7 Operation / Maintenance Plan and Monitoring Program

As has been stressed throughout this document, the implementation of the Herring River restoration project will require a long-term, systematic plan for monitoring, management, and maintaining the tidal control structures and other features of the system. This section is intended to provide an overview of the currently envisioned program for this management. As an *adaptive management* plan, it is stressed that the nature and timing of specific management actions will depend on environmental monitoring at each step of the restoration process and upon the system's response with respect to project objectives.

7.1 Adaptive Management and Regulation of Tidal Flows

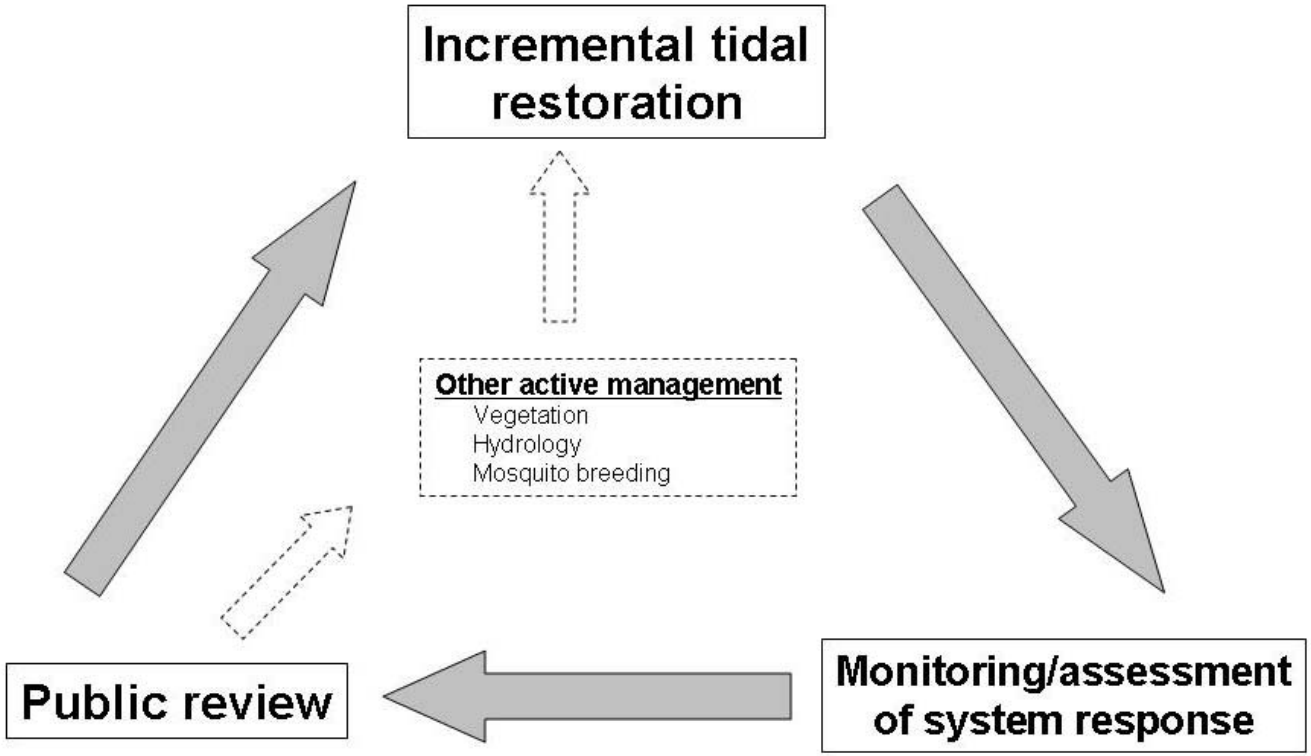
As discussed previously, the modified tidal control structure at Chequesset Neck Road (or at alternative locations) will be designed so that increases to tidal flows can be undertaken in an incremental fashion, i.e. in small steps, over a relatively long time period. During this time period, multi-disciplinary environmental monitoring that is already underway will continue. The design of tide-control structures will allow adjustments in tide heights if monitoring shows changes that are inconsistent with project objectives. The model below (Figure 21) reflects the iterative process of adapting the management protocol to the observed results. It is proposed that incremental changes in tidal flow will be the responsibility of the Herring River Restoration Committee (HRRC), including the Towns of Wellfleet and Truro, and the National Park Service. This responsibility will be explained by the Memoranda of Understanding (MOUs) developed between the Towns and the NPS. An Operation and Management Agreement will be developed in accordance with the MOUs.

