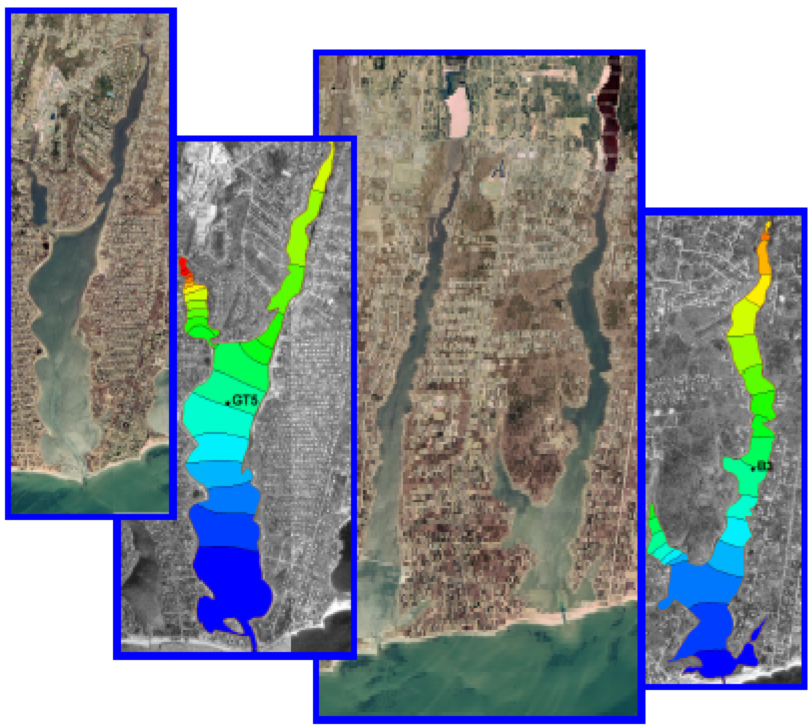
FINAL

Great, Green and Bournes Pond Embayment Systems Total Maximum Daily Loads For Total Nitrogen

(Report # 96-TMDL-6 Control #181.0)



COMMONWEALTH OF MASSACHUSETTS
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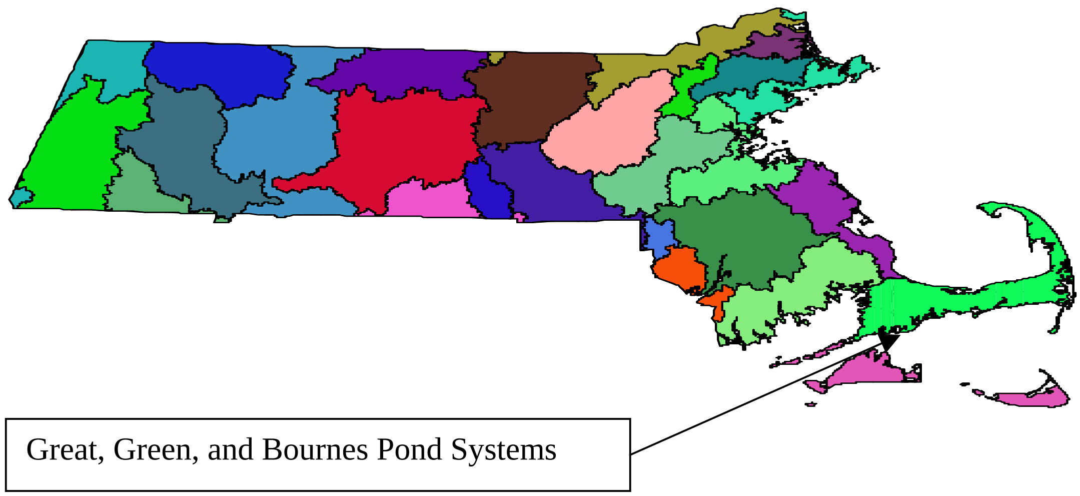
April 6, 2006

Great, Green, and Bournes Pond
Total Maximum Daily Loads
For Total Nitrogen



Key Feature: Total Nitrogen TMDL for Popponesset Bay
Location: EPA Region 1
Land Type: New England Coastal
303d Listing:

The waterbody segments impaired and on the Category 5 list include Great Pond, Perch Pond, Green Pond, and Bournes Pond (including Israels Cove). Additionally, as a result of the study to produce this TMDL document the Coonamessett River was also deemed impaired.

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 Town of Falmouth the problems in coastal waters 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

