II. PREVIOUS NITROGEN MANAGEMENT STUDIES

Nutrient additions to aquatic systems can lead to a series of processes in a water body that result in impaired water quality. Effects include excess plankton and macrophyte growth, which in turn lead to reduced water clarity, excess organic matter, the development of lowered dissolved oxygen, especially in bottom waters, and the limitation of the growth of desirable species such as eelgrass. In most marine and estuarine systems, such as those that make up the coastal embayments of Chatham, 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).

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 is an attempt to link water quality model predictions to actual measured values for specific nutrient species thereby enabling calibration of the prediction process for specific conditions in each of the coastal embayments of southeastern Massachusetts, beginning with the embayment systems located in the Town of Chatham.

The first steps of the MEP nutrient analysis process implemented in the Town of Chatham were to measure physical conditions in the various water bodies and to develop hydrodynamic models to simulate and quantify the transport of water in and out of the embayments. This allowed tidal flushing to be evaluated. The results of this work are reported in Kelley, *et al.* (2001). Based on those findings, and on additional biological and chemical measurements made within the embayments, a water quality model was developed that used the tidal flushing inputs and simulated the calculated and measured nitrogen loads to the embayments. This model was then calibrated in a process that rationalizes the resulting calculated water column concentrations with measured values from monitoring programs over the past four years. The water quality model then becomes a predictive tool for evaluating the effects of various nitrogen loading scenarios on nitrogen concentrations in the embayments.

The concern about excessive nitrogen loading to the water bodies in the Chatham study area is evidenced by the number of studies and analyses conducted over the past 10 years. This section summarizes these studies in chronological order to help put the present study in historical perspective.

The first identified study that addresses nitrogen problems in Chatham is the Comprehensive Harbor Management Plan (HWH, 1992). The harbor plan focuses on the Stage Harbor system consisting of Stage Harbor, Mitchell River, Mill Pond (and Little Mill Pond), Oyster Pond and Oyster River. The water quality section inventories the existing water quality and presents an analysis of threats to water quality. The only existing water quality data presented in Comprehensive Harbor Management Plan were fecal coliform measurements at a series of stations in the Stage Harbor system. The analyses of threats to water quality in the system were broken down into six general source types: stormwater runoff, sewage, fertilizers and pesticides, animal waste, household hazardous waste and marinas. The first four are capable of increasing nitrogen levels in the ponds, contributing to eutrophication in this system.

The analysis presented in HWH (1992) predicts levels of nitrogen entering the Stage Harbor system in historical, present and future land use development. This approach requires that a "buildout" analysis be performed to estimate the potential number of additional residences that could be constructed under present zoning regulations. These residences generate additional nitrogen loadings that reach the Stage Harbor system through both surface runoff and groundwater. The study then examined the quantity of nitrogen, expressed as total nitrogen (TN), coming from each source. For the effluent emanating from individual septic systems the analysis used a TN concentration of 40 mg/L and a flow rate of 55 gallons per day for two occupancy rates, depending on the time of year: 1.86 and 3 people per unit. A review was also conducted on leaching rates for fertilizer resulting in an average estimate of 3 pounds per 1000 ft^2 applied to an average lawn size of 6000 ft^2 with approximately 18 inches/year of precipitation entering the groundwater. Pavement and roof runoff TN concentrations were estimated as 2 mg/L and 0.75 mg/L, respectively, with direct runoff flow of 40 inches/year. Precipitation causes direct deposition of nitrogen to the system watershed. Since vegetation removes most of the dissolved nitrogen, a background source concentration of 0.05 mg/L was used for groundwater while direct precipitation to the water bodies was estimated as 0.3 mg/L of dissolved inorganic nitrogen.

Using estimates of flushing from each of the water bodies in the Stage Harbor system an evaluation was performed on resulting nitrogen loadings to be expected in the estuaries. Oyster Pond, Oyster River and Mitchell River were found to approach or exceed the Buzzards Bay recommended limits for shallow, rapidly flushed water bodies for present and future buildout conditions. Stage Harbor, being directly connected to Nantucket Sound with a higher flushing rate, and Mill Pond, being deeper and supposedly able to assimilate more nitrogen, were found to be within the limits. Calculations were also performed for dredging and shoaling alternatives.

