# FINAL
# Little Pond
# Embayment System
# Total Maximum Daily Loads
# For Total Nitrogen
## (Report # 96-TMDL-8
## Control #246)


**COMMONWEALTH OF MASSACHUSETTS**
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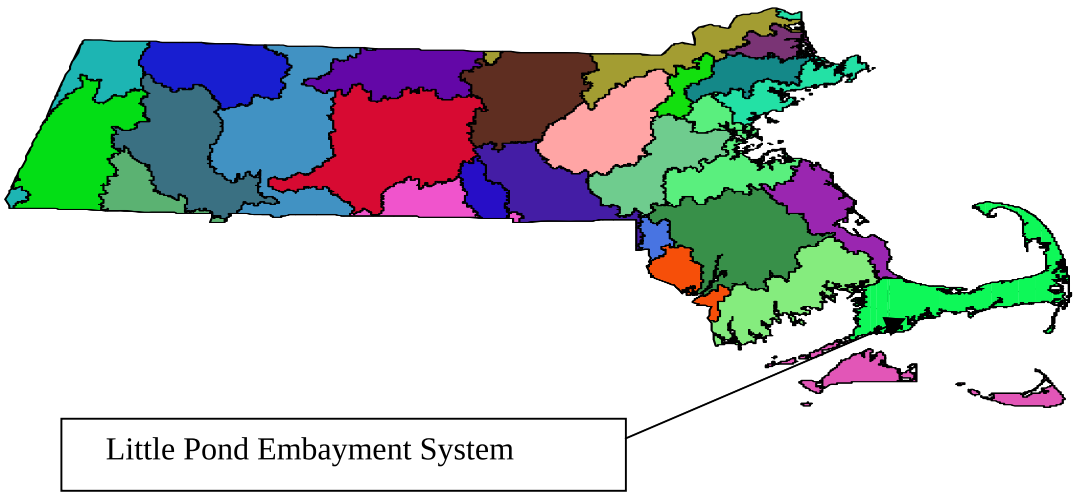



**Key Feature:** Total Nitrogen TMDL for Falmouth
**Location:** EPA Region 1
**Land Type:** New England Coastal
**303d Listing:** The waterbody segments impaired and on the Category 5 list includes Little Pond.

**Data Sources:** University of Massachusetts – Dartmouth/School for Marine Science and Technology; US Geological Survey; Applied Coastal Research and Engineering, Inc.; Cape Cod Commission, Town of Falmouth
**Data Mechanism:** Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model
**Monitoring Plan:** Town of Falmouth monitoring program (possible assistance from SMAST)
**Control Measures:** Sewering, Storm Water Management, Attenuation by Impoundments and Wetlands, Fertilizer Use By-laws

# EXECUTIVE SUMMARY

## Problem Statement

Excessive nitrogen (N) originating primarily from on-site wastewater disposal (both conventional septic systems and innovative/alternative systems) has led to significant decreases in the environmental quality of coastal rivers, ponds, and harbors in many communities in southeastern Massachusetts. In the coastal waters of Massachusetts the problems include:

- Loss of eelgrass beds, which are critical habitats for macroinvertebrates and fish
- Undesirable increases in macro algae, which are much less beneficial than eelgrass
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life
- Reductions in the diversity of benthic animal populations
- Periodic algae blooms

With proper management of nitrogen inputs these trends can be reversed. Without proper management more severe problems might develop, including:

- Periodic fish kills
- Unpleasant odors and scum
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities

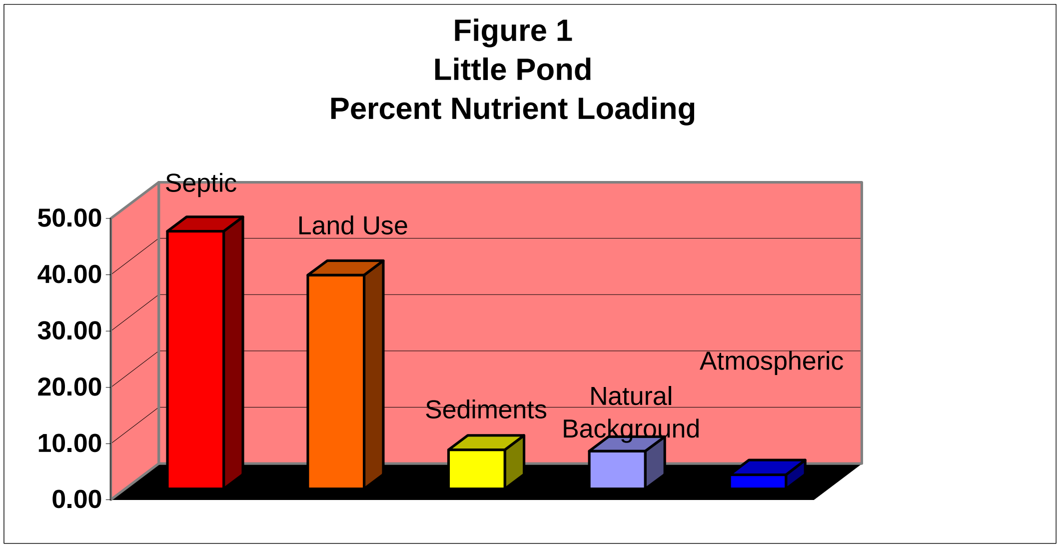
Coastal communities, including Falmouth, rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings will result in complete replacement of eelgrass by macro-algae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a complete loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of the Little Pond Embayment System will be greatly reduced, and could cease altogether.

## Sources of nitrogen

Nitrogen enters the waters of coastal embayments from the following sources:

- The watershed
    - On-site subsurface wastewater disposal systems
    - Natural background
    - Runoff
    - Fertilizers
    - Wastewater treatment facilities
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments

Most of the present controllable N load originates from individual subsurface wastewater disposal (septic) systems, primarily serving individual residences, as seen in the following figure.




**Target Threshold Nitrogen Concentrations and Loadings**
The N loadings (the quantity of nitrogen) to the Little Pond embayment system is 22.76 kg/day. The resultant concentrations of N in this embayment range from 3.18 mg/L (milligrams per liter of nitrogen) at the head of Little Pond to 0.49 mg/L in the lower section of Little Pond.

In order to restore and protect this embayment system, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below the thresholds that cause the observed environmental impacts. This concentration will be referred to as the target threshold Nconcentration. It is the goal of the TMDL to reach this target threshold N concentration, as it has been determined for each impaired waterbody segment. The Massachusetts Estuaries Project (MEP) has determined that, for this embayment system, an N concentration of 0.45 mg/L is protective of water quality standards. The mechanism for achieving this target N concentration is to reduce the N loadings to the embayment. Based on the MEP work and their resulting Technical Report, MassDEP has determined that the Total Maximum Daily Load (TMDL) of N that will meet the target threshold is 7 kg/day. This document presents the TMDL for this water body segment and provides guidance to Falmouth on possible ways to reduce the nitrogen loadings to within the recommended TMDL, and protect the waters for this embayment.

**Implementation**
The primary goal of implementation will be lowering the concentrations of N by greatly reducing the loadings from on-site subsurface wastewater disposal systems through a variety of centralized or decentralized methods such as sewering and treatment with nitrogen removal technology, advanced treatment of septage, and/or installation of N-reducing on-site systems.

These strategies, plus ways to reduce N loadings from stormwater runoff and fertilizers, are explained in detail in the "MEP Embayment Restoration Guidance for Implementation Strategies", that is available on the DEP website at: http://www.mass.gov/dep/water/resources/coastalr.htm. The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an adaptive management approach.

Finally, growth within the community of Falmouth that would exacerbate the problems associated with N loadings, should be guided by considerations of water quality-associated impacts.

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## Introduction

Section 303(d) of the Federal Clean Water Act requires each state (1) to identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL allocation establishes the maximum loadings (of pollutants of concern), from all contributing sources, that a water body may receive and still meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.

2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point sources (discernable, confined, and concrete sources such as pipes) and non-point sources (diffuse sources that carry pollutants to surface waters through runoff or groundwater).

3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.