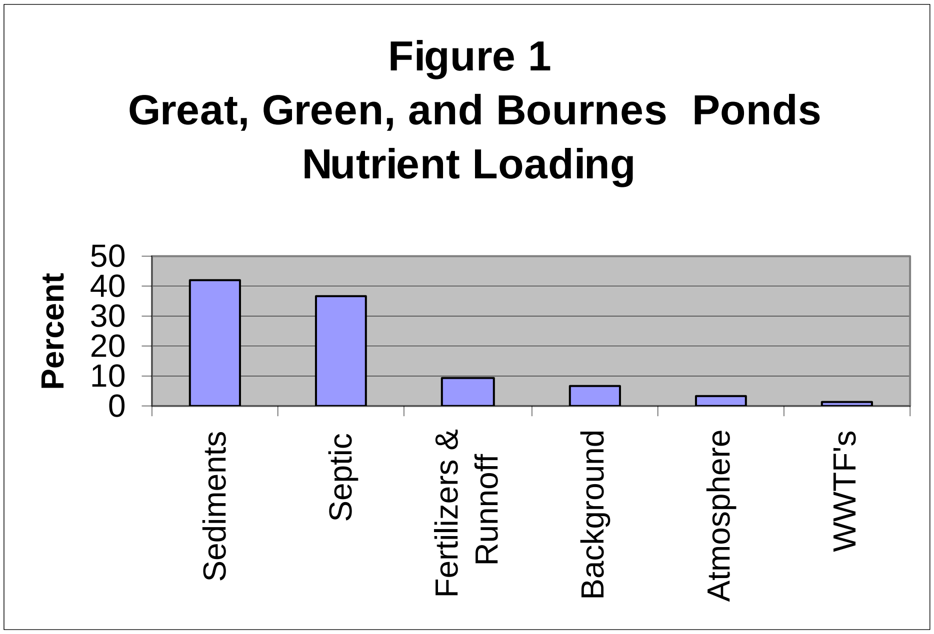
Coastal communities, including Falmouth, rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings will result in complete 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 Great, Green and Bournes Pond Embayment Systems coastal waters 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 these three embayments systems range from 2.2 kg/day in Israels Cove, to 83.13 kg/day in Green Pond. The resultant concentrations of N in these three sub-embayments range from 1.36mg/L (milligrams per liter of nitrogen) in the Backus Brook tributary of Green Pond to 0.39 mg/L in the lower sub-embayment of Bournes Pond.

In order to restore and protect these three embayment systems, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below the threshold concentrations that cause the observed environmental impacts. This concentration will be referred to as the target threshold concentration. It is the goal of the TMDL to reach this target threshold concentration, as it has been determined for each impaired waterbody segment. The Massachusetts Estuaries Project (MEP) has determined that, for these three embayment systems, N concentrations in the range from 0.40 to 0.45 mg/L are protective. The mechanism for achieving these target N concentrations is to reduce the N loadings to the embayments. The Massachusetts Estuaries Project (MEP) has determined that the Total Maximum Daily Loads (TMDL) of N that will meet the target thresholds range from 0.39-46.26 kg/day. This document presents the TMDLs for each impaired water body segment and provides guidance to the affected towns on possible ways to reduce the nitrogen loadings to within the recommended TMDL, and protect the waters for these three embayments.

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, upgrade/repairs of failed on-site systems, 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 MassDEP website at (http://www.mass.gov/dep/water/resources/restore.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 communities of Falmouth, Sandwich, Mashpee and Bourne (the three latter towns are part of the upper watershed only) 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 Towns 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 Great, Green and Bournes Pond Embayment Systems, 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 TMDLs for total N for the Great, Green and Bournes Pond Embayment Systems are 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 was collected over a study period from 1989 to 2003. This study period will be referred to as the "Present Conditions" in the TMDL since it is the most recent data available. The accompanying MEP Technical Report presents the results of the analyses of these three coastal embayment systems using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model). The analyses were performed to assist the Towns 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 assessments of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure that were conducted on each embayment. These assessments served as the basis for generating N loading thresholds for use as goals for watershed N management. The TMDLs are based on the site specific thresholds generated for each 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 Great, Green and Bournes Pond Embayment Systems in Falmouth Massachusetts, at the southwestern edge of Cape Cod, faces Vineyard Sound to the south, and consists of a number of sub-embayments of varying size and hydraulic complexity, characterized by limited rates of flushing, shallow depths and heavily developed watersheds (see Figures 2 and 3 on following pages). The three embayment systems studied constitute important components 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 sub-embayments within the Great, Green and Bournes Pond Embayment Systems are at risk of further eutrophication from high nutrient loads in the groundwater and runoff from their watersheds. Because of excessive nutrients, these three embayment systems are already listed as waters requiring TMDLs (Category 5) in the MA 2002 Integrated List of Waters, as summarized in Table 1A. These three embayment systems are broken down into four waterbody segments in this List.

Table 1A. The Great, Green and Bournes Pond Embayment Systems Waterbody Segments in Category 5 of the Massachusetts 2002 Integrated List[1]

NAME	WATERBODY SEGMENT	DESCRIPTION	SIZE	Pollutant Listed
Great Pond System				
Great Pond	MA96-54_2002	From inlet of Coonamessett River to Vineyard Sound (excluding Perch Pond), Falmouth	0.4 sq mi	-Nutrients -Pathogens
Perch Pond	MA96-53_2002	Connects to northwest end of Great Pond, west of Keechipam Way, Falmouth	0.03 sq mi	-Pathogens
Green Pond System				
Green Pond	MA96-55_2002	East of Acapesket Road, outlet to Vineyard Sound, Falmouth.	0.21 sq mi	-Nutrients -Pathogens
Bournes Pond System				
Bournes Pond	MA96-57_2002	West of Central Avenue, to Vineyard Sound, Falmouth.	0.24 sq mi	-Nutrients -Pathogens

[1] These segments are also classified as Category 5 on the Draft 2004 Integrated List.

A complete description of each embayment system is presented in Chapters I and IV of the MEP Technical Report. A majority of the information on these three embayment systems is drawn from this report. Chapter VI and VII of the MEP Technical Report provide assessment data which show that the Israels Cove sub-embayment in the Bournes Pond System is impaired for nutrients, eelgrass, and loss of benthic fauna habitat. Additionally Chapter VI of the MEP Technical Report provides assessment data that show that the Coonamessett River in the Great Pond System is impaired for nutrients. Both of these waterbody segments were previously unassessed. The MEP Technical Report also provides adequate nutrient concentration and loading data for the calculation of a TMDL on each of these two additional waterbody segments. Thus, TMDLs were prepared for all 6 sub-embayments as listed in Table 1B below.