The components of the adaptive management plan for the Herring River project, which will be incorporated into the Operation and Management Agreement, are summarized as follows:

Restoration Objectives: the foundation of any such plan is a clear presentation of objectives, such that decisions and directions are formulated with continual reference to those goals.

Physical Controls: under any of the alternatives being considered for implementation, there are a number of variables to consider in controlling and managing tidal regimes, including where (within the river system), when and how much to increase tidal exchange. Given the presence or absence of social constraints (e.g. low-lying roads, the CYCC, etc.) some sub-basins can accommodate greater tidal range than others; thus physical controls need to be strategically located and sized. As mentioned above, both ecological (fish migrations) and social (summertime road use) constraints should dictate the timing of adjustments in tidal exchange. Step-wise culvert openings could be suspended or

Figure 21. Conceptual Model of an Interactive Adaptive Management Process



See text (p.95) for explanation.

implemented more slowly if monitoring indicates undesirable results. In short, the Herring River proposal contains numerous opportunities for application of control measures to manage the tidal regime under any of the proposed scenarios.

Hypothesized System Response: any of the tidal control scenarios will allow for projections of how the Herring River floodplain will respond in terms of tidal regime and associated effects to vegetation, sediment, water quality, flooding of properties, etc. An important step in the establishment of the tidal control scenarios will be to predict these effects to the degrees possible via modeling and other scientific/engineering applications.

Monitoring Projected Change: as each tidal regime adjustment is implemented, systematic monitoring will be conducted to measure environmental responses. Some of the components of the anticipated monitoring are summarized below.

Technical and Public Review of Monitoring Results: technical and public review of the Herring River restoration project has been a priority since inception. This aspect will continue to be an important part of the process during implementation and monitoring.

Criteria and Protocol for Changing Physical Controls and Managing Vegetation: vegetation management issues are discussed in Section 6 of this document; the criteria for implementing such management as well as for changing the physical controls will be further developed as part of the Detailed Restoration Plan. This will include the protocol for making such physical adjustments and implementing vegetation management.

In addition to the adaptive management issues that pertain to the Herring River floodplain overall, there are particular ecological and social concerns that need to be considered within specific sub-watershed areas. The matrix below (**Table 2**) attempts to summarize these, although it should be recognized that other issues may emerge. It is anticipated that the adaptive management program will consider and adjust for each of these concerns in site-specific detail.

7.1.1 Salt water intrusion

Nearly all residences surrounding the river floodplain derive their water supply from private wells set in the fresh groundwater aquifer. There have been concerns that the restoration of seawater flow across the floodplain could cause saltwater intrusion into some of these wells; however, work by US Geological Survey and National Park Service hydrogeologists has shown that very few of these wells could be adversely affected (Fitterman & Dennehy 1990, Martin 2004, Masterson 2004). In fact, most recent modeling indicates that restoring tides to diked marshes, and thereby increasing their average surface-water level, actually causes the adjacent freshwater aquifer to thicken (Masterson &

Table 2: Herring River Ecological and Social Concerns by Sub-watershed

Issues	Mouth of River	Lower Basin	Mill Creek	Lower Pole Dike Creek	Upper Pole Dike Creek	Duck Harbor	Bound Brook	Upper Basin	Pole Dike Creek above Route 6	Main Stem above Route 6
Marine biota	X	X	X	X	X	X	X	X	X	X
Floodwater mosquitoes		X	X	X	X	X	X	X	X	
Golf course flooding			X							
Low-lying roads		X		X	X		X	X	X	
Migratory fish	X	X	X	X	X			X	X	X
***Phragmites* control**		X	X				X			
Private structures		X	X		X					
Sediment & aquaculture	X	X								
Subsidence & hydroperiod		X	X	X	X	X	X			
Surface water quality	X	X	X	X	X	X	X	X	X	X
Groundwater quality		X	X		X		X			
Woody plant dieback		X	X	X		X	X	X	X	
Rare species - saline	X	X	X	X	X	X	X	X		
Rare species - freshwater			X	X	X		X	X		X