4. Specification of load allocations, based on the loading capacity determination, for non-point sources and point sources, that will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDL will serve as a guide for future implementation activities. The MassDEP will work with the Town to develop specific implementation strategies to reduce N loadings, and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Little Pond Embayment System, the pollutant of concern for this TMDL (based on observations of eutrophication), is the nutrient N. Nitrogen is the limiting nutrient in coastal and marine waters, which means that as its concentration is increased, so is the amount of plant matter. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton that impair eelgrass beds and imperil the healthy ecology of the affected water bodies.

The TMDL for total N for the Little Pond Embayment System is based primarily on data collected, compiled, and analyzed by University of Massachusetts Dartmouth's School of Marine Science and Technology (SMAST), the Cape Cod Commission, and others, as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from 1997 to 2004. This study period will be referred to as the "Present Conditions" in the TMDL since it contains the most recent data available. The accompanying MEP Technical Report can be found at http://www.oceanscience.net/estuaries/reports.htm. The accompanying MEP Technical Report presents the results of the analyses of this coastal embayment system using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model). The analyses were performed to assist Falmouth with decisions on current and future wastewater planning, wetland restoration, anadromous fish runs, shellfisheries, open-space, and harbor maintenance programs. A critical element of this approach is the assessment of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure that was conducted on this embayment. These assessments served as the basis for generating an N loading threshold for use as a goal for watershed N management. The TMDL is based on the site specific threshold generated for this embayment. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision making process in the Town of Falmouth.

## Description of Water Bodies and Priority Ranking

The Little Pond Embayment System in Falmouth, Massachusetts, at the southwestern edge of Cape Cod, faces Vineyard Sound to the south, and consists of a single embayment with varying hydraulic complexity, characterized by limited rates of flushing, shallow depths, and heavily developed watersheds (see Figure 2 on following page). This embayment system constitutes an important component of the Town's natural and cultural resources. The nature of enclosed embayments in populous regions brings two opposing elements to bear: 1) as protected marine shoreline they are popular regions for boating, recreation, and land development and 2) as enclosed bodies of water, they may not be readily flushed of the pollutants that they receive due to the proximity and density of development near and along their shores. In particular, the Little Pond Embayment System is at risk of further eutrophication from high nutrient loads in the groundwater and runoff from its watershed. This embayment system is already listed as a waterbody segment requiring a TMDL (Category 5) in the MA 2004 Integrated List of Waters, as summarized in Table 1A.

**Table 1A. The Little Pond Embayment System Waterbody Segment in Category 5 of the Massachusetts 2006 Integrated List**

| NAME | WATERBODY SEGMENT | DESCRIPTION | SIZE | Pollutant Listed |
|---|---|---|---|---|
| **Little Pond System** | | | | |
| Little Pond | MA96-56_2004 | West of Vista Boulevard, outlet to Vineyard Sound, Falmouth | 0.07sq mi | -Nutrients |

A complete description of this embayment system is presented in Chapters I and IV of the MEP Technical Report. A majority of the information on this embayment system is drawn from this report. Chapter VI and VII of the MEP Technical Report provide assessment data that show that the Little Pond embayment system is impaired because of nutrients, eelgrass, low dissolved oxygen levels, elevated chlorophyll *a* levels, and benthic fauna habitat. Please note that pathogens are listed in Tables 1A and 1B for completeness. Further discussion of pathogens is beyond the scope of this TMDL.

**Table 1B. Comparison of impaired parameters for the Little Pond Embayment System**

| NAME | DEP Listed Impaired Parameter | SMAST Listed Impaired Parameter |
|---|---|---|
| **Little Pond System** | | |
| Little Pond | -Nutrients | -Nutrients<br>-Eelgrass<br>-DO level<br>-Chlorophyll<br>-Benthic fauna |

The embayment addressed by this document is determined to be a high priority based on 3 significant factors: (1) the initiative that the Town has taken to assess the conditions of the entire embayment system, (2) the commitment made by the Town to restore and preserve the embayment, and (3) the extent of impairment in the embayment. In particular, this embayment is at risk of further degradation from increased N loads entering through groundwater and surface water from their increasingly developed watersheds. In both marine and freshwater systems, an excess of nutrients results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources. The general conditions related to the major indicators of habitat impairment, due to excess nutrient loading, are summarized and tabulated in Table 1C. Observations are summarized in the Problem Assessment section below, and detailed in Chapter VII, Assessment of Embayment Nutrient Related Ecological Health, of the MEP Technical Report.

**Figure 2 :Overview of Little Pond, Falmouth**

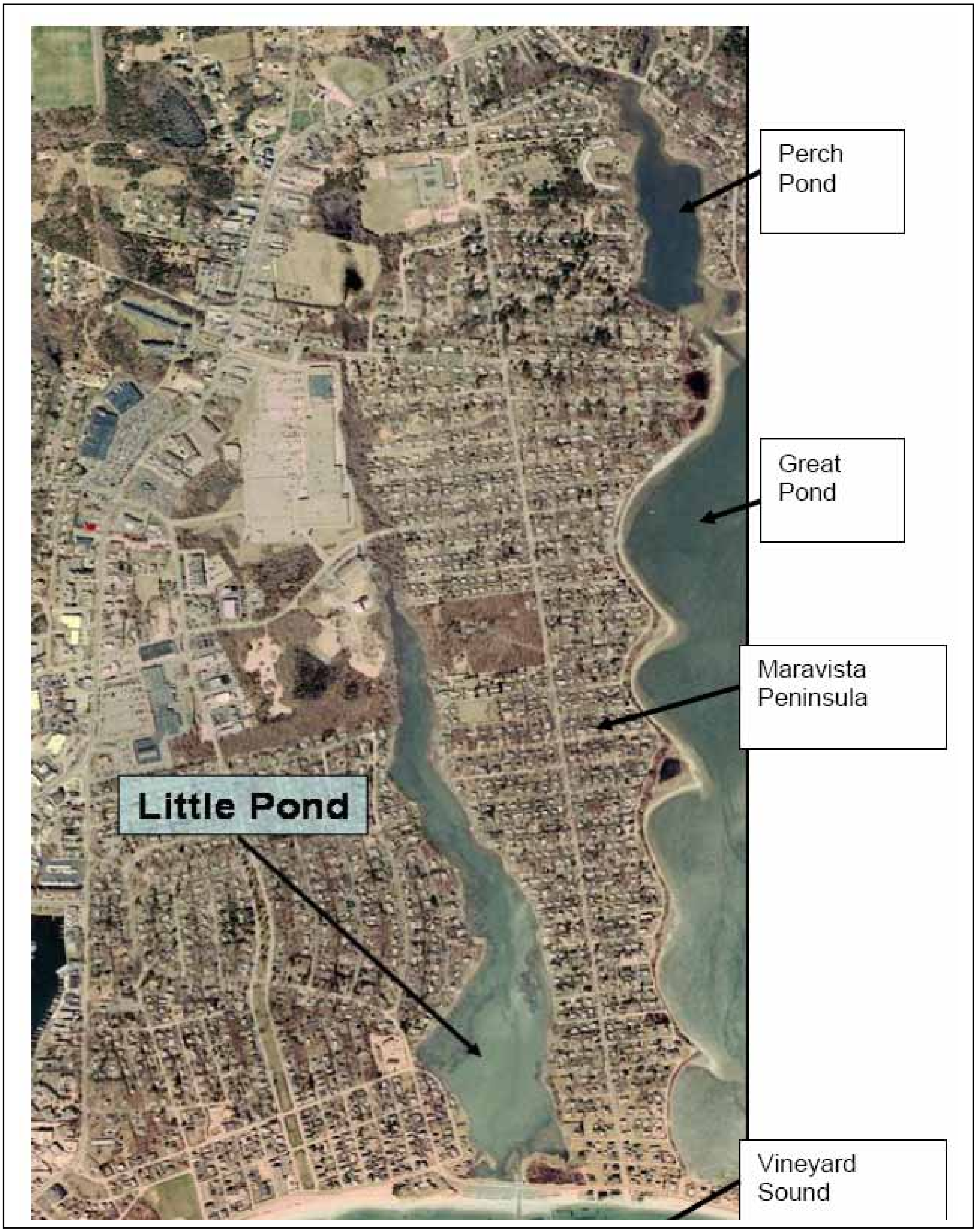


**Table 1C. General summary of conditions related to the major indicators of habitat impairment observed in the Little Pond Embayment Systems.**

| Embayment | Eelgrass Loss[1] | Dissolved Oxygen Depletion | Chlorophyll *a*[2] | Macro-algae | Benthic Fauna[3] |
|---|---|---|---|---|---|
| **Little Pond System** | | | | | |
| Little Pond | >77% | <6 mg/L up to 27% of time<br><4 mg/L up to 11% of time<br>SI/SD | >10ug/L up to 47% of time<br>>20 ug/L up to 7% of time<br>SI | SI | SI/SD |