Table 1B. Comparison of impaired parameters for the six impaired Sub-embayments within the Great, Green and Bournes Pond Embayment Systems

NAME	DEP Listed Impaired Parameter	SMAST Listed Impaired Parameter
Great Pond System		
Great Pond	-Nutrients -Pathogens	-Nutrients -DO level -Chlorophyll -Macroalgae -Eelgrass loss -Benthic fauna
Perch Pond	-Pathogens	-Nutrients -DO level -Chlorophyll -Macroalgae -Eelgrass loss -Benthic fauna
Coonamessett River		-Nutrients
Green Pond System		
Green Pond	-Nutrients -Pathogens	-Nutrients -DO level -Chlorophyll -Macroalgae -Eelgrass loss -Benthic fauna
Bournes Pond System		
Bournes Pond	-Nutrients -Pathogens	-Nutrients -DO level -Chlorophyll -Macroalgae -Eelgrass loss -Benthic fauna
Israels Cove		-Nutrients -Eelgrass loss -Benthic fauna

The sub-embayments addressed by this document are determined to be high priorities based on 3 significant factors: (1) the initiative that the Town has taken to assess the conditions of the three entire embayment systems, (2) the commitment made by the Town to restoring and preserving the sub-embayments, and (3) the extent of impairment in the sub-embayments. In particular, these sub-embayments are 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 loadings, are summarized and tabulated in Table 1C. Where more than one listing of conditions is listed (ex. MI/SI) a gradient of increasing water quality is present sampling from the upper sub-embayment to the lower sub-embayment. This is due to the cleaner tidal flushing water from Vineyard Sound. Observations are summarized in the Problem Assessment section below,

Figure 2 Overview of Green Pond and Bournes Pond, Falmouth, MA

Figure 3 Overview of Perch Pond and Great Pond, Falmouth, MA

and detailed in Chapter VII, Assessment of Embayment Nutrient Related Ecological Health, of the MEP Technical Report.

Table 1C. General summary of conditions related to the major indicators of habitat impairment observed in the Great, Green, and Bourne Pond Embayment Systems.

Embayment/ Sub-embayment	Eelgrass Loss[1]	Dissolved Oxygen Depletion	Chlorophyll *a*[2]	Macro-algae	Benthic Fauna[3]
Great Pond System					
Great Pond	~100%	<6 mg/L up to 66% of time <4 mg/L up to 41% of time SI/SD	>10ug/L up to 96% of time >20 ug/L up to 64% of time SI/MI	SI	SI/MI
Perch Pond	NS	Previously measured anoxia SI/SD	No data	SI	SI/SD
Green Pond System					
Green Pond	~100%	<6 mg/L up to 29% of time <4 mg/L up to 4% of time MI/SI	>10ug/L up to 99% of time >20 ug/L up to 84% of time SI/SD	No data	SI/SD
Bournes Pond System					
Bournes Pond	~64%	<6 mg/L up to 73% of time <4 mg/L up to 47% of time SI/SD	>10ug/L up to 78% of time >20 ug/L up to 32% of time SI	SI	GF/MI/SI
Israels Cove	~100%	No mooring data	No data	No data	MI/SI

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

GF – Good to Fair – little or no change from normal conditions*
MI – Moderately Impaired – slight to reasonable change from normal conditions*
SI – Significantly Impaired- considerably and appreciably changed from normal conditions*
SD – Severe Degraded – critically or harshly changed from normal conditions*
NS - Non-supportive habitat. No eelgrass was present in 1951 Survey data.
* - 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/esttmdls.htm).

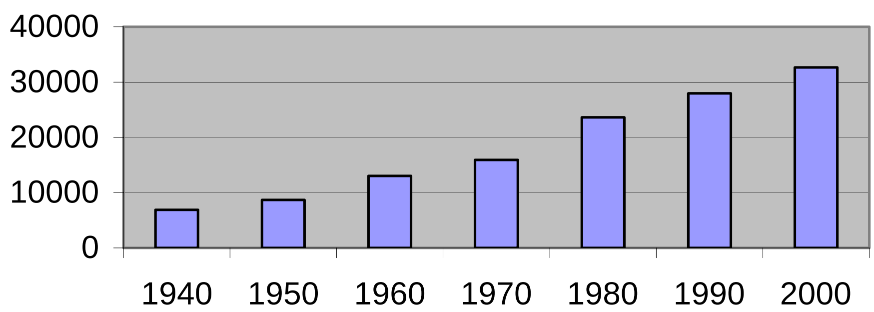
Problem Assessment

The watersheds of Great, Green and Bournes Pond embayments have all 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).

The increase in year round residents is illustrated in the following figure:

Figure 4
Falmouth Resident 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 of benthic animals, and periodic algal blooms. Eelgrass beds, which are critical habitats for macroinvertebrates and fish, have almost completely disappeared from these waters. Furthermore, the eelgrass was replaced by macro algae, 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.

Habitat and water quality assessments were conducted on each of the three embayment systems based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. The three embayment systems in this study display a range of habitat quality. In general, the habitat quality of the sub-embayments studied 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 highest inland and lowest near the mouths. Eelgrass has been dramatically reduced from the original 1951 survey. The only remaining eelgrass in Bournes Pond is near the tidal inlet and the vestigial eelgrass growth in Great and Green Pond is also near the tidal inlet. The dissolved oxygen records for Great Pond and Perch Pond showed significant decreases in dissolved oxygen (including periods of anoxia) accompanied by elevated levels of chlorophyll *a* (above 40 ug/L). Green Pond also showed significant depletion in dissolved oxygen, but only down to 4 mg/L. This depletion in dissolved oxygen was also accompanied by high levels of chlorophyll *a* (20 ug/L). Bournes Pond was in similar condition with dissolved oxygen depletions reaching 3 mg/L and accompanied by chlorophyll *a* levels above 20 ug/L. The benthic infauna study on all three embayment systems showed the similar pattern of improvement increasing as the distance to the tidal inlets decreases. All three showed significant habitat impairment in the uppermost reaches with improvement to moderate habitat impairment approaching the inlets. Only in the Bournes Pond enbayment did habitat improve to moderately healthy near the tidal inlet.