Garabedian 2007), providing even more protection from saltwater intrusion than exists under today's tide-restricted conditions. A nearly complete inventory and analysis of all private properties (nearly 200) within 250 feet of the expected spring-tide flooding height in the Herring River has at the date of this writing found only five vulnerable wells. Meanwhile, the USGS has installed and periodically monitors seven wells that penetrate the freshwater/saltwater interface in groundwater below developed uplands adjacent to the Herring River; this monitoring will continue both to test model predictions and to ensure that any rise in the fresh/salt interface, however unlikely, is documented.

Monitoring Results

The depth of the fresh/salt groundwater interface did not change between 1990 and 2003, meaning that the thickness of the freshwater aquifer did not change (Martin 2004).

Previous USGS studies showed that there was little chance that restoring the river would affect the private wells, as there were 20 meters of freshwater between the domestic well screens and the salt/freshwater interface (Fitterman & Dennehy 1991). Further study used computer modeling of groundwater flow to predict the thickness of the freshwater aquifer for different simulated conditions for opening or removing tidal control structures. The study showed that the freshwater aquifer would thicken, not thin, under all restoration scenarios unless it was assumed that undiluted seawater extending throughout the floodplain; this last is a highly unrealistic scenario, however, because discharging fresh groundwater will continue to mix with tidal seawater and yield a typical gradient in salinity from the mouth of the river upstream (Martin 2004).

7.1.2 Water column pH, and metals

Water quality is tested monthly at ten stations in the Herring River in locations from High Toss Road to Egg Island, including in the major tributary streams.

Monitoring Results

Monitoring has shown that the pH of the river is much lower (i.e., more acidic) upstream of the dike, especially in the vicinity of acid sulfate soils (Figure 8). PHs as low as 4 have been recorded within the river system, in contrast to the pH 8 in Wellfleet Harbor. Low pH can be directly toxic to fish, and can cause aluminum and other metals to leach from native clays in concentrations that further stress aquatic animals (Soukup & Portnoy 1986).

7.1.3 Fecal coliform

The presence of coliform bacteria has routinely necessitated the closure of shellfish beds at the mouth of the river. Shellflishing is currently prohibited upstream of the dike and for about 1000 meters downstream (Figures 9 and 13). Fecal coliform accumulate around tidal restrictions because of poor flushing (Portnoy & Allen 2006). The effects of the dike further compound the situation as lower salinity, lower pH, and lower dissolved oxygen, all found upstream of the dike, extend the lifetime of fecal coliform (Portnoy & Allen 2006). Fecal coliform bacteria are monitored at nine different surface water stations in the Herring River in locations from High Toss Road to Egg Island.

Monitoring Results

Monitoring by NPS indicates that the highest concentrations in river sediment occur from 200 to 1,400 meters above the dike.

7.1.4 Tide heights, salinity, and oxygen content

Tide heights, salinity, and oxygen levels in the river are monitored from June through September at a sampling station located approximately 1,200 meters above the dike, and in Wellfleet Harbor in the channel between Egg Island aquaculture beds and Great Island. In addition, APCC volunteers are monitoring porewater salinity in the root zone along wetland transects both seaward and above the dike structure to establish a baseline.

Monitoring Results

Monitoring indicates that tide heights, surface-water salinity, and dissolved oxygen are all at lower levels in the river upstream of the dike due to the tidal flow restriction. The entire main stream reach from the mid-Lower Basin to Route 6 is subject to summertime dissolved oxygen stress (Figure 6). Porewater salinities decline greatly with distance upland from the creek bank in the diked river.

7.1.5 Wetland water levels

Wetland water levels are lower throughout the floodplain due to diking and are predicted to recover once tides are restored (Spaulding & Grilli 2001, 2005). Wetland vegetation and biogeochemical cycling have been altered radically by the depression in wetland water levels since 1909, witness the extent of upland tree species (Figure 11) and acid sulfate soils (Figure 8) in the original saltmarsh. Currently, monthly monitoring occurs at five stations in the system.