The Cape Cod Commission (CCC) conducted a nitrogen loading study for the Pleasant Bay system to determine the maximum allowable loads that 16 subembayments could tolerate based on a series of regulatory limits (CCC, 1998). The CCC began the study by delineating the watersheds that drain into the various subembayments and that provide the nitrogen loads. Land use was determined using data within the CCC's GIS system and then modified as needed in consultation with the local communities. The CCC staff then used their loading protocol as defined in Technical Bulletin 91-001 (CCC, 1991). This protocol assigns loading from a variety of land use types in a generally similar manner as was done by HWH (1992) for the Stage Harbor system. Total nitrogen concentrations from wastewater were assumed to be 35 mg/L; 1.5 mg/L for road runoff; 0.75 mg/L for roof runoff and direct precipitation; and 0.05 mg/L for natural area runoff. Average residential lawn size was assumed to be 5000 ft^2 with a fertilizer application rate of 3 lb/1000 ft^2. Recharge rates used were 40 in/yr for impervious surfaces and 16 in/yr (Brewster, Harwich) or 17 in/yr (Chatham, Orleans, Eastham, Wellfleet, Truro, Provincetown) for natural areas. Both existing and buildout conditions were analyzed. Flushing times were determined for each embayment for both existing and pre-break inlet configurations.

The resulting nitrogen loads were compared to critical levels, here defined as the Buzzards Bay Project Outstanding Resource Waters (BBP ORW) and Outstanding Resource Waters – Nitrogen (ORW-N) limits. Within the Chatham part of the study area, it was found that Muddy Creek exceeded both the nitrogen limits for both configurations while Ryder Cove exceeded the ORW-N limit with the pre-break configuration. This pattern was repeated for the same water bodies under the buildout scenario but with greater exceedences. In addition, difficulties in predicting the change in offshore nitrogen concentrations as New Inlet migrated

south to its pre-breach condition (directed toward Nantucket Sound rather than the Atlantic Ocean) made future evaluation of critical nitrogen loads questionable.

The Pleasant Bay Resource Management Plan was prepared by the Pleasant Bay Technical Advisory Committee and Ridley & Associates, Inc. (PBTSC and Ridley & Associates, 1998). The purpose of the plan was not only to reconcile both sustainability and restoration of the Pleasant Bay ecosystem but also to enhance public access and enjoyment of the bay, encouraging recreational, residential and commercial use consistent with resource sustainability. The management plan referred to the CCC study for analyses of nutrient loading and water quality and advocated continued monitoring of the water body.

The most recent study of nitrogen loading to the Chatham study area was performed by Stearns & Wheler as part of its needs assessment for the Chatham wastewater management planning study (Stearns & Wheler, 1999). The study area was divided into three groups that were analyzed separately: Pleasant Bay Region, Stage Harbor System, and the South Coast Embayments (see Figure I-1). The study followed a similar protocol as the earlier studies: use of existing subwatersheds information, calculation of existing and future nitrogen loading to each water body based on land use in its subwatershed, calculation of steady-state nitrogen concentration to be expected based on flushing rate estimates, and finally, comparison of calculated loading to critical nitrogen loading limits to determine if exceedences should be expected, or at what point exceedences may occur as a result of buildout.

An analysis of existing loading to the Pleasant Bay systems embayments was based on the previous Pleasant Bay study by the CCC (1998). An analysis of the existing loading to the Stage Harbor system embayments was based on the previous Stage Harbor study by HWH (1992), and included additional estimates modified to incorporate actual 1997 water use in the watersheds. The south coast embayments had not been previously studied. Therefore these embayment loadings were determined from the CCC protocol using three approaches: Technical Bulletin 91-001 (CCC, 1991), actual 1997 water consumption, and estimates from Title 5 design flows. The loadings based on actual water consumption were lowest of the three and thought to be the most accurate. It was found that the existing nitrogen loadings for all embayments are lower than the critical nitrogen loading for the BBP-SA standard. Taylor Pond and Sulphur Springs exceeded the more stringent ORW-N standard. The analysis was repeated for future seasonal and year round buildout conditions.

