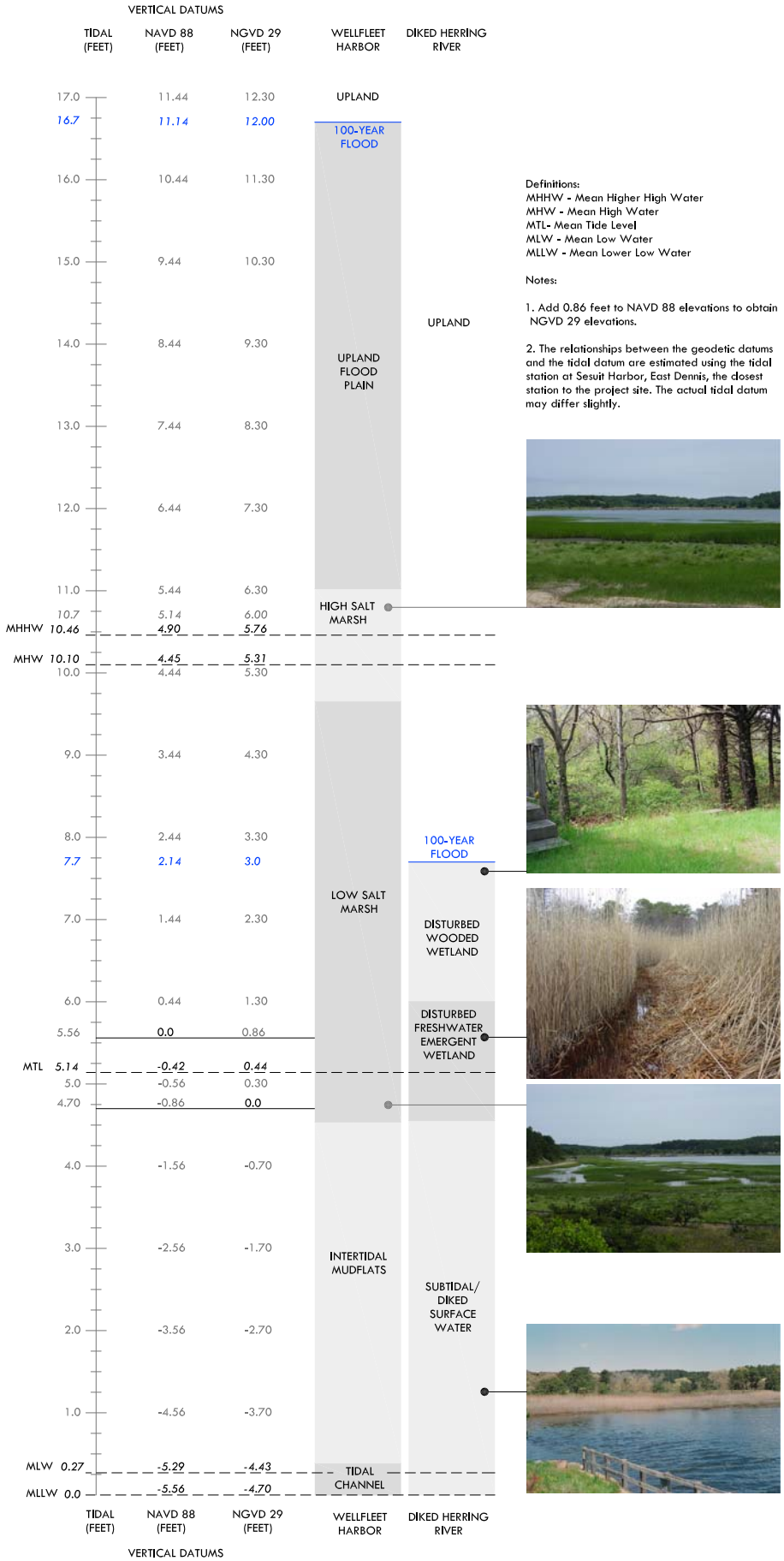
2.6.1 Estuarine Restoration: Understanding the Baseline Condition