1 Based on comparison of present conditions to 1951 Survey data.
2 Algal blooms are consistent with chlorophyll *a* levels above 20ug/L
3 Based on observations of the types of species, number of species, and number of individuals

SI – Significantly Impaired- considerably and appreciably changed from normal conditions*
SD – Severe Degraded – critically or harshly changed from normal conditions*
* - These terms are more fully described in MEP report "Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators"
December 22, 2003: http://www.mass.gov/dep/water/resources/coastalr.htm

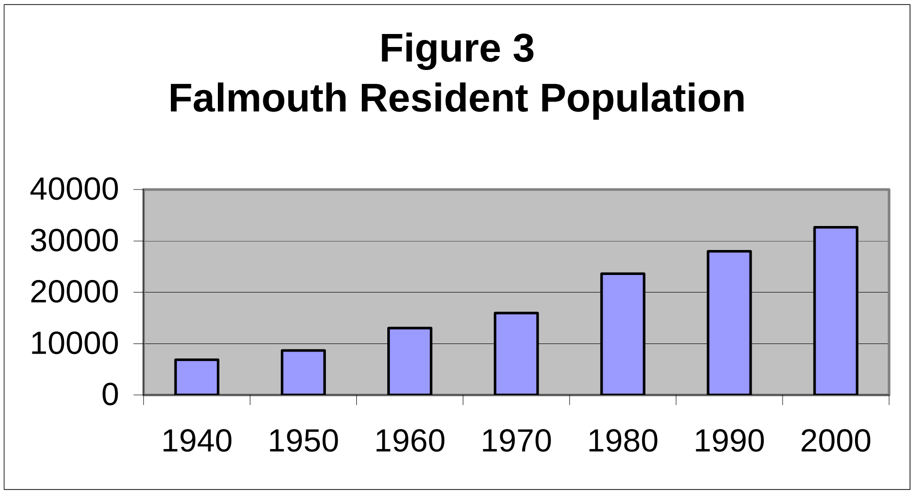
## Problem Assessment

The watershed of Little Pond embayment has had rapid and extensive development of single-family homes and the conversion of seasonal into full time residences. This is reflected in a substantial transformation of land from forest to suburban use between the years 1950 to 2000. Water quality problems associated with this development result primarily from on-site wastewater treatment systems, and to a lesser extent, from runoff - including fertilizers - from these developed areas.

On-site subsurface wastewater disposal system effluents discharge to the ground, enter the groundwater system and eventually enter the surface water bodies. In the sandy soils of Cape Cod, effluent that has entered the groundwater travel towards the coastal waters at an average rate of one foot per day. The nutrient load to the groundwater system is directly related to the number of subsurface wastewater disposal systems, which in turn are related to the population. The population of Falmouth, as with all of Cape Cod, has increased markedly since 1950. In the period from 1950 to 2000 the number of year round residents has almost quadrupled. In addition, summertime residents and visitors swell the population of the entire Cape by about 300% according to the Cape Cod Commission http://www.capecodcommission.org/data/trends98.htm#population).

Prior to the 1950's there were few homes and many of those were seasonal. During these times water quality was not a problem and eelgrass beds were plentiful. Dramatic declines in water quality, and the quality of the estuarine habitats, throughout Cape Cod, have paralleled its population growth since these times. The problems in these particular sub-embayments generally include periodic decreases of dissolved oxygen, decreased diversity and quantity of benthic animals, and periodic algal blooms. Eelgrass beds, which are critical habitat for macroinvertebrates and fish, have almost completely disappeared from these waters. Furthermore, the eelgrass was replaced by macroalgae, which are undesirable, because they do not provide high quality habitat for fish and invertebrates. In the most severe cases habitat degradation could lead to periodic fish kills, unpleasant odors and scums, and near loss of the benthic community and/or presence of only the most stress-tolerant species of benthic animals.

Coastal communities, including Falmouth, rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as commercial fin fishing and shellfishing. The continued degradation of these coastal sub-embayments, as described above, will significantly reduce the recreational and commercial value and use of these important environmental resources. The increase in year round residents is illustrated in the following figure:




Habitat and water quality assessments were conducted on this embayment system based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. The embayment system in this study displays a range of habitat quality. In general, the habitat quality is highest near the tidal inlet on Vineyard Sound and poorest in the inland-most tidal reaches. This is indicated by gradients of the various indicators. Nitrogen concentrations are high throughout with a slight decrease in the central section. Eelgrass has been dramatically reduced from the original 1951 survey. The only remaining eelgrass in Little Pond is in the lower basin near the tidal inlet. The dissolved oxygen records showed significant decreases in dissolved oxygen (including significant periods of anoxia in the deeper waters) accompanied by elevated levels of chlorophyll *a* (5-10 ug/L). The benthic infauna study showed a lack of diversity and poor distribution, but was overall characterized by lack of species and individuals.

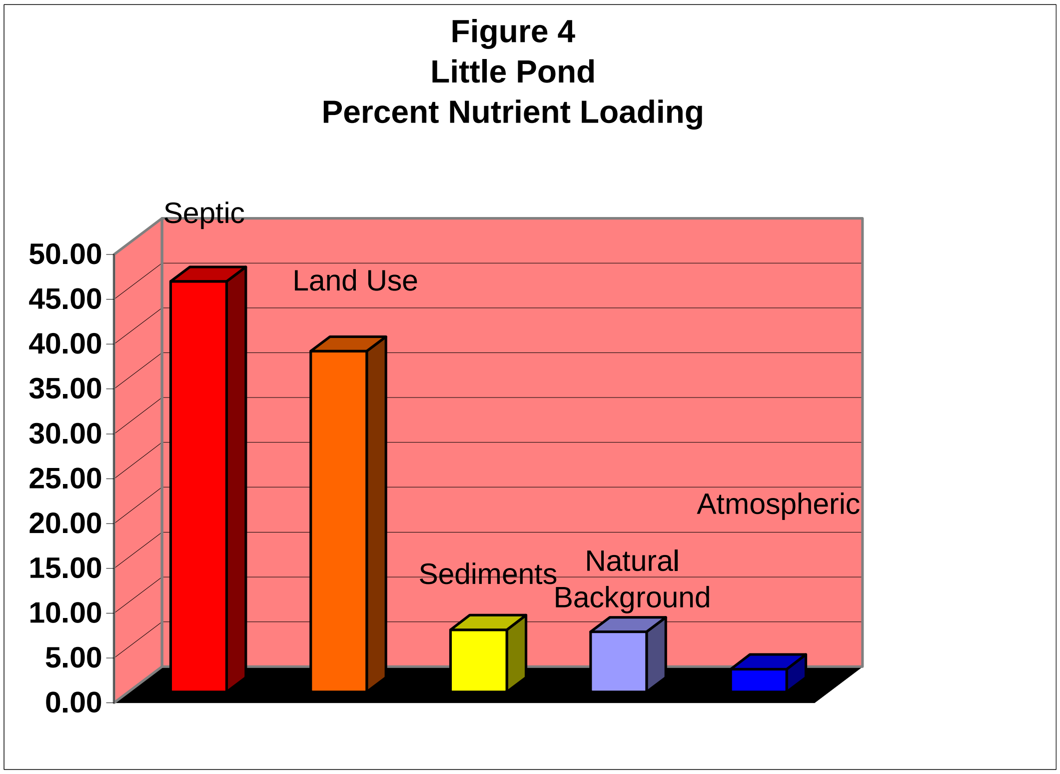
## Pollutant of Concern, Sources, and Controllability

In the coastal embayments of the Town of Falmouth, as in most marine and coastal waters, the limiting nutrient is nitrogen. Nitrogen concentrations beyond those expected naturally contribute to undesirable conditions, including the severe impacts described above, through the promotion of excessive growth of plants and algae, including nuisance vegetation.

