II. PREVIOUS STUDIES RELATED TO NITROGEN MANAGEMENT

In most marine and estuarine systems, such as the Little Pond embayment system in Falmouth, the limiting nutrient, and thus the nutrient of primary concern, is nitrogen. In large part, if nitrogen addition is controlled, then eutrophication is controlled. This approach has been formalized through the development of tools for predicting nitrogen loads from watersheds and the concentrations of water column nitrogen that may result. Additional development of the eutrophication management approaches via the reduction of nitrogen loads has also generated specific guidelines as to what is to be considered acceptable water column nitrogen concentrations to achieve desired water quality goals (e.g., see Cape Cod Commission 1991, 1998; Howes et al. 2003).

Until recently, these tools for predicting loads and concentrations tended to be generic in nature, and overlooked some of the site-specific characteristics associated with a given water body. The present Massachusetts Estuaries Project (MEP) study focuses on linking water quality model predictions, based upon watershed nitrogen loading and embayment recycling and system hydrodynamics, to actual measured values for specific nutrient species. The linked watershed-embayment model is built using embayment specific measurements, thus enabling calibration of the prediction process for specific conditions in each of the coastal embayments of southeastern Massachusetts, including the Little Pond System.

The Town of Falmouth, Massachusetts, has long recognized the potential threat of nutrient over-enrichment of its coastal salt ponds and embayments. In the mid-1980's the Town enacted an innovative Nutrient Overlay By-law that tied watershed development to water quality within the adjacent embayment. The goal was to keep nitrogen concentrations in the receiving systems below thresholds that were projected to cause water quality shifts. A water quality monitoring program, Falmouth PondWatch, was established to provide on-going nutrient related embayment health information in support of the By-law. Little Pond was among the first three Ponds (Oyster Pond, Little Pond, Green Pond) to undergo water quality monitoring in the Town of Falmouth. These approaches were primarily initiated for planning as development within coastal watersheds progressed. Falmouth's Planning Department has continued to enhance its tools for gauging future nutrient effects from changing land-uses. The GIS database used in the present study is part of that continuing effort. Unfortunately, monitoring has documented that most regions within the Town's coastal ponds are currently showing water quality declines and are beyond the limits set by the By-law.

Data generated by the Falmouth PondWatch program has yielded clear indications of impairment to the Little Pond system and has assisted the Town in the development of initial management options for improving the ecological health of the system. Specifically, the PondWatch program water quality database for Little Pond assisted the Town of Falmouth in the design and permitting of the redesign of the inlet between Little Pond and Vineyard Sound thereby allowing increased flushing of the overall system, as the channel from Vineyard Sound to the Little Pond lower basin was opened (dredged). The new inlet to Little Pond was completed in February of 1995. The inlet cross-section was widened to allow greater water exchange with the small tides in Vineyard Sound (<0.5m), however, the total cross-section was only slightly increased to prevent the potential of increased flooding of upland areas during storm tides. Despite initial management efforts for improving the habitat health of Little Pond, as has been observed in other Falmouth salt ponds in the vicinity of Little Pond (e.g. Great Pond, Green Pond, Bournes Pond), Little Pond exhibits high nutrient levels and periodic oxygen depletions in its upper reaches and water column nutrient levels exceed those historically specified by the Falmouth Nutrient Overlay Bylaw.

Based on the summary of results from the 1994 and 1995 water quality sampling seasons Little Pond shows characteristics of a eutrophic coastal salt pond with high nutrient loads. At the time of sampling in 1994 and 1995 nitrogen levels in the pond consistently exceeded limits set by the above mentioned Nutrient Bylaw. The high nitrogen levels reported within the system were primarily responsible for periodic and often severe low oxygen events experienced in the pond. Additionally, the effect of regular oxygen stress within Little Pond resulted in impoverished or non-existent benthic animal communities by the end of both the 1994 and 1995 summer seasons. Eelgrass beds were reported to have all but disappeared reflecting limited watercolumn transparency due to increased phytoplankton production. As well, macroalgal blooms leading to floating mats on the water surface have led to further declines in oxygen conditions. These conditions have persisted in the intervening years and accurately describe the present water quality of Little Pond.