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.

Each of the embayments 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 these sub-embayments. This is a result of nutrient loads causing excessive growth of algae in the water (phytoplankton) and algae growing on eel grass (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 these three enbayment systems originates from the sediments and on-site subsurface wastewater disposal systems (septic systems), with considerably less N originating from natural background sources, runoff, fertilizers, waste water treatment facilities, and atmospheric deposition. Although this figure shows that overall the sediments are a large N source, examination of the sections of individual sub-embayments indicates that some of them have sediments that provide a significant sink of N (Table 3).). Under certain environmental conditions sediments can denitrify, thus freeing up capacity in the sediments to absorb more nitrogen. Where the sediments result in N loading it should be emphasized that this is a result of N loading from other sources. As the N loading from other sources decreases, the sediment N loading will decrease.

The level of “controllability” of each source, however, varies widely:

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

<u>Sediment nitrogen</u> 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;

<u>Fertilizer – related nitrogen</u> loadings can be reduced through bylaws and public education;

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

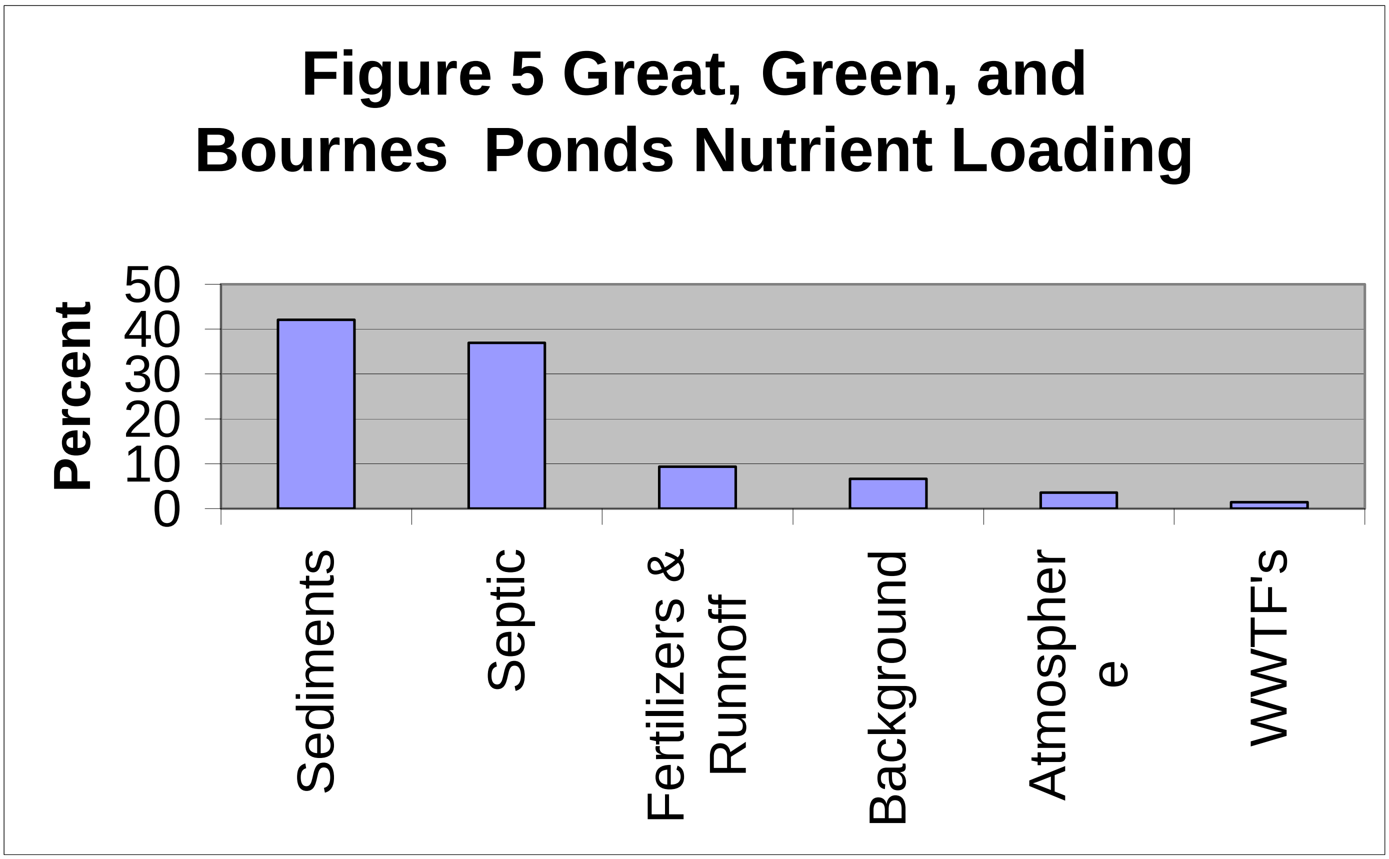
<u>Septic system sources of nitrogen</u> are the largest controllable sources. These can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations,

upgrading/repairing failed systems, 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 was still forested and contains no anthropogenic sources. It cannot be controlled locally.

WWTFs effluent nitrogen can be reduced by advanced treatment processes that include denitrification.