7.1.6 Wetland vegetation and invasive species

Limiting tidal flow has resulted in the conversion of many tidal marsh habitats into shrub-dominant wetland habitats (Fig. 11) because the natural tidal flow regime has been eliminated. Currently, monitoring of wetland plant communities occurs at three year intervals and will be performed at two-year intervals following modification of the tidal control structure. Monitoring includes a minimum of four plant community sampling transects seaward of the dike and a minimum of ten sampling transects above the dike.

7.1.7 Wetland surface sedimentation

Monitoring sedimentation on the diked Herring River floodplain is especially important because much of the marsh plain has subsided about 80 cm and is now, relative to sea level, about a meter below the unrestricted saltmarshes seaward of the dike (Portnoy & Giblin 1997a). If the elevation of the wetland does not increase at a rate equal to or exceeding sea level rise, the sediment may remain waterlogged throughout the tidal cycle, discouraging the re-establishment of saltmarsh plants.

In order to monitor sediment elevation change, sediment elevation tables (SETs) are used; and in order to monitor sediment accretion, feldspar marker horizons are utilized (Northeast Coastal and Barrier Network 2005). Both of these devices were installed in 2000 at three tidally unrestricted sites downstream of the dike, three in *Phragmites* communities in the lower basin, and three in wetlands above High Toss Road.

7.1.8 Shellfish bed sedimentation

There is concern that tidal restoration may affect sedimentation seaward of the dike where there are extensive shellfish beds. Both hydrodynamic studies estimating current velocities (Spaulding & Grilli 2001, 2005) and an analysis of past and current sedimentation patterns in the river and Wellfleet Harbor (Dougherty 2004) provide strong evidence that there will

be little change in sediment transport seaward of the dike structure with tidal restoration. Nevertheless, NPS surveyed sediment grain size and organic content on aquaculture beds at Mayo Beach, Egg Island, Powers Landing and the town propagation beds in 2004, and plans to repeat the survey in 2007, with help from Wellesley College.

7.1.9 Shellfish

While monitoring the sediment quality of shellfish beds has been important, it is also important to monitor shellfish species occurrence and densities in the Herring River estuary. Routine shellfish bed closures gained the attention of the public and monitoring showed declining counts of shellfish in areas upstream of the dike (Roman 1987). Monitoring is performed in areas below (harbor-side) and above (upstream) the dike with a baseline year of 2005.

7.1.10 Estuarine fish

Estuarine fish monitoring occurs three times per year below and above the dike as well as along the Herring River upstream of High Toss Road.

Monitoring Results

Monitoring in the mid-1980s (Roman 1987) and more recently as part of the CCNS Inventory and Monitoring Program (Gwilliam 2005) showed that fish diversity and abundance declined with distance above the dike structure.

7.1.11 Birds

Previous studies (Roman 1987) have shown that diking has caused the occurrence of songbirds to become more frequent, while waterfowl and shorebird species have declined in abundance, with the shift from original open marsh and mudflat habitats to shrubs. Pre-restoration monitoring has been performed since 2004 by staff and qualified volunteers from the Massachusetts Audubon Society. Monitoring is completed at five locations in the lower Herring River, including Merrick Island at the old bridge, High Toss Bridge to the north, High Toss Bridge to the south, Herring River Dike to the north, and Herring River Dike to the south. All locations except at Merrick Island are monitored year-round on a monthly basis. Merrick Island counts take place weekly and only during the spring breeding season, from April to June.

The data compiled through the Audubon Society will become available in the fall of 2007.

7.1.12 Mosquitoes and other insects

Adult mosquito monitoring is performed by the Cape Cod Mosquito Control Project (CCMCP) weekly from June to September at a station near High Toss Road. It is anticipated that the CCMCP will continue its monitoring program, but will likely modify its protocols in response to post-restoration conditions and/or as per National Park Service recommendation. The monitoring of other insects may also be incorporated into a National Park Service program.