At the time of the 1995 summer sampling season, the enlarged, modified inlet to Little Pond had only been in place for approximately five months and the strong gradient in nitrogen, oxygen and turbidity from the inlet to the headwaters of the pond remained similar to previous years. As of the summer 1995 sampling period, there appeared to be a reduction in macro-algae in the pond but water clarity and nutrient levels were similar to 1994 levels. Similarly, although PondWatch sampling suggested that oxygen levels may have been improving slightly, an oxygen mooring placed at a central location in the pond during what is generally considered the lowest oxygen period indicated short term anoxia. The observed oxygen levels measured by the mooring in 1995 were similar to oxygen levels obtained by moored oxygen instruments deployed in Little Pond in previous years. According to the of results from the 1994 and 1995 water quality sampling seasons, the new inlet had not created a significant change in the nutrient water quality of the pond. At the time, this was not an unexpected finding given the short interval between installation of the widened inlet and the 1995 summer field sampling. More importantly, dredging of the channel through the flood tidal delta had not yet been undertaken.

Concurrent with the water quality monitoring of Little Pond as initiated by the Falmouth PondWatch program, estuarine research was being conducted on the system yielding an additional level of understanding regarding primary production within this salt pond system, the ponds oxygen status and freshwater flows (groundwater and surfacewater) to the pond. As early as the summer of 1989 a study was undertaken in Little Pond to ascertain the effects of sampling frequency on measurements of seasonal primary production and oxygen status in near-shore coastal ecosystems (Taylor and Howes, 1994). During the June to December 1989 measurement period oxygen levels near the sediment surface (~15 cm) showed large and high frequency fluctuations with 5 to 8 sustained periods of hypoxia (DO < 50% atmospheric equilibrium. Additionally, oxygen levels in the summer of 1989 showed reduced levels during a week long event in mid-June, a 3 week event between July and August, and several day events in September, October and November. The most sustained oxygen depletion was correlated with a large six week bloom occurring in July and August of 1989. During and after the bloom the physical and biological processes of oxygen re-supply to the pond water column were barely able to keep up with the oxygen demand of the environment. Though the study did not specifically and directly attribute the low oxygen conditions to nutrient loading, it clearly revealed that the Little Pond system was experiencing periods of oxygen stress indicating a level of habitat impairment.

Additional research was undertaken within the Little Pond system towards refining patterns of freshwater flow as both a groundwater and surface water input and the effect of flow patterns on nutrient transport to the system. In short, groundwater was shown to dominate the freshwater budget to Little Pond, accounting for greater than 95 percent of the total annual input (Millham and Howes, 1994). Furthermore, the groundwater portion of the freshwater budget was nearly equally partitioned between direct groundwater seepage to the embayment waters and groundwater seepage to a stream with final discharge as surfacewater flow. As is common with many embayments on Cape Cod, freshwater inputs showed a rapid decrease toward the mouth of the estuary and greater than 80 percent of the freshwater input being introduced to the Little Pond system within the upper half. This characteristic will ultimately have management implications relative to the effectiveness of nutrient load removals as groundwater/surfacewater discharges focus the introduction of watershed generated nutrients in the head of the embayment system.

As part of on-going research and engineering efforts related to Little Pond, the geologic history of the pond was determined as was the recent history of shoreline change (See Section V). The short and long term trends in coastal processes as relate to the ecological health of Little Pond set an important background for the present restoration and management of this system. In addition, the previous studies of Little Pond dissolved oxygen status, groundwater and surface water hydrology provide an important basis for comparison to recent MEP measurements and help to establish the degree of stability of current conditions. In addition, for the MEP modeling analysis, the data from the previous studies were evaluated relative to the needs of the Linked Watershed-Embayment Model.