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 7 and 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 embayments: (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 stations within each 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 3 years of sub-embayment-specific data to select target/threshold N concentrations for each sub-embayment. This is done by refining the draft threshold N concentrations that were developed as the initial step of the MEP process. The target 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 N concentration at the sentinel station. Differences between the modeled N load required to achieve the target 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 TMDLs. Two outputs are related to N **concentration**:

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

A brief overview of each of the outputs follows:
<u>Nitrogen concentrations in the sub-embayments</u>

a) Observed “present” conditions:
Table 2 presents the average concentrations of N measured in these three embayments from seven years of data collection (during the period 1989 through 2003). Concentrations of N are the highest in Backus Brook (1.364

mg/L). Nitrogen in the other sub-embayments ranges in concentration from 0.387 to 0.998 mg/L, resulting in overall ecological habitat quality ranging from moderately high to poor. The individual station means and standard deviations of the averages are presented in Tables A-1 of Appendix A.

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 vary. Great Pond, Perch Pond, and the Coonamessett River have a threshold N concentration of 0.404 mg/L. Green Pond had a threshold N concentration of 0.421 mg/L. Bournes Pond and Israels Cove have a threshold N concentration of 0.454 mg/L.

The findings of the analytical and modeling investigations for this embayment system are discussed and explained below:

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

Table 2. Observed present nitrogen concentrations and target threshold station nitrogen concentrations derived for the Great, Green, and Bournes Pond Embayment Systems

Sub-embayments (Sentinel Station I.D.)	Sub-embayment Observed Nitrogen Concentration [1] (mg/L)	Target Sentinel Threshold Station Nitrogen Concentrations (mg/L)
Great Pond (GT5)	0.54-0.74[2]	0.40
Perch Pond	0.90	
Coonamessett River	0.88	
Green Pond (G4)	0.44-0.99[2]	0.42
Bournes Pond (B3)	0.39-0.88[2]	0.45
Israels Cove	0.67	
Vineyard Sound (Boundary Condition)	0.28	

[1] calculated as the average of the separate yearly means of 1989-2003 data. Overall means and standard deviations of the average are presented in Tables A-1 Appendix A
[2] listed as a range since it was sampled as several segments (see Table A-1 Appendix A)

Threshold N levels for each of the embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. In these systems, high habitat quality was defined as supportive of eelgrass and diverse benthic animal communities. Dissolved oxygen and chlorophyll *a* were also considered in the assessment.

Overall N loads (Tables ES-1 and ES-2 of the MEP Technical Report) for the Great, Green and Bournes Pond embayment systems were comprised primarily of wastewater N and the load from benthic flux. Land-use and wastewater analysis found that overall almost 77% 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 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 Great, Green and Bournes Pond embayment systems in Falmouth were determined as follows:

Great Pond Threshold Nitrogen Concentrations

•Within the Great/Perch Pond Estuary the most appropriate sentinel station was the upper station within the large main basin (Station GT5 in Figure VIII-1 of the MEP Technical Report). For embayment restoration, an additional requirement within Perch Pond and upper Great Pond was to ensure that N in these sub-systems has been reduced to levels supportive of healthy infauna habitat when the eelgrass threshold was met for the main basin of Great Pond.

•The target nitrogen concentration for restoration of eelgrass in this system was determined to be 0.40 mg/L N within the large main basin (Station GT5). 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 N of 0.591 mg/L N at GT5 (2) sparse eelgrass can still be found adjacent to the inlet at tidally averaged N of 0.34 mg/L N, and (3) eelgrass beds are not supported at similar depths within the lower basin of Great or Green Ponds at a tidally averaged N of 0.409 mg/L N and (4) the eelgrass beds in Bournes Pond (threshold 0.45 mg/L N, discussed below) are in much shallower water which is important for light penetration. The moderately impaired upper region of the basin currently supports a tidally corrected average concentration of 0.59 mg/L N. The significantly impaired upper tributary and Perch Pond have much higher N levels, >0.78 mg/L N. Based upon sequential reductions in watershed nitrogen loading in the analysis described in the Section VIII-3 of the MEP Technical Report, the sentinel station achieved an average N level of 0.40 mg L-1 and the lower main basin <0.30 mg/L N. This indicates that significant eelgrass habitat restoration would occur within the regions of the 1951 eelgrass coverage. Based upon these data and the deeper waters of Great Pond, the threshold N level was set at 0.40 mg/L N, lower than for Bournes Pond (0.42-0.45 mg/L N).

Green Pond Threshold Nitrogen Concentrations

•Within the Green Pond Estuary the most appropriate sentinel station was about 2/3 of the distance from the headwaters to the tidal inlet (G4 in Figure VIII-2 of the MEP Technical Report). For embayment restoration, an additional requirement within the upper 2/3 of the estuary was to ensure that N in this region has been reduced to levels supportive of healthy infauna habitat when the eelgrass threshold was met for the lower 1/3 of the embayment.

•The target nitrogen concentration for restoration of eelgrass in this system was determined to be 0.42 mg/L N for Station G4 and 0.4 mg N L-1 in the lower basin (below the bridge). This threshold level is consistent with the findings that (1) eelgrass beds have been lost in the lower basin which currently supports at tidally averaged N of 0.53 mg/L N at G4 and 0.41 mg/L N below the bridge (G5), (2) sparse eelgrass can be still be found adjacent to the inlet at tidally averaged N of 0.41 mg/L N, (3) the eelgrass beds in Bournes Pond (threshold 0.45 mg/L N) at shallower water depths which is important for light penetration, and (4) the restriction of eelgrass beds to the margins in the region of the sentinel station (G4) in 1951 with more complete coverage in the lower basin. Based upon these data, the threshold N level was set at 0.40 mg/L N for complete coverage of the lower basin and 0.42 mg/L N at the sentinel station to re-establish the marginal beds (both conditions are required in this system). Based on the results of the Linked Watershed – Embayment Model approach, it appears that achieving the nitrogen target at the sentinel location is restorative of eelgrass habitat throughout the lower Green Pond main basin and marginal beds above the bridge (1951 distribution) and restorative of infaunal habitat throughout the estuary.

