# II. PREVIOUS STUDIES RELATED TO NITROGEN MANAGEMENT

Nutrient additions to aquatic systems cause shifts in a series of biological processes that can result in impaired nutrient related habitat quality. Effects include excessive plankton and macrophyte growth, which in turn lead to reduced water clarity, organic matter enrichment of waters and sediments with the concomitant increased rates of oxygen consumption and periodic depletion of dissolved oxygen, especially in bottom waters, and the limitation of the growth of desirable species such as eelgrass. Even without changes to water clarity and bottom water dissolved oxygen, the increased organic matter deposition to the sediments generally results in a decline in habitat quality for benthic infaunal communities (animals living in the sediments). This habitat change causes a shift in infaunal communities from high diversity deep burrowing forms (which include economically important species), to low diversity shallow dwelling organisms. This shift alone causes significant degradation of the resource and a loss of productivity to both the local shell fisherman and to the sport-fishery and offshore fin fishery, which are dependant upon these highly productive estuarine systems as a habitat and food resource during migration or during different phases of their life cycles. This process is generally termed “eutrophication” and in embayment systems, unlike in shallow lakes and pond, it is not a necessarily a part of the natural evolution of a system.

In most marine and estuarine systems, such as the Lewis Bay System, 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 approach 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. 2002).

These tools for predicting loads and concentrations tend to be generic in nature, and overlook some of the specifics for any 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 Lewis Bay System. As the MEP approach requires substantial amounts of site specific data collection, part of the program is to review previous data collection and modeling efforts. These reviews are both for purposes of “data mining” and to gather additional information on an estuary’s habitat quality or unique features.

A number of studies relating to nitrogen loading, hydrodynamics and habitat health have been conducted within the Lewis Bay System over the past decade. A preliminary analysis of the circulation and nitrogen loading was performed, ca. 2001 for the Bureau of Resource Protection, Massachusetts Department of Environmental Protection (Tetra Tech EM Inc. 2005). The study was an initial assessment of watershed nitrogen loading to Lewis Bay (inclusive of Parker’s River and Swan Pond). The project employed an earlier generation watershed loading model (Waquoit Bay Nitrogen Loading Model, Valiela et. al., 1996), which pre-dates the MEP Linked Watershed-Embayment Modeling Approach. Loading was based upon a historical watershed derived by the Cape Cod Commission based upon available water table elevations. The watershed loading estimates were based upon MASSGIS land-use data, rather than local

municipal assessors data. No site specific nitrogen attenuation measurements were made relative to the surface freshwater systems within the Bay's watershed and approximations were used to determine the load from the Hyannis WWTF. The hydrodynamic modeling employed RMA Numerical Models, but collection of data against which the model performance could be assessed, was limited by the project's scope. For example, two tide gages were deployed for 29 days in the summer of 2001, one in upper Lewis Bay and the other in Mill Creek in order to calibrate the hydrodynamic model simulations, however the offshore driving tide was not measured.

Review of the results relative to the Lewis Bay system, brought forward a variety of issues, summarized below:

- This model is not calibrated nor validated relative to Total Nitrogen within the waters of the Lewis Bay System (i.e. modeled results were not compared to observation data).

- The watershed N model employed general nitrogen loading and attenuation factors and is not site specific (an occupancy rate of 1.79 people per house for each system compared to the 2000 Census data which lists Barnstable as having a rate of 2.44). No assessment of seasonal occupancy was made.

- As regards the WWTF nitrogen plume analysis:

    1. Total Nitrogen levels in discharged effluent estimates were based upon only inorganic forms (ammonium and nitrate), without inclusion of the organic fraction;

    2. Ratios of TN/Cl from 4 groundwater sampling wells at various distances from the discharge site were used to determine denitrification during transport using a linear regression approach, but the statistical analysis showed a very weak relationship, with the near regressions functionally based on a single point. The result suggested a 57% loss of nitrogen during aquifer transport, in spite of detailed wastewater plume studies by the USGS (Ashumet Valley Plume, Tri-Town Septage Facility in Orleans) and MEP (West Falmouth WWTF) showing negligible removal in Cape Cod soils;

    3. Much of the error in the WWTF TN load can be attributed to the assumption by the project team that the effluent discharge was ca. 28 mg N/L, rather than the 5 mg N/L measured by the facility as part of its discharge permit.

Given that this was a preliminary effort and did not use site-specific land-use or nitrogen attenuation factors, had limited data collection to support the hydrodynamic modeling and did not calibrate/validate the water quality model, and since the watershed delineation has been refined by the MEP and USGS using the West Cape groundwater model, the MassDEP has determined that the present MEP assessment and modeling effort should supersede its previous project and provides the sufficient accuracy for watershed nitrogen management planning, under the CWMP process.

An important ecological restoration effort within the Lewis Bay System has recently been initiated by the US Army Corps of Engineers in collaboration with the Town of Barnstable. The project is focused upon the restoration of the Stewarts Creek Salt Marsh, which is tidally restricted at its outlet to Hyannis Harbor (Stewarts Creek Restoration Project) Stewarts Creek is

a 55 acre tidal wetland site whose inlet has been restricted by a roadway/culvert. The salt marsh pond drains into Hyannis Harbor through a 60-foot-long, 3-foot diameter culvert, and the restriction has resulted in degradation of the salt marsh system. The major feature of the project includes the construction of a new, larger inlet to the pond to replace the existing culvert. Improving tidal flow is expected to restore the degraded salt marsh and riverine/ benthic habitat, including open water habitat. The restoration is scheduled to start in October of 2007 and be completed in 2008.