Ecological restoration has been an increasing focus of the scientific and regulatory communities for the past several decades, as recognition has grown of impacted natural ecosystems and the inability to mitigate for the impacts by creation of "replacement" systems. Broadly, ecological restoration is defined as the process of reestablishing a self-sustaining habitat that closely resembles a natural condition in terms of structure and function (NOAA). More specifically to the Herring River project, wetlands restoration is "*the act, process, or result of returning a degraded wetland or a former wetland to a close approximation of its condition prior to disturbance*" (WRP). Fundamental to understanding the

existing degraded conditions, and for planning estuarine restoration, is a clear understanding of the tidal regime and dependent ecosystem of Wellfleet Harbor.

Land surface elevation with respect to tidal levels is the primary factor determining conditions within an estuary. For consistency and to follow current standards, all elevations within this CRP are expressed using the most current geodetic datum, the North American Vertical Datum of 1988 (NAVD88). Figure 2 (following page) provides a reference to compare geodetic datums to tidal datums. Tidal datums, such as Mean Lower Low Water (MLLW), popularly used on NOAA charts and tide tables, vary from location to location. NAVD88 is constant throughout North America and is typically used by engineers and land surveyors. Tidal datums are based on local tidal benchmarks that are operated by the National Ocean Service (NOS). The tidal datums shown in Figure 2 are based the closet NOS tidal benchmark in Cape Cod Bay, at Sesuit Harbor, East Dennis, and may vary slightly at Wellfleet Harbor. See the Glossary for more thorough definitions of tidal and geodetic datums.

The significance of tidal inundation to saltmarsh ecology is well documented (Nixon 1982, Teal 1986). Regularly flooded saltmarshes, or low saltmarshes, are flooded during all high tides and occur at elevations from about mean tide level to mean high water. These marshes are dominated by smooth cordgrass (*Spartina alterniflora*). High saltmarshes are only flooded during semi-monthly spring tide cycles and are generally situated between mean high water and the highest reach of the tide. High marshes are dominated by salt meadow grass (*Spartina patens*) along with two commonly associated species – spike grass (*Distichlis spicata*) and black grass (*Juncus gerardii*). Figure 2 also compares tidal flooding levels in Wellfleet Harbor below the dike to the Herring River above the dike. From these basic guidelines come the initial criteria for establishing tidal flooding above the dike to just above the mean high water level to promote the restoration of both low and high saltmarshes in areas that historically supported them. In practice, the system will function in a much more complex fashion due to a variety of factors. For example, tidal levels will vary due to winds, currents, and micro-topography. Freshwater dilution and mixing with saltwater will cause salinity to vary in different sub-basins. Previous saltmarsh surfaces have subsided, likely to different degrees, and may also recover elevation, through sediment accumulation, at different rates. Accordingly, in addition to more refined modeling to predict the response of the system under different tidal control options, the CRP includes an iterative and adaptive approach to manage incremental restoration in response to observed and measured conditions.



Definitions:
MHHW - Mean Higher High Water
MHW - Mean High Water
MTL- Mean Tide Level
MLW - Mean Low Water
MLLW - Mean Lower Low Water

Notes:

1. Add 0.86 feet to NAVD 88 elevations to obtain NGVD 29 elevations.

2. The relationships between the geodetic datums and the tidal datum are estimated using the tidal station at Sesuit Harbor, East Dennis, the closest station to the project site. The actual tidal datum may differ slightly.

Figure 2. Relationships between Datums and Conditions in Wellfleet Harbor and the Herring River under Existing Conditions

2.6.2 Summary of Adverse Ecological Effects from Tidal Restriction, Marsh Drainage, and Floodplain Alterations

Ecologists have developed a clear understanding of the adverse ecological effects that tidal flow restrictions have on estuarine habitats and tidal rivers like the Herring River (Breemen 1982, Portnoy 1999, Roman et al. 1984, Sinicrope et al. 1990, Steever et al. 1976, Thom 1992, Zedler 1988). For the Herring River system, adverse ecological effects resulting from dike emplacement, saltmarsh ditch-draining, stream culvert installation, and road construction, include:

Tidal Range Restriction – Lack of Tidal Inflow and Outflow

The tidal range restriction of the current dike – from a harbor side range of more than ten feet to less than two feet above the dike – causes myriad environmental problems for the estuarine habitats.