Bournes Pond Threshold Nitrogen Concentrations

•Within the Bournes Pond Estuary the most appropriate sentinel station was 2/3 of the way down the upper tributary (Station B3 in Figure VIII-3 of the MEP Technical Report). This location was selected because (1) it was the upper extent of the full channel eelgrass bed coverage in 1951 (and is slightly above the eelgrass record for 1979), (2) restoration of nitrogen conditions supportive of eelgrass at this location will necessarily result in even higher quality conditions throughout the entire lower basin and Israels Cove, and (3) restoration of nitrogen concentrations at this site should result in conditions similar to 1951 within the upper 2/3 of the upper tributary, which will be supportive of high quality habitat for benthic infaunal communities.

•The target nitrogen concentration for restoration of eelgrass in this system was determined to be 0.45 mg/L N within the lower 1/3 of the tributary (Station B3), 0.31 mg/L N within the lower basin adjacent to the inlet and 0.42 mg/L N within Israels Cove. Although there is only one sentinel Station (B3), the thresholds analysis placed an additional requirement that the N level in the upper region of the lower basin (Station B4) was supportive of healthy infauna habitat when the eelgrass threshold was met for the lower 1/3 of the embayment. The sentinel station (B3) under present loading conditions supports a tidally corrected average concentration of 0.643 mg/L N. Based upon sequential reductions in watershed nitrogen loading in the analysis described in Section VIII-3 of the MEP Technical Report, the sentinel station achieved an average N level of 0.45 mg L-1, the lower basin <0.355 mg/L N, and Israels Cove 0.42 mg/L N. This indicates that significant eelgrass habitat restoration would occur within the regions of the 1951 coverage. Based on the site-specific eelgrass and TN data for Bournes Pond, restoration of eelgrass beds within Israels Cove should occur when N levels are lowered to 0.42 mg/L N and restoration of eelgrass beds within the lower 1/3 of the estuary (from B3 south) should occur when TN levels are lowered to 0.45 mg/L N at the sentinel station.

It is important to note that the analysis of future nitrogen loading to the Great, Green and Bournes 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-uses, 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 Great, Green and Bournes Pond estuarine systems is that restoration will necessitate a reduction in the present (2003) nitrogen inputs and management options to negate additional future nitrogen inputs.

<u>Nitrogen loadings to the sub-embayments</u>

a) Present loading rates:

In the Great, Green, and Bournes Pond embayment systems overall, the highest N loading from controllable sources is from on-site wastewater treatment systems, which is almost always the highest N loading source in each sub-embayment. On-site septic system loadings range from 1.78 kg/day in Israels Cove to as high as

36.36 kg/day in Great Pond. Nitrogen loading from the nutrient-rich sediments (referred to as benthic flux) is significant in these embayments. 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 ranges from 2.2 kg/day in Israels Cove to 83.13 kg/day in the Green 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.

Table 3. Nitrogen loadings to the Great, Green, and Bournes Pond embayments from within the watersheds (natural background, land use-related runoff, and septic systems), from WWTFs from the atmosphere, and from nutrient-rich sediments within the embayments.

Waquoit System Sub-embayments	Natural Background [1] Watershed Load (kg/day)	Present Land Use Load [2] (kg/day)	Present Septic System Load (kg/day)	Present WWTF Load (kg/day)	Present Atmospheric Deposition (kg/day)	Present Benthic Flux [3] (kg/day)	Total nitrogen load from all sources (kg/day)
GREAT POND SYSTEM							
Great Pond	8.68	11.26	36.36	1.48	3.22	-0.27	60.73
Perch Pond	0.29	0.90	4.47	0.00	0.22	-1.39	4.49
Great Pond System Total	**8.97**	**12.16**	**40.83**	**1.48**	**3.44**	**-1.66**	**65.22**
GREEN POND SYSTEM							
Green Pond System Total	**2.20**	**3.65**	**18.70**	**1.37**	**1.61**	**55.60**	**83.13**
BOURNES POND SYSTEM							
Bournes Pond	1.49	2.19	10.71	0.00	1.61	28.45	44.45
Israels Cove	0.21	0.27	1.78	0.00	0.26	-0.32	2.2
Bournes Pond System Total	**1.70**	**2.46**	**12.49**	**0.00**	**1.87**	**28.13**	**46.65**

[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 (to) the sediments

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

As previously indicated, the present N loadings to the Great, Green and Bournes Pond embayment systems studied 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.

Table 4 lists the present controllable watershed N loadings from the Great, Green and Bournes Pond embayment systems. The last two columns indicate one scenario of the reduced sub-watershed loads and percentage reductions that could achieve the target concentrations in the sentinel systems (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 embayments, 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. The presentation of load reductions in Table 4 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 threshold concentrations range from 55% in the Green Pond up to 87 % in Israels Cove. 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

Table 4. Present Controllable Watershed nitrogen loading rates, calculated loading rates that are necessary to achieve target threshold nitrogen concentrations, and the percent reductions of the existing loads necessary to achieve the target threshold loadings.