The Towns of Barnstable and Yarmouth, while both being actively engaged in the study and management of municipal infrastructure and natural resources, committed early on to gathering baseline water quality monitoring data in support of the MEP. Each Town operates a Water Quality Monitoring Program collecting water quality data on all of its embayment systems. The focus of the effort has been to gather site-specific data on the current nitrogen related water quality to support evaluations of observed water quality and habitat health. Water quality monitoring of the Lewis Bay System has been a joint coordinated effort initiated in 2001 with support from Three Bays Preservation and the Coastal Systems Programs at SMAST-UMD. The Barnstable/Yarmouth Water Quality Monitoring Program for Lewis Bay developed the baseline data from sampling stations distributed throughout the main basin and its tributaries (Figure II-1). Additionally, as remediation plans for this and other various systems are implemented throughout the Towns of Barnstable and Yarmouth, the continued monitoring is planned to provide quantitative information to the Towns relative to the efficacy of remediation efforts.

The joint Town of Barnstable/Yarmouth Water Quality Monitoring Program provided the quantitative water column nitrogen data (2001-2006) required for the implementation of the MEP's Linked Watershed-Embayment Approach. The MEP effort also builds upon previous watershed delineation and land-use analyses, the previous embayment hydrodynamic and water quality modeling and historical eelgrass surveys. This information is integrated with MEP higher order biogeochemical analyses and water quality modeling necessary to develop critical nitrogen targets for the Lewis Bay Estuarine System. The MEP has incorporated all appropriate data from all previous studies to enhance the determination of nitrogen thresholds for the Lewis Bay System and to reduce costs to the Towns of Barnstable and Yarmouth.

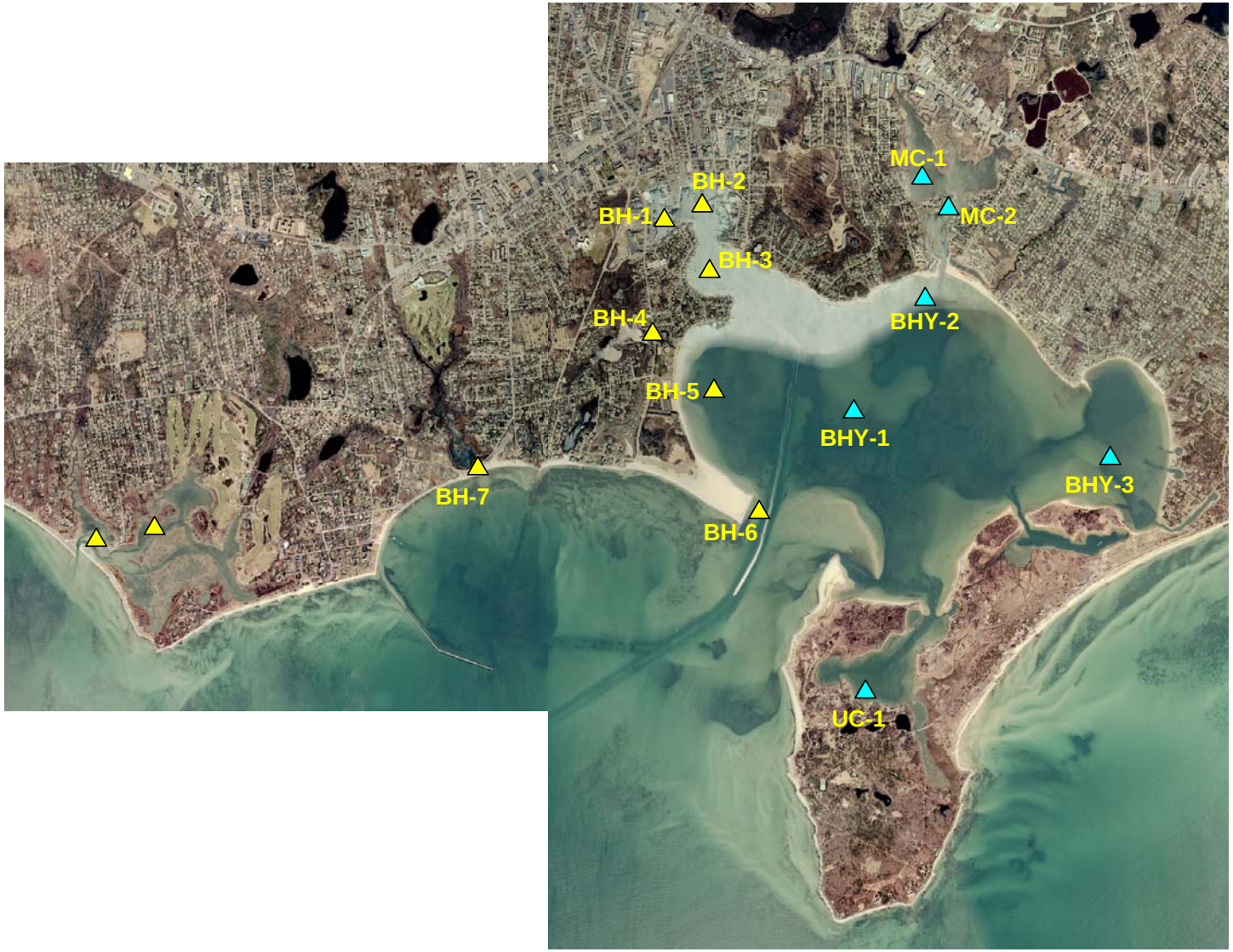


Figure II-1. Town of Barnstable/Yarmouth Water Quality Monitoring Program. Estuarine water quality monitoring stations sampled by the Town and volunteers. Stream water quality stations sampled weekly by the MEP. Halls Creek along the eastern shore of Centerville Harbor will be assessed in a future MEP Technical Report on the Lewis Bay System.