The embayment covered in this TMDL has had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the Town of Falmouth, the USGS, and the Cape Cod Commission. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report.

These investigations revealed that loadings of nutrients, especially N, are much larger than they would be under natural conditions, and as a result the water quality has deteriorated. A principal indicator of decline in water quality is the disappearance of eelgrass from a large percentage of its natural habitat in this embayment. This is a result of nutrient loads causing excessive growth of algae in the water (phytoplankton) and algae growing on eelgrass (epiphyton), both of which result in the loss of eelgrass through the reduction of available light levels.

As is illustrated by Figure 5, most of the N affecting this embayment system originates from on-site subsurface wastewater disposal systems (septic systems), with a slightly lower level coming from fertilizers and runoff, and considerably less N originating from sediments, natural background sources, and atmospheric deposition.




The level of "controllability" of each source, however, varies widely:

Atmospheric nitrogen cannot be adequately controlled locally – it is only through region- and nation-wide air pollution control initiatives that significant reductions are feasible;

Sediment nitrogen control by such measures as dredging is not feasible on a large scale. However, the concentrations of N in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document. Increased dissolved oxygen will help keep nitrogen from fluxing;

Fertilizer – related nitrogen loadings can be reduced through bylaws and public education;

Stormwater sources of N can be controlled by best management practices (BMPs), bylaws and stormwater infrastructure improvements;

Septic system sources of nitrogen are the largest controllable sources. These can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, transporting and treating septage at treatment facilities with N removal technology either in or out of the watershed, or installing nitrogen-reducing on-site wastewater treatment systems.

Natural Background is the background load as if the entire watershed were still forested and contains no anthropogenic sources. It cannot be controlled locally.

Cost/benefit analyses will have to be conducted on all of the possible N loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

## Description of the Applicable Water Quality Standards

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen, but have only narrative standards that relate to the other variables, as described below:

314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(c) states, "Nutrients – Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication".

314 CMR 4.05(b) 1:

(a) Class SA

1. Dissolved Oxygen -
a. Shall not be less than 6.0 mg/l unless background conditions are lower;
b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 75% of saturation due to a discharge; and
c. site-specific criteria may apply where background conditions are lower than specified levels or to the bottom stratified layer where the Department determines that designated uses are not impaired.

(b) Class SB

1. Dissolved Oxygen -
a. Shall not be less than 5.0 mg/L unless background conditions are lower;
b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 60% of saturation due to a discharge; and
c. site-specific criteria may apply where back-ground conditions are lower than specified levels or to the bottom stratified layer where the Department determines that designated uses are not impaired.

Thus, the assessment of eutrophication is based on site specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the US Environmental Protection Agency in their draft Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (EPA-822-B-01-003, Oct 2001). The Guidance Manual notes that lakes, reservoirs, streams, and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management. However, individual estuarine and coastal marine waters have unique characteristics, and development of individual water body criteria is typically required.

It is this framework, coupled with an extensive outreach effort that the Department, and technical support of SMAST, that MassDEP is employing to develop nutrient TMDLs for coastal waters.

## Methodology - Linking Water Quality and Pollutant Sources

Extensive data collection and analyses have been described in detail in the MEP Technical Report. Those data were used by SMAST to assess the loading capacity of each sub-embayment. Physical (Chapter V), chemical, and biological (Chapters IV, VII, and VIII**)** data were collected and evaluated. The primary water quality objective was represented by conditions that:

1) restore the natural distribution of eelgrass because it provides valuable habitat for shellfish and finfish
2) prevent algal blooms
3) protect benthic communities from impairment or loss
4) maintain dissolved oxygen concentrations that are protective of the estuarine communities.

The details of the data collection, modeling and evaluation are presented and discussed in Chapters IV, V, VI, VII and VIII of the MEP Technical Report. The main aspects of the data evaluation and modeling approach are summarized below, taken from pages 4 through 8 of that report.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and N characteristics, and is characterized as follows:

- requires site specific measurements within the watershed and each sub-embayment;
- uses realistic "best-estimates" of N loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- spatially distributes the watershed N loading to the embayment;
- accounts for N attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes N regenerated within the embayment;
- is validated by both independent hydrodynamic, N concentration, and ecological data;
- is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model has been applied previously to watershed N management in over 15 embayments throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated, and has use as a management tool for evaluating watershed N management options.

The Linked Model, when properly calibrated and validated for a given embayment, becomes a N management planning tool as described in the model overview below. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. In addition, since the Linked Model uses a holistic approach that incorporates the entire watershed, embayment, and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries.

The Linked Model provides a quantitative approach for determining an embayment's: (1) N sensitivity, (2) N threshold loading levels (TMDL) and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics (Figure I-2 of the MEP Technical Report). This methodology integrates a variety of field data and models, specifically:

• Monitoring - multi-year embayment nutrient sampling

• Hydrodynamics -

- embayment bathymetry (depth contours throughout the embayment)
- site specific tidal record (timing and height of tides)
- water velocity records (in complex systems only)
- hydrodynamic model

• Watershed Nitrogen Loading

- watershed delineation
- stream flow (Q) and N load
- land-use analysis (GIS)
- watershed N model

• Embayment TMDL - Synthesis

- linked Watershed-Embayment Nitrogen Model
- salinity surveys (for linked model validation)
- rate of N recycling within embayment
- dissolved oxygen record
- macrophyte survey
- infaunal survey (in complex systems)

***Application of the Linked Watershed-Embayment Model***

The approach developed by the MEP for applying the linked model to specific sub-embayments, for the purpose of developing target N loading rates, includes:

1) selecting one or two sub-embayments within the embayment system, located close to the inland-most reach or reaches, which typically has the poorest water quality within the system. These are called “sentinel” stations;

2) using site-specific information and a minimum of three years of sub-embayment-specific data to select target threshold N concentrations for each sub-embayment. This is done by refining the draft target threshold N concentrations that were developed as the initial step of the MEP process. The target threshold N concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

3) running the calibrated water quality model using different watershed N loading rates, to determine the loading rate which will achieve the target threshold N concentration at the sentinel station. Differences between the modeled N load required to achieve the target threshold N concentration, and the present

watershed N load, represent N management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses, and the modeling activities described above, resulted in four major outputs that were critical to the development of the TMDL. Two outputs are related to N **concentration**:

- the present N concentrations in the sub-embayments
- site-specific target threshold N concentrations

and, two outputs are related to N **loadings:**

- the present N loads to the sub-embayments
- load reductions necessary to meet the site specific target threshold N concentrations

In summary: meeting the water quality standards by reducing the nitrogen concentration (and thus the nitrogen load) at the sentinel station(s), the water quality goals will be met throughout the entire system.

A brief overview of each of the outputs follows:
Nitrogen concentrations in the sub-embayments

a) Observed "present" conditions:
Table 2 presents the average concentration of N measured in this embayment from eight years of data collection (during the period 1997 through 2004). ). Concentrations of N are the highest at the most upstream end of Little Pond 2.32 mg/L (Station LP Head). Nitrogen at the other stations in the embayment ranges in concentration from 0.94 to 0.75 mg/L, resulting in overall ecological habitat quality which is significantly impaired. The overall means and standard deviations of the averages are presented in Tables A-1 of Appendix A (reprinted from Table VI-1 of the accompanying Tech Report).

b) Modeled site-specific target threshold nitrogen concentrations:

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. Prior to conducting the analytical and modeling activities described above, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and N concentrations. The Linked Model was then used to determine site-specific threshold N concentrations by using the specific physical, chemical, and biological characteristics of each sub-embayment.