Similar to previous studies, the 1999 Stearns & Wheler analysis utilized the Buzzards Bay Project methodology (EPA, 1991) that incorporated a simplistic approach aimed at general planning analyses that was based on “local” residence times. First, this method assumes that tidal waters exiting from a sub-embayment during the ebb cycle are totally replaced with “pristine” water from the downstream sub-embayment. While this assumption may be valid for the main portion of Stage Harbor, where tidal waters are exchanged directly with Nantucket Sound, it is not valid for sub-embayments such as Little Mill Pond, where tidal waters are exchanged with nutrient over-loaded Mill Pond. Secondly, the absence of eelgrass in much of Oyster Pond, Little Mill Pond, and Mill Pond (MassGIS, 1994) indicate embayments exhibiting ecological stress. The existence of sparse/patchy eelgrass beds in portions of these embayments indicates a long-term decline in water quality.

Signs of ecological deterioration and overall habitat stress within all of the Chatham embayment systems prompted the actual measurement of nitrogen concentrations in these embayment systems as initiated in 1998 (Duncanson, 2000; Howes and Schlezinger, 2000). The results of the multi-year water quality monitoring effort begun in 1998 were combined with

additional levels of analysis including embayment specific hydrodynamic modeling, water quality modeling, and habitat assessment (Kelley *et al*., 2001 and Applied Coastal *et al*., 2001). Based on the site-specific nutrient analysis for the coastal embayment nutrient threshold development, it appeared that most of the sub-embayments in Chatham already exceeded some or all of the total nitrogen-based water quality criteria used to evaluate critical nitrogen loads.

The water quality analysis and modeling effort in 2001 (Kelley *et al*., 2001) represented an initial effort at the linked water quality modeling approach; however, limitations in the embayment water quality data set and data gaps precluded accurate calibration of the water quality model. Specifically, major shortcomings that limited the utility of the analysis included inconsistent water column nitrogen concentrations in the Bassing Harbor system with regards to the ecological health of the system and incorrect watershed loading to the Mill Creek/Taylors Pond computed by the Town's wastewater engineering consultant (Stearns and Wheler).

To address some of the shortcomings inherent in the 2001 study, the Town funded EarthTech to model the impact of drinking water wells and the existing wastewater treatment facility on the Mill Creek/Taylors Pond watershed. In addition, water column nitrogen measurements have continued since 2001 and updated benthic flux measurements were obtained within the Bassing Harbor system. This additional information was incorporated into the MEP study to improve the water quality analysis of Chatham's coastal embayments.

The indication of a long term decline in water quality and habitat health throughout the Chatham embayment systems is fully explored in this MEP critical nutrient threshold report and incorporates a detailed discussion of historic changes in benthic communities (Section VII). The 4-year water quality monitoring effort combined with the historic information on the benthic community forms the basis for determining appropriate site-specific nutrient thresholds.

Although some researchers, including the CCC, have utilized the Buzzards Bay Project methodology as a general planning tool for determining critical nitrogen loads, it is inappropriate for developing site-specific guidelines regarding nitrogen loading limits. For the Pleasant Bay Region, the Stage Harbor System, and the South Coast Embayments (Figure I-1), water column MEP data indicate that all of Chatham's systems currently show nutrient related degradation of estuarine habitat. In addition, limits indicative of maintaining healthy shellfish resources also are exceeded in most systems, where the nitrogen level is higher than 0.15 mg/L over background concentrations in Nantucket Sound or the Atlantic Ocean (Cape Cod Commission, 1998). Since the site-specific data supercedes information obtained from the more generic calculations utilizing the Buzzards Bay Project methodology, future nitrogen management decisions should incorporate information obtained directly from Chatham's coastal embayments. The MEP approach presented in this report develops site-specific critical nutrient thresholds for the five Town of Chatham embayment systems addressed in this report.