Plant Community Changes - Saltmarsh Habitat Reduction and Invasive Species

The reduction of salt water input onto the river floodplain and intensified marsh drainage efforts (ditch-draining) had a gradual, but dramatic, impact upon the species composition of the naturally occurring saltmarsh plant communities by removing salt and dewatering soils. The reduction in salinity denies saltmarsh plants, such as *Spartina alterniflora, S. patens*, and *Juncus gerardii* among others, their competitive edge over herbaceous freshwater wetland species, such as cattail (*Typha* spp). Cattail-dominant plant communities gradually replaced characteristic saltmarsh vegetation. Aerial photographs taken in 1938 show the river floodplain apparently dominated by cattails. By the 1960s, the intensified drainage for mosquito control further dewatered the soils and allowed upland grasses, forbs, and even trees to replace the cattails (Portnoy & Soukup 1982). For example, black cherry (*Prunus serotina*) and pitch pine (*Pinus rigida*) are now dominant in areas that were once naturally occurring saltmarsh habitats. Drainage made it possible for upland plants to invade the floodplain and shade out wetland species adapted to the previously saturated soils. By the 1970s much of the original Herring River wetlands had been converted from saltmarsh to upland forest and shrublands (Portnoy and Soukup 1982). Meanwhile, original subtidal and intertidal substrates between the dike and High Toss Road have converted to a large monotypic stand of common reed (*Phragmites australis*).

Elimination of Salt Water Inputs and Water Quality Degradation

Elimination of salt water input to the estuary and marsh dewatering together resulted in a dramatic degradation of the estuarine water quality with severe ecological consequences. Saltmarsh diking and drainage allows air to enter the normally anaerobic subsurface environment of the saltmarsh, converting it to an aerobic environment where both organic material and iron-sulfur minerals can be readily oxidized. In saltmarsh peat, a product of iron-sulfur mineral oxidation is sulfuric acid, which lowers pH when reaching surface waters. Low pH can cause fish kills and, in 1980, thousands of adult American eels (*Anguilla rostrata*) were killed as a result of a large pulse of acidic water released into the

Herring River main channel following a period of heavy rainfall. Main stream pH was highly acidic (pH 4), while ditches were ten times more acidic (Soukup & Portnoy 1986). These ditches contained water so acidic that predatory fish that normally prey upon floodwater mosquito larvae were chemically blocked from major mosquito breeding sites (Portnoy 1984). Low pH causes leaching of toxic metals, particularly aluminum and ferrous iron, further degrading water quality.

The elimination of tidal flushing in the Herring River wetland system that still contained abundant organic matter, caused regular summertime dissolved oxygen depletions and fish kills in the river main stem (Portnoy 1991). Conditions were worst in mid-summer, when oxygen demand was highest, and compelled NPS to begin controlling the emigration of juvenile herring (*Alosa* spp.) to avert complete mortality and loss of the anadromous run (Portnoy et al. 1987).

Sedimentation Cessation and Land Subsidence

Measurements indicate that, relative to sea level, much of the diked Herring River floodplain is approximately three feet below its prior, pre-dike elevation and the surfaces of existing saltmarsh seaward of the dike (Portnoy & Giblin 1997a). Tidal restrictions radically affect the important process of sedimentation on the saltmarsh. Coastal marshes must increase in elevation at a pace equal to or greater than the rate of sea-level rise in order to persist. This increase in elevation (accretion) is dependent on several processes, including transport of inorganic sediment into an estuary and its deposition onto the marsh surface during flood tides. This sediment transport must occur to promote the growth of *Spartina* grasses and to gradually increase the elevation of the marsh surface. However, the 1909 diking has effectively blocked inorganic sediment from reaching the saltmarshes within the Herring River basin. Additionally, marsh drainage has increased the rate of organic peat decomposition by aerating the sediment and also had caused sediment pore spaces to collapse. All of these processes have contributed to severe historic and continuing subsidence in Herring River's diked wetlands.