As listed in Table 2, the site-specific target (threshold) N concentrations is 0.45 mg/L.
The findings of the analytical and modeling investigations for this embayment system are discussed and explained below:

The target threshold N concentration for an embayment represents the average water column concentration of N that will support the habitat quality being sought. The water column N level is ultimately controlled by the integration of the watershed N load, the N concentration in the inflowing tidal waters (boundary condition) and dilution and flushing via tidal flows. The water column N concentration is modified by the extent of sediment uptake and/or regeneration and by direct atmospheric deposition.

The target threshold N concentration this embayment system was developed to restore or maintain SA waters or high habitat quality. In this system, high habitat quality was defined as supportive of eelgrass, diverse benthic animal communities, and dissolved oxygen levels that would support Class SA waters. Chlorophyll *a* was also considered in the assessment.

**Table 2. Observed present nitrogen concentrations and sentinel station threshold nitrogen target concentrations derived for the Little Pond Embayment Systems**

| Embayment (sentinel station) | Embayment Observed Nitrogen Concentration [1] (mg/L) | Sentinel Station Target Threshold Nitrogen Concentration (mg/L) |
|---|---|---|
| Little Pond (LP2) | 2.32-0.75[2] | 0.45 |
| Vineyard Sound (Boundary Condition) | 0.28 | |

[1] calculated as the average of the separate yearly means of 1997-2004 data. Overall means and standard deviations of the average are presented in Appendix A

[2] listed as a range since it was sampled as several segments (Appendix A)

Watershed N loads (Tables ES-1 and ES-2 of the MEP Technical Report) for Little Pond embayment system were comprised primarily of wastewater N. Land-use and wastewater analysis found that overall 55% of the controllable N load to the embayments was from septic system effluent. This controllable load does not include atmospheric deposition or benthic flux.

A major finding of the MEP clearly indicates that a single total nitrogen threshold can not be applied to Massachusetts' estuaries, based upon the results of the Great, Green and Bournes Pond Systems, Popponesset Bay System, the Hamblin / Jehu Pond / Quashnet River analysis in eastern Waquoit Bay and the Pleasant Bay and Nantucket Sound embayments associated with the Town of Chatham. This is almost certainly going to be true for the other embayments within the MEP area, as well.

The threshold nitrogen levels for the Little Pond embayment system in Falmouth were determined as follows:

Little Pond Threshold Nitrogen Concentrations

The target nitrogen concentration for restoration of eelgrass in this system was determined to be 0.45mg/L N for Station LP2 and TN <0.45 mg/L N in the lower basin. This threshold level is consistent with the findings that (1) eelgrass beds have been lost in the lower basin which currently supports a tidally averaged TN of 0.84 mg/L N at LP2 and 0.71 mg/L N in the lower basin (LP3), (2) sparse eelgrass can be still be found within the lower basin at tidally averaged TN of 0.61 mg/L N, and (3) the eelgrass beds in Bournes Pond (threshold 0.45 mg/L N) at water depths similar to those in the lower basin of Little Pond, which is important for light penetration. Based upon these data, the threshold TN level at the sentinel station was set at 0.45 mg/L N to achieve eelgrass habitat recovery throughout the lower basin and to re-establish the marginal beds seen in 1995 near LP-2. .

The nitrogen load reductions within the system necessary to achieve the threshold nitrogen concentrations required 100% removal of septic load (associated with direct groundwater discharge to the embayment) for the systems' lower watersheds. In addition, a portion of the septic load entering the pond from the fresh water stream also must be removed to meet the threshold nitrogen concentrations. For the load reduction scenario evaluated, the Little Pond Stream sub-watershed required removal of approximately 60% of the septic load (Table VIII-2 of the MEP Technical Report).

It is important to note that the analysis of future nitrogen loading to the Little Pond estuarine systems focuses upon additional shifts in land-use from forest/grasslands to residential and commercial development. However, the MEP analysis indicates that significant increases in nitrogen loading can occur under present land-use conditions, due to shifts in occupancy, shifts from seasonal to year-round usage and increasing use of fertilizers (presently less than half of the parcels use lawn fertilizers). Therefore, watershed-estuarine nitrogen management must include management approaches to prevent increased nitrogen loading from both shifts in land-uses (new sources) and from loading increases of current land-uses. The overriding conclusion of the MEP analysis of the Little Pond estuarine system is that restoration will necessitate a reduction in the present (2004) nitrogen inputs and management options to negate additional future nitrogen inputs.

Nitrogen loadings to the embayment

a) Present loading rates:

In the Little Pond embayment system overall, the highest N loading from controllable sources is from on-site wastewater treatment systems, which is almost always the highest N loading source On-site septic system loadings were 10.42 kg/day across Little Pond. Nitrogen loading from the nutrient-rich sediments (referred to as benthic flux) is not significant in this embayment. As discussed previously, however, the direct control of N from sediments is not considered feasible. However, the magnitude of the benthic contribution is related to the watershed load. Therefore, reducing the incoming load should reduce the benthic flux over time. The total N loading from all sources was 22.76 kg/day across Little Pond embayment. A further breakdown of N loading, by source, is presented in Table 3. The data on which Table 3 is based can be found in Table ES-1 of the MEP Technical Report.

| Little Pond Embayment | Natural Background [1] Watershed Load (kg/day) | Present Land Use Load [2] (kg/day) | Present Septic System Load (kg/day) | Present Atmospheric Deposition (kg/day) | Present Benthic Load [3] (kg/day) | Total nitrogen load from all sources (kg/day) |
|---|---|---|---|---|---|---|
| **LITTLE POND SYSTEM** | | | | | | |
| Little Pond | 1.53 | 8.65 | 10.42 | 0.58 | 1.58 | 22.76 |

**Table 3. Nitrogen loading to Little Pond embayment from within the watershed (natural background, land use-related runoff, and septic systems), from the atmosphere, and from nutrient-rich sediments within the embayment.**

[1] assumes entire watershed is forested (i.e., no anthropogenic sources)

[2] composed of fertilizer and runoff and atmospheric deposition to lakes

[3] nitrogen loading from the sediments

As previously indicated, the present N loadings to Little Pond embayment system must be reduced in order to restore conditions and to avoid further nutrient-related adverse environmental impacts. The critical final step in the development of the TMDL is modeling and analysis to determine the loadings required to achieve the target N concentrations.

b) Nitrogen loads necessary for meeting the site-specific target nitrogen concentrations.

Table 4 lists the present controllable watershed N loadings from Little Pond embayment system. The last two columns indicate one scenario of the reduced loads and percentage reductions that could achieve the target concentrations in the sentinel system (see following section). It is very important to note that load reductions can be produced through reduction of any or all sources of N, potentially increasing the natural attenuation of nitrogen within the freshwater systems to the embayment, and/or modifying the tidal flushing through inlet reconfiguration (where appropriate). The load reductions presented below represent only one of a suite of potential reduction approaches that need to be evaluated by the communities involved. This presentation is to establish the general degree and spatial pattern of reduction that will be required for restoration of these N impaired embayments. The loadings presented in Table 4 represent one, but not the only, loading reduction scenario that can meet the TMDL goal. Other alternatives may also achieve the desired threshold concentration as well and can be explored using the MEP modeling approach. In the scenario presented, the percentage reductions in N loadings to meet the target threshold concentrations range from 55% in Little Pond and 33 % in Little Pond Stream. Table VIII-2 of the MEP Technical Report (and rewritten as Appendix B of this document) summarizes the present loadings from on-site subsurface wastewater disposal systems and the reduced loads that would be necessary to achieve the threshold N concentrations in the Little Pond embayment system, under the scenario modeled here. In this scenario only the on-site subsurface wastewater disposal system loads were reduced to the level of the target threshold watershed load. It should be emphasized once again that this is only one scenario that will meet the target N concentrations in the sentinel systems, which is the ultimate goal of the TMDL. There can be variations depending on the chosen sub-watershed and which controllable source is selected for reduction. Alternate scenarios will result in different amounts of nitrogen being reduced in different sub-watersheds. For example, taking out additional nitrogen upstream will impact how much nitrogen has to be taken out downstream. The Town of Falmouth should take any reasonable effort to reduce the controllable nitrogen sources.