Sub-embayments	Present controllable watershed load [1] (kg/day)	Target threshold watershed load[2] (kg/day)	Percent watershed load reductions needed to achieve threshold loads
Great Pond	49.1	18.81	60.5
Perch Pond	5.37	0.90	83.3
Green Pond	23.72	10.16	54.6
Bournes Pond	12.90	3.28	74.6
Israels Cove	2.05	0.27	86.8

[1] Composed of combined land use, WWTP effluent, 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

to achieve the threshold N concentrations in Great, Green and Bournes Pond embayment systems, 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 at the sentinel stations, 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 towns involved should take any reasonable effort to reduce the controllable nitrogen sources.

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 TMDLs for the Great, Green and Bournes Pond embayment systems are aimed at determining the loads that would correspond to sub-embayment-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. 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 less than 0.74% (279.25 kg/year) as compared to the overall nitrogen load (37543 kg/year) to the embayments. Looking at individual sub-embayments this load ranged from 0.250-1.51% compared to the individual nitrogen load to each sub-embayment (Appendix C). 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 load is obviously negligible when compared to other sources.

EPA policy also requires that stormwater regulated under the NPDES program be identified and included as a wasteload allocation. As discussed below, for the purpose of this TMDL, stormwater loadings are not differentiated into point and non-point sources.

EPA and MassDEP authorized the Towns of Falmouth, Sandwich, Mashpee and Bourne for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. The watershed of the embayments studied that is in Sandwich, Mashpee and Bourne are located in an area subject to the requirements of the permit, as EPA has mapped these entire areas of the watershed as regulated areas. EPA did not designate the entire watershed area in Falmouth as a regulated urbanized area. While communities need to comply with the Phase II permit only in the mapped Urbanized Areas, the Town of Falmouth has decided to extend all the stormwater permit requirements throughout the entire town, including this watershed area.

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 the loading capacity allocated to existing and future nonpoint sources. In the case of the Great, Green and Bournes Pond embayment systems, the nonpoint source loadings are primarily from on-site subsurface wastewater disposal systems. Additional N sources include: natural background, stormwater runoff (including N from fertilizers), atmospheric deposition, the Massachusetts Military Reservation WWTF plume and nutrient-rich sediments. The Massachusetts Military Reservation WWTF effluent plume enters into both the Great Pond Embayment system and the Green Pond Embayment system. This load is 2.85 kg/day and represents approximately 1.5% of the total nitrogen load.

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, Sandwich, Mashpee and Bourne 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: $PON_{projected} = (R_{load})(D_{PON}) + PON_{present\ offshore}$

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

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

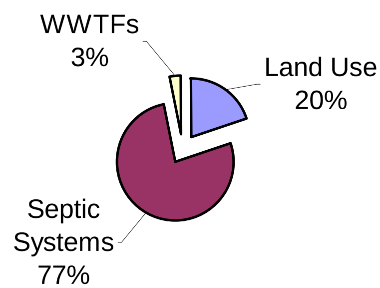
$$D_{PON} = (PON_{present\ embayment} - PON_{present\ offshore})$$

The benthic flux modeled for the Great, Green and Bournes embayment systems 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 wastewater treatment facilities. The following figure emphasizes the fact that the overwhelming majority of locally controllable N comes from on-site subsurface wastewater disposal systems. Please note the 3% assigned to WWTF loading is the remaining plume from the former Massachusetts Military Reservation WWTF. Due to the fact that it is not economically feasible or reasonable to treat this plume it was not included in Table 4.

Figure 6
Percent Contribution of Locally Controllable Sources of Nitrogen



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 Great, Green, and Bournes Embayment Systems 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, 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, which 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 $\geq$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 50% 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 use is converted to wastewater. Actual water use and conversion studies in the area have shown that this conversion rate is conservation 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 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 2 times higher than the next highest data point in the series raises the average 0.05 mg N/L, 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 threshold sites/nitrogen concentrations

Conservatism was used in the selection of the threshold sites and N concentrations. Sites were 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 thresholds in the sentinel sub-embayments will result in reductions of N concentrations in the rest of the systems.

3 Conservative approach

The target loads were based on tidal 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 TMDLs for the waterbody segments are based on the most critical time period, i.e. the summer growing season, the TMDLs are 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 sub-embayments 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 that nitrogen sources can take considerable time to migrate to impacted waters.

TMDL Values for Great, Green, and Bournes Pond Embayment Systems

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of each sub-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 Great, Green and Bournes embayment systems the TMDLs were calculated by projecting reductions in locally controllable on-site subsurface wastewater disposal system, stormwater runoff, and fertilizer sources. Once again the goal of this TMDL is to achieve the identified N threshold concentration in the identified sentinel system. 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 Loads (TMDL) for the Great, Green, and Bournes Pond Embayment Systems, represented as the sum of the calculated target thresholds loads (from controllable watershed sources), atmospheric deposition, and sediment sources (benthic flux).

Sub-embayment	Target Threshold Watershed Load [1] (kg/day)	Atmospheric Deposition (kg/day)	Benthic Flux [2] (kg/day)	TMDL [3] (kg/day)
Great Pond[4]	18.81	3.22	0.47	22.50
Perch Pond	0.90	0.22	-0.53	0.59
Great Pond System Total	**19.71**	**3.44**	**-0.06**	**23.09**
Green Pond System Total	**10.16**	**1.61**	**34.49**	**46.26**
Bournes Pond	3.28	1.61	19.28	24.17
Israels Cove	0.27	0.26	-0.14	0.39
Bournes Pond System Total	**3.55**	**1.87**	**19.14**	**24.56**

[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] The sum of target threshold watershed load, atmospheric deposition load, and benthic flux load.
[4] Includes the Coonamessett River.