Nuisance Insect Production

Construction of the dike and salt-marsh drainage were management measures meant to reduce populations of nuisance insects, primarily mosquitoes. The principal nuisance mosquitoes that currently emerge from the diked river floodplain are freshwater and brackish species, not those from saltmarsh habitats (CCMCP unpublished data, Portnoy 1984). Reduced tidal range, marsh drainage, and degraded water quality also has made it impossible for predatory fish to reach the surface of the marsh to feed upon mosquito larvae.

Impeding Herring Migration

An estuary is by definition open to the ocean, allowing river herring and other anadromous fish to use estuaries as staging areas as part of their seasonal migrations to and from breeding habitats. An unrestricted estuary features a gradual transition in salinity from

seawater to freshwater, providing migratory species (anadromous herring and catadromous American eels) a salinity gradient in which to adapt physiologically. The dike physically impedes migratory fish passage (P. Brady, personal communication) and creates an artificially abrupt transition from seawater to fresh river water. As described above, the tidal restriction also upsets wetland biogeochemical cycling which in turn severely degrades the chemical quality of aquatic habitat.

2.7 Summary of Purpose and Need

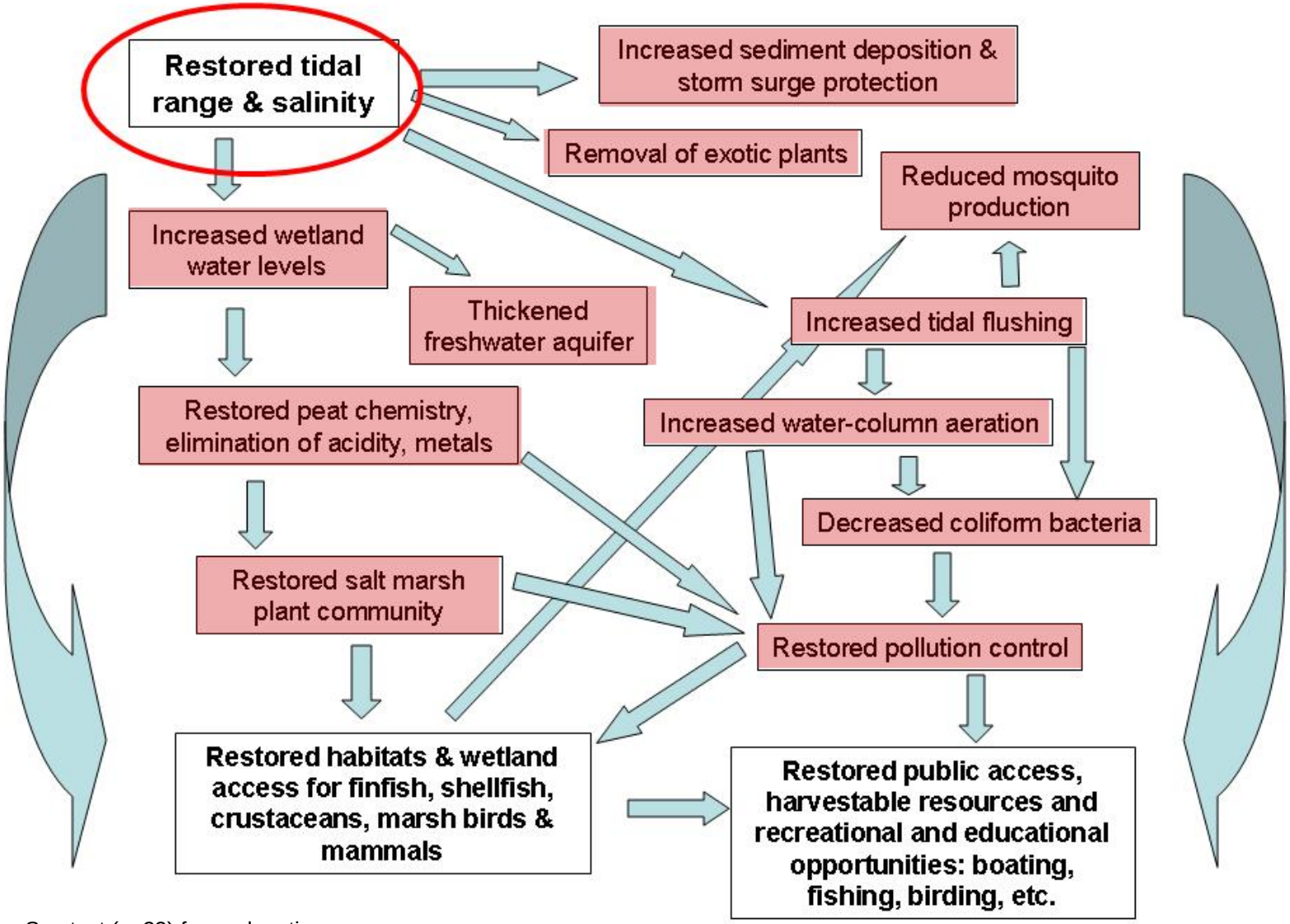
As described above, there are numerous elements of the Herring River system that have been impacted by long-standing tidal restrictions. The basic purpose and need of the Herring River Restoration Project is to implement changes in the current tidal controls to restore natural estuarine habitats and their functions to the maximum extent practicable. Expected changes in the system resulting from restored tidal regime are diverse but interdependent. They are summarized in Figure 3 and further described in the text that follows (from Portnoy 2004).