**Table 4. Present Controllable Watershed nitrogen loading rate, calculated loading rate that is necessary to achieve the target threshold nitrogen concentration, and the percent reduction of the existing load necessary to achieve the target threshold load.**

| Embayments | Present controllable watershed load [1] (kg/day) | Target threshold watershed load[2] (kg/day) | Percent controllable watershed load reductions needed to achieve threshold loads |
|---|---|---|---|
| Little Pond | 19.07 | 5.36 | 72 |

[1] Composed of combined land use, and septic system loadings
[2] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold N concentrations identified in Table 2 above and derived from data found in Table ES2 of the Tech Report

## Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a water body for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. The TMDLs are established to protect and/or restore the estuarine ecosystem, including eelgrass, the leading indicator of ecological health, thus meeting water quality goals for aquatic life support. Because there are no “numerical” water quality standards for N, the TMDL for the Little Pond embayment system is aimed at determining the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems.

The effort includes detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time), for each sub-embayment. The results of the mathematical model are correlated with estimates of impacts on water quality, including negative impacts on eelgrass (the primary indicator), as well as dissolved oxygen, chlorophyll, and benthic infauna.

The TMDL can be defined by the equation:

TMDL = BG + WLAs + LAs + MOS

Where

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
LAs = portion allotted to (cultural) non-point sources
MOS = margin of safety

**Background Loading**

Natural background N loading estimates are presented in Table 3 above. Background loading was calculated on the assumption that the entire watershed is forested, with no anthropogenic sources of N.

**Wasteload Allocations**

Wasteload allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. In the Little Pond embayment system there are no direct point source discharges to the surface water. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of storm water be included in the waste load component of the TMDL. On Cape Cod the vast majority of storm water percolates into the ground and aquifer and proceeds into the embayment systems through groundwater migration. The Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source – combining the assessments of waste water and storm water (including storm water that infiltrates into the soil and direct discharge pipes into water bodies) for the purpose of developing control strategies. Although the vast majority of storm water percolates into the ground, there are a few storm water pipes that discharge directly to water bodies that are subject to the requirements of the Phase II Storm Water NPDES Program. Therefore, any storm water discharges subject to the requirements of storm water Phase II NPDES permit must be treated as a waste load allocation. Since the majority of the nitrogen loading comes from septic systems, fertilizer, and storm water that infiltrates into the groundwater, the allocation of nitrogen for any storm water pipes that discharge directly to any of the embayments is insignificant as compared to the overall groundwater load. Based on land use, the Linked Model accounts for loading for storm water, but does not differentiate storm water into a load and waste load allocation. Nonetheless, based on the fact that there are few storm water discharge pipes within NPDES Phase II communities that discharge directly to embayments or waters that are connected to the embayments, the waste load allocation for these sources is considered to be insignificant. This is based on the percent of impervious surface within 200 feet of the waterbodies and the relative load from this area compared to the overall load (Table IV-4 of the MEP Technical Report). Although most stormwater infiltrates into the ground on Cape Cod, some impervious areas within approximately 200 of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of waste load allocation it was assumed that all impervious surfaces within 200ft of the shoreline discharge directly to the waterbody. This calculated load is 0.46% of the total nitrogen load or 4.98 kg/year as compared to the overall nitrogen load of 7569 kg/year to the embayment (see Appendix C for details). This conservative load is obviously negligible when compared to other sources.

EPA and MassDEP authorized the Town of Falmouth for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. The entire area of the Little Pond watershed falls within the covered urban area as designated by EPA

The Phase II general permit requires the permittee to determine whether the approved TMDL is for a pollutant likely to be found in storm water discharges from the MS4. The MS4 is required to implement the storm water waste load allocation, BMP recommendations, or other performance requirements of a TMDL and assess whether the waste load allocation is being met through implementation of existing stormwater control measures or if additional control measures are necessary.

**Load Allocations**

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Little Pond embayment system, the nonpoint source loadings are primarily from on-site subsurface wastewater disposal systems and land use. Additional N sources include: natural background, atmospheric deposition, and nutrient-rich sediments.

Generally, stormwater that is subject to the EPA Phase II Program would be considered a part of the wasteload allocation, rather than the load allocation. As presented in Chapter IV, V, and VI, of the MEP Technical Report, on Cape Cod the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater. Given this, the TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and storm water for the purpose of developing control strategies. Ultimately, when the Phase II Program is implemented in Falmouth new studies, and possibly further modeling, will identify what portion of the stormwater load may be controllable through the application of Best Management Practices (BMPs).

The sediment loading rates incorporated into the TMDL are lower than the existing sediment flux rates listed in Table 3 above because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments, and therefore, over time, reductions in loadings from the sediments will occur. Benthic N flux is a function of N loading and particulate organic nitrogen (PON). Projected benthic fluxes are based upon projected PON concentrations and watershed N loads, and are calculated by multiplying the present N flux by the ratio of projected PON to present PON, using the following formulae:

Projected N flux = (present N flux) (PON projected / PON present)

When: $\text{PON projected} = (R_{load})\ (D_{PON}) + \text{PON}_{\text{present offshore}}$

When $R_{load} = \text{(projected N load) / (Present N load)}$

And $D_{PON}$ is the PON concentration above background determined by:

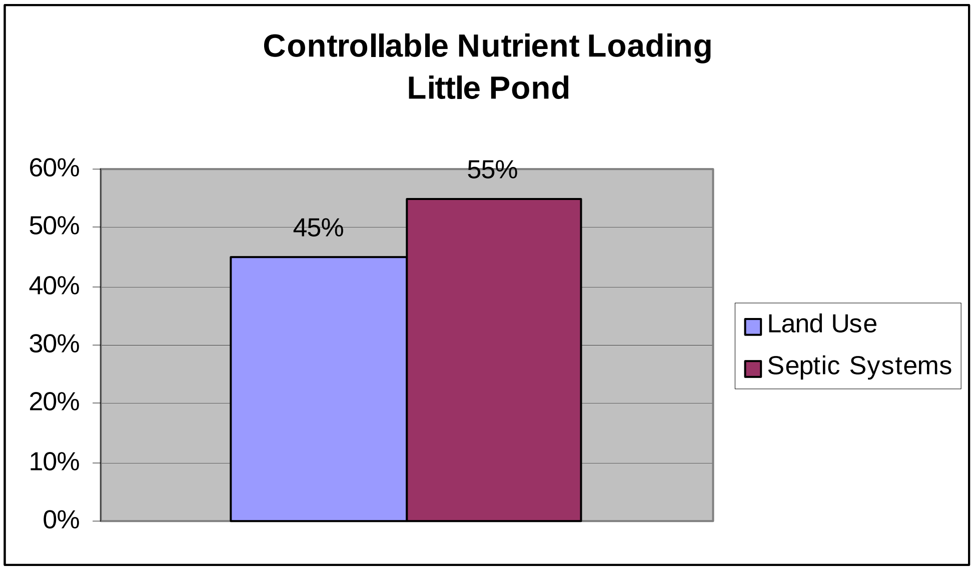
$$D_{PON} = (\text{PON}_{\text{present embayment}} - \text{PON}_{\text{present offshore}})$$

The benthic flux modeled for the Little Pond embayment system is reduced from existing conditions based on the load reduction and the observed PON concentrations within each sub-embayment relative to Vineyard Sound (boundary condition). The benthic flux input to each sub-embayment was reduced (toward zero) based on the reduction of N in the watershed load.

The loadings from atmospheric sources incorporated into the TMDL, however, are the same rates presently occurring, because, as discussed above, local control of atmospheric loadings is not considered feasible.

Locally controllable sources of N within the watersheds are categorized as on-site subsurface wastewater disposal system wastes, land use (which includes stormwater runoff and fertilizers), and waste water treatment facilities. The following figure emphasizes the fact that the overwhelming majority of locally controllable N comes from on-site subsurface wastewater disposal systems.

**Figure 5**




## Margin of Safety

Statutes and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA para 303 (d)(20©, 40C.G.R. para 130.7©(1)]. The EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. The MOS for the Little Pond Embayment System TMDL is implicit, and the conservative assumptions in the analyses that account for the MOS are described below.