Restored tidal range leads to higher sediment transport and deposition onto the wetland surface, as sediment-carrying flood tides again flood over creek banks and onto the marsh platform. This surface has subsided over the past 100 years of diking; therefore, restored sedimentation can allow the wetland surface to rise, thereby increasing storm-surge protection for roads and other structures at the edge of the floodplain.

Restored tidal range, i.e. higher high tides, lower low tides and, thus, increased intertidal volume, greatly increases tidal flushing. Better flushing will reduce floodwater mosquito breeding on the wetland surface, dilute the presently high fecal coliform counts that have closed river-mouth shellfish beds, and improve water-column aeration by flooding the wetland twice each day with oxygen-rich Cape Cod Bay water.

Tidal restoration would also result in higher average water levels in the estuary's wetlands, with associated additional benefits. For example, groundwater modeling predicts that the freshwater lens, the source of drinking water for all properties surrounding the floodplain, will thicken with a higher mean water level in the estuary. Within the wetland proper, higher water levels will resaturate wetland soils that have been drained by diking and ditch drainage since 1909, and reverse the chemistry that has caused high acidity, mobilized toxic metals and triggered fish kills in receiving waters. Despite higher high tides and an increased mean water level, low tides will actually be lower with tidal restoration, improving low-tide drainage and reducing mosquito breeding sites on the wetland surface. Improved water quality also would reduce mosquito production by enhancing aquatic habitat quality for the mosquito's major predatory fish species, including mummichogs (*Fundulus heteroclitus*) and sticklebacks (*Gasterosteus* spp).

Figure 3. Ecological and Social Benefits of Herring River Tidal Restoration



See text (p. 22) for explanation.

Restored salinity will stress many of the salt-sensitive non-native plants that have invaded the floodplain and enable recolonization of native saltmarsh plants. Higher salinity also would reduce the survival time of coliform bacteria, adding to the dilution effect of increased tidal flushing to further depress fecal coliform counts in shellfish beds.

The reestablishment of tidal range, salinity, overall water quality, and the salt-marsh plant community, will restore hundreds of acres of wetland habitats and access to those habitats by finfish, shellfish, marsh birds and mammals. For people, this means better boat access throughout the Herring River estuary, on higher tides across an open marsh instead of the presently drained shrub thicket, with fewer mosquitoes. More importantly, it also means more extensive, abundant and diverse marine resources for observation, education and harvest both within the estuary and in nearby coastal waters.