1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayments. Nitrogen transfer through direct groundwater discharge to estuarine waters is based upon studies indicating negligible aquifer attenuation and dilution, i.e. 100% of load enters embayment. This is a conservative estimate of loading because studies have also shown that in some areas less than 100% of the load enters the estuary. Nitrogen from the upper watershed regions, which travel through ponds or wetlands, almost always enter the embayment via stream flow, are directly measured (over 12-16 months) to determine attenuation. In these cases the land-use model has shown a slightly higher predicted N load than the measured discharges in the streams/rivers that have been assessed to date. Therefore, the watershed model as applied to the surface water watershed areas again presents a conservative estimate of N loads because the actual measured N in streams was lower than the modeled concentrations.

The hydrodynamic and water quality models have been assessed directly. In the many instances where the hydrodynamic model predictions of volumetric exchange (flushing) have also been directly measured by field measurements of instantaneous discharge, the agreement between modeled and observed values has been ≥95%. Field measurement of instantaneous discharge was performed using acoustic doppler current profilers (ADCP) at key locations within the embayment (with regards to the water quality model, it was possible to conduct a quantitative assessment of the model results as fitted to a baseline dataset - a least squares fit of the modeled versus observed data showed an $R^2$>0.95, indicating that the model accounted for 95% of the variation in the field data). Since the water quality model incorporates all of the outputs from the other models, this excellent fit indicates a high degree of certainty in the final result. The high level of accuracy of the model provides a high degree of confidence in the output; therefore, less of a margin of safety is required.

In the case of N attenuation by freshwater ponds, attenuation was derived from measured N concentrations, pond delineations and pond bathymetry. These attenuation factors were higher than that used in the land-use model. The reason was that the pond data were temporally limited and a more conservative value of 40% was more protective and defensible.

In the case of the nitrogen load assessed to lawn fertilization rates for residential lawns, based on an actual survey, it is likely that this represents a conservative estimate of the nitrogen load. This too makes a more conservative margin of safety.

The nitrogen loading calculations are based on a wastewater engineering assumption that 90% of water used is converted to wastewater. Actual water use and conversion studies in the area have shown that this conversion rate is conservative adding to the margin of safety.

The nitrogen loading calculations for homes, which do not have metered water use, are based on a conservative estimate of water use compared to actual water use in the metered sections of the watershed. This adds to the margin of safety.

Similarly, the water column N validation dataset was also conservative. The model is validated to measured water column N. However, the model predicts average summer N concentrations. The very high or low measurements are marked as outliers. The effect is to make the N threshold more accurate and scientifically defensible. If a single measurement two times higher than the next highest data point in the series, raises the average 0.05 mg/L Nitrogen, this would allow for a higher "acceptable" load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the N threshold for a system. This effectively strengthens the data set so that a higher margin of safety is not required.

Finally, the reductions in benthic regeneration of N are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of PON, due to lower primary production rates under the reduced N loading in these systems. As the N loading decreases and organic inputs are reduced, it is likely that rates of coupled remineralization-nitrification, denitrification and sediment oxidation will increase.

Benthic regeneration of N is dependant upon the amount of PON deposited to the sediments and the percentage that is regenerated to the water column versus being denitrified or buried. The regeneration rate projected under reduced N loading conditions was based upon two assumptions:(1) PON in the embayment in excess of that of inflowing tidal water (boundary condition) results from production supported by watershed N inputs and 2) Presently enhanced production will decrease in proportion to the reduction in the sum of watershed N inputs and direct atmospheric N input. The latter condition would result in equal embayment versus boundary condition production and PON levels if watershed N loading and direct atmospheric deposition could be reduced to zero (an impossibility of course). This proportional reduction assumes that the proportion of remineralized N will be the same as under present conditions, which is almost certainly an underestimate. As a result, future N regeneration rates are overestimated which adds to the margin of safety.

2. Conservative sentinel station/target threshold nitrogen concentration

Conservatism was used in the selection of the sentinel station and target threshold N concentration. The site was chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher N concentrations. Meeting the target threshold N concentration at the sentinel station will result in reductions of N concentrations in the rest of the system.

3 Conservative approach

The target loads were based on tidally averaged N concentrations on the outgoing tide, which is the worst case condition because that is when the N concentrations are the highest. The N concentrations will be lower on the flood tides; therefore, this approach is conservative.

In addition to the margin of safety within the context of setting the N threshold levels, described above, a programmatic margin of safety also derives from continued monitoring of these sub-embayments to support adaptive management. This continuous monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the N management plan. This will allow refinements to the plan to ensure that the desired level of restoration is achieved.

**Seasonal Variation**

Since the TMDL for the waterbody segment is based on the most critical time period, i.e. the summer growing season, the TMDL is protective for all seasons. The daily loads can be converted to annual loads by multiplying by 365 (the number of days in a year). Nutrient loads to the embayment are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Second, as a practical matter, the types of controls necessary to control the N load, the nutrient of primary concern, by their very nature do not lend themselves to intra-annual manipulation since the majority of the N is from non-point sources. Thus, the annual loads make sense, since it is difficult to control non-point sources of nitrogen on a seasonal basis and nitrogen sources can take considerable time to migrate to impacted waters.

**TMDL Values for Little Pond Embayment System**

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of the embayment were calculated by considering all sources of N grouped by natural background, point sources, and non-point sources. A more meaningful way of presenting the loadings data, from an implementation perspective, is presented in Table 5. In this table the N loadings from the atmosphere and nutrient-rich sediments are listed separately from the target watershed threshold loads, which are composed of natural background N along with locally controllable N from the on-site subsurface wastewater disposal systems, stormwater runoff, and fertilizer sources. In the case of the Little Pond embayment system the TMDL was calculated by projecting reductions in locally controllable on-site subsurface wastewater disposal systems. Once again the goal of this TMDL is to achieve the identified target threshold N concentration at the identified sentinel station. The target load identified in this table represents one alternative loading scenario to achieve that goal but other scenarios may be possible and approvable as well.

**Table 5. The Total Maximum Daily Load (TMDL) for Little Pond Embayment System, represented as the sum of the calculated target threshold load (from controllable watershed sources), atmospheric deposition, and sediment sources (benthic load).**

| Sub-embayment | Target Threshold Watershed Load [1] (kg/day) | Atmospheric Deposition (kg/day) | Benthic Load [2] (kg/day) | TMDL [3] (kg/day) |
|---|---|---|---|---|
| Little Pond | 5.36 | 0.58 | 1.58 | 7 |

[1] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 2

[2] Projected sediment N loadings obtained by reducing the present loading rates (Table 3) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON.
[3] Sum of target threshold watershed load, atmospheric deposition load, and benthic flux load.

## Implementation Plans

The critical element of this TMDL process is achieving the sentinel station specific target threshold N concentration presented in Table 2 above, which is necessary for the restoration and protection of water quality and eelgrass habitat within the Little Pond embayment system. In order to achieve this target threshold N concentration, N loading rates must be reduced throughout this embayment. Table 5, above, lists the target watershed threshold load. If this threshold loads is achieved, this embayment will be protected.

As previously noted, this loading reduction scenario is not the only way to achieve the target threshold N concentration. Falmouth is free to explore other loading reduction scenarios through additional modeling as part of the Comprehensive Wastewater Management Plan (CWMP). It must be demonstrated, however, that any alternative implementation strategies will be protective of Little Pond, and that none of the embayment will be negatively impacted. To this end, additional linked model runs can be performed by the MEP at a nominal cost to assist the planning efforts of the Town in achieving target N loads that will result in the desired target threshold N concentrations.

The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the MassDEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results.

Because the vast majority of controllable N load is from individual on-site subsurface wastewater disposal systems for private residences, the CWMP should assess the most cost-effective options for achieving the target N watershed loads, including but not limited to, sewering and treatment for N control of sewage and septage at either centralized or de-centralized locations, and denitrifying systems for all private residences.

Falmouth is urged to meet the target threshold N concentration by reducing N loadings from any and all sources, through whatever means are available and practical, including reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater BMPs, in addition to reductions in on-site subsurface wastewater disposal system loadings.

MassDEP's MEP Implementation Guidance report: http://www.mass.gov/dep/water/resources/coastalr.htm provides N loading reduction strategies that are available to Falmouth and that could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- Wastewater Treatment
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment
    - Community Treatment Plants
    - Municipal Treatment Plants and Sewers
- Tidal Flushing
    - Channel Dredging
    - Inlet Alteration
    - Culvert Design and Improvements
- Stormwater Control and Treatment *
    - Source Control and Pollution Prevention
    - Stormwater Treatment
- Attenuation via Wetlands and Ponds
- Water Conservation and Water Reuse
- Management Districts

- Land Use Planning and Controls
    - Smart Growth
    - Open Space Acquisition
    - Zoning and Related Tools
- Nutrient Trading

* The Town of Falmouth is one of the 237 communities in Massachusetts covered by the Phase II stormwater program requirements.

**Monitoring Plan for TMDL Developed Under the Phased Approach**

MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. They include 1) tracking implementation progress as approved in the Town CWMP plan and 2) monitoring ambient water quality conditions at the sentinel stations identified in the MEP Technical Report.

The CWMP will evaluate various options to achieve the goals set out in the TMDL and Technical Report. It will also make a final recommendation based on existing or additional modeling runs, set out required activities, and identify a schedule to achieve the most cost effective solution that will result in compliance with the TMDL. Once approved by the Department tracking progress on the agreed upon plan will, in effect, also be tracking progress towards water quality improvements in conformance with the TMDL.

Relative to water quality, MassDEP believes that an ambient monitoring program, much reduced from the data collection activities needed to properly assess conditions and to populate the model, will be important to determine actual compliance with water quality standards. Although the TMDL load values are not fixed, the target threshold nitrogen concentrations at the sentinel stations are fixed. In addition, there are target threshold N concentrations that are provided for many other non-sentinel locations in subembayments to protect nearshore benthic habitat. These are the water quality targets, and a monitoring program should encompass these stations at a minimum. Through discussions amongst the MEP it is generally agreed that existing monitoring programs, which were designed to thoroughly assess conditions and populate water quality models, can be substantially reduced for compliance monitoring purposes. Although more specific details need to be developed MassDEP's current thinking is that about half the current effort (using the same data collection procedures) would be sufficient to monitor compliance over time and to observe trends in water quality changes. In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years. Finally, in addition to the above, existing monitoring conducted by MassDEP for eelgrass should continue into the future to observe any changes that may occur to eelgrass populations as a result of restoration efforts.

The MEP will continue working with the Towns to develop and refine monitoring plans that remain consistent with the goals of the TMDL. It must be recognized however that development and implementation of a monitoring plan will take some time, but it is more important at this point to focus efforts on reducing existing watershed loads to achieve water quality goals.

## Reasonable Assurances

MassDEP possesses the statutory and regulatory authority, under the water quality standards and/or the State Clean Water Act (CWA), to implement and enforce the provisions of the TMDL through its many permitting programs, including requirements for N loading reductions from on-site subsurface wastewater disposal systems. However, because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. Falmouth has demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The Town expects to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems, stormwater, and runoff (including fertilizers), and to prevent any future degradation of these valuable resources. Moreover, reasonable assurances that the TMDL will be implemented include enforcement of regulations; availability of financial incentives; and local, state, and federal programs for pollution control. Storm water NPDES permit coverage will address discharges from municipally owned storm water drainage systems. Enforcement of regulations controlling non-point discharges include local implementation of the Commonwealth's Wetlands Protection Act and Rivers Protection Act; Title 5 regulations for on-site subsurface wastewater disposal systems, and other local regulations such as the Town of Rehoboth's stable regulations. Financial incentives include federal funds available under Sections 319, 604 and 104(b) programs of the CWA, which are provided as part of the Performance Partnership Agreement between MassDEP and EPA. Other potential funds and assistance are available through Massachusetts' Department of Agriculture's Enhancement Program and the United States Department of Agriculture's Natural Resources Conservation Services. Additional financial incentives include income tax credits for Title 5 upgrades and low interest loans for Title 5 on-site subsurface wastewater disposal system upgrades available through municipalities participating in this portion of the state revolving fund program.

As the towns implement this TMDL, the TMDL values (kg/day of nitrogen) will not be used by MassDEP as an enforcement tool, but may be used by local communities as a management tool. There will be slight variations in these values depending on the scenario the towns use to implement it. They are also modeled values and thus would be inappropriate to use as an enforcement tool. There could also be slight variations between the actual nitrogen concentration at the sentinel stations and the site specific target threshold nitrogen concentration at the sentinel stations as the nitrogen load is reduced and the waterbodies begin to approach the water quality standards (Description of the Applicable Water Quality Standards section**).** It will be these latter two standards, the nitrogen concentration at the sentinel station and more importantly, the applicable water quality standards that will be used as the measure of full implementation and compliance with these water quality standards.

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## Appendix A

Summarizes the nitrogen concentrations for Little Pond embayment system (from Chapter VI of the accompanying MEP Technical Report)

Table VI-1. PondWatcher measured data, and modeled Total Nitrogen concentrations for the Little Pond system used in the model calibration plots of Figure VI-2. All concentrations are given in mg N/L. "Data mean" values are calculated as the average of the separate yearly means.

| Sub-Embayment | WQ Station | 1997 mean | 1998 mean | 1999 mean | 2000 mean | 2001 mean | 2002 mean | 2003 mean | 2004 mean | data mean | s.d. all data | N | model min | model max | model average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Little Pond Head | LP Head | 2.049 | 3.186 | 2.156 | 2.833 | 2.674 | 1.752 | 2.373 | 1.345 | 2.321 | 0.746 | 29 | 1.920 | 2.501 | 2.236 |
| Little Pond upper | LP1 | 0.854 | 0.777 | 0.851 | 1.096 | 0.904 | 1.067 | 0.942 | 0.977 | 0.942 | 0.266 | 54 | 0.939 | 0.969 | 0.955 |
| Little Pond mid | LP2 | 0.654 | 0.745 | 0.962 | 1.006 | 0.900 | 0.931 | 0.829 | 1.082 | 0.898 | 0.267 | 54 | 0.827 | 0.849 | 0.837 |
| Little Pond lower | LP3 | 0.486 | 0.722 | 0.742 | 0.734 | 0.831 | 0.744 | 0.853 | 0.883 | 0.745 | 0.237 | 58 | 0.623 | 0.771 | 0.705 |

## Appendix B

Summarizes the present septic system loads, and the loading reductions that would be necessary to achieve the TMDL by reducing septic system loads, ignoring all other sources.

Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Little Pond system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

| sub-embayment | present septic load (kg/day) | threshold septic load (kg/day) | threshold septic load % change |
|---|---|---|---|
| Little Pond | 10.419 | 0.000 | -100.0% |
| Surface Water Sources | | | |
| Little Pond Stream | 5.496 | 2.198 | -60.0% |

**Appendix C**
The Little Pond Embayment System estimated wasteload allocation (WLA) from runoff of all impervious areas within 200 feet of waterbodies.

| Watershed Name | Impervious watershed buffer areas[1] | | Total watershed Impervious areas | | Total Impervious watershed load | Total watershed load | Impervious watershed buffer area WLA | |
|---|---|---|---|---|---|---|---|---|
| | Acres | % | Acres | % | Kg/year | Kg/year | Kg/year[2] | %[3] |
| Little Pond | 16.7 | 18.6 | 243.5 | 29.7 | 510 | 7569 | 34.98 | 0.46 |

[1]The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated from GIS. Due to the soils and geology of Cape Cod it is unlikely that runoff would be channeled as a point source directly to a waterbody from areas more than 200 feet away. Some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of the wasteload allocation (WLA) it was assumed that all impervious surfaces within 200 feet of the shoreline discharge directly to the waterbody.

[2]The impervious subwatershed buffer area (acres) divided by total subwatershed impervious area (acres) then multiplied by total impervious subwatershed load (kg/year).

The impervious subwatershed buffer area WLA (kg/year) divided by the total subwatershed load (kg/year) then multiplied by100

**Appendix D**
**This figure is based on Figure III-1 of the MEP Technical report.**