Implementation Plans

The critical element of this TMDL process is achieving the sub-embayment specific N concentrations presented in Table 2 above, that are necessary for the restoration and protection of water quality and eelgrass habitat within the Great, Green and Bournes embayment system. In order to achieve those target concentrations, N loading rates must be reduced throughout these three embayments. Table 5, above, is based on Table ES-2 of the MEP Technical Report. It lists target watershed threshold loads for each sub-embayment. If those threshold loads are achieved, these three embayments will be protected.

As previously noted, this loading reduction scenario is not the only way to achieve the target N concentrations. The Towns are 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 the overall Great, Green and Bournes Ponds, and that none of the sub-embayments 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 Towns in achieving target N loads that will result in the desired threshold 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.

The Towns, however, are urged to meet the target threshold N concentrations 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.

Although it is not explained in detail previously in this TMDL, it should be noted here that a portion of the upper watershed of these three embayment systems is located in Sandwich, Mashpee, and Bourne. Thus the development of any implementation plan should keep in mind that all four towns needs to be included in coordinating efforts to maximize the reduction in TN loading.

DEP's MEP Implementation Guidance report (http://www.mass.gov/dep/water/resources/restore.htm) provides N loading reduction strategies that are available to the Towns of Falmouth, Sandwich, Mashpee and Bourne, 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 Towns of Falmouth, Sandwich, Mashpee and Bourne are four of the 237 communities in Massachusetts covered by the Phase II stormwater program requirements.

Monitoring Plan for TMDL Developed Under the Phased Approach

MassDEP recommends that the Town of Falmouth develop a detailed monitoring plan as part of the Comprehensive Wastewater Management Planning process and as part of the detailed plan for TMDL implementation process. The monitoring plan must be designed to determine if water quality improvements occur as a result of implementing this TMDL. This monitoring plan should be developed and conducted in phases according to the identification of N reduction options as part of the adaptive management approach to achieving water quality standards. The Department recognizes the long-term nature of the time horizon for full implementation of the TMDL; however, reasonable milestones in the shorter term are necessary.
Growth should be guided by a consideration of water quality-associated impacts.

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, 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, Sandwich, Mashpee and Bourne have demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The Towns expect 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 MA 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.

Appendix A

Table A – 1: Summarizes the nitrogen concentrations for Great, Green, and Bournes Pond Embayment Systems (from Chapter VI of the accompanying MEP Technical Report)

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

Sub-Embayment	monitoring station	data mean	s.d. all data	N	model min	model max	model average
Coonemessett River (fresh water)	GT1	0.855	0.187	51	-	-	0.851
Coonemessett River (estuarine)	GT2	0.881	0.218	100	0.834	0.915	0.875
Great Pond - upper	GT3	0.739	0.221	105	0.709	0.854	0.782
Perch Pond	GT4	0.895	0.239	101	0.802	0.902	0.859
Great Pond - mid	GT5	0.644	0.189	104	0.508	0.648	0.591
Great Pond - lower	GT6	0.543	0.181	104	0.280	0.493	0.339
Backus Brook (fresh water)	G1	1.364	0.381	64	-	-	0.528
Green Pond - upper	G2	0.988	0.340	138	0.821	1.025	0.932
Green Pond - upper	G2a	0.927	0.270	134	0.666	0.958	0.792
Green Pond - mid	G3	0.750	0.222	138	0.553	0.750	0.642
Green Pond - mid	G4	0.540	0.140	136	0.431	0.652	0.526
Green Pond - lower	G5	0.440	0.133	210	0.346	0.503	0.409
Bournes Brook (fresh water)	B1	0.928	0.422	52	-	-	0.874
Bournes Pond - upper	B2	0.880	0.291	109	0.846	0.940	0.901
Bournes Pond - mid	B3	0.670	0.264	105	0.496	0.753	0.643
Bournes Pond - lower	B4	0.482	0.142	101	0.322	0.555	0.428
Israels Cove	B5	0.674	0.194	100	0.591	0.663	0.633
Bournes Pond - lower	B6	0.367	0.110	100	0.283	0.497	0.340
Vineyard Sound	VS	0.280	0.065	196	-	-	0.280

Appendix B

Table B –1 Summarizes the present on-site subsurface wastewater disposal system loads, and the loading reductions that would be necessary to achieve the TMDL by reducing on-site subsurface wastewater disposal 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 Ashumet Valley systems. 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
Great Pond	21.28	0.00	-100.0%
Perch Pond	4.47	0.00	-100.0%
Green Pond	16.62	4.43	-73.4%
Bournes Pond	8.30	0.00	-100.0%
Israels Cove	1.78	0.00	-100.0%
Surface Water Sources			
Coonamessett River (Great Pond)	15.08	7.54	-50.0%
Backus Brook (Green Pond)	2.08	2.08	0.0%
Bournes Brook (Bournes Pond)	2.41	1.08	-55.0%

Appendix C
The Great, Green, and Bournes Pond Embayment Systems estimated wasteload allocation (WLA) from runoff of all impervious areas within 200 feet of waterbodies.

Subwatershed Name	Impervious subwatershed buffer areas[1]		Total subwatershed Impervious areas		Total Impervious subwatershed load	Total subwatershed load	Impervious subwatershed buffer area WLA	
	Acres	%	Acres	%	Kg/year	Kg/year	Kg/year[2]	%[3]
Great Pond	35.0	22.6	213.7	19.8	746	10299	122.18	1.19
Perch Pond	11.2	8.9	108.9	8.9	188	2041	19.34	0.95
Coonamessett River	9.7	4.0	559.2	8.8	1385	9493	24.02	0.25
Green Pond	17.5	15.4	178.5	12.3	688	8941	67.45	0.75
Bournes Pond	14.1	13.1	74.4	14.3	472	5924	89.45	1.51
Israels Cove	2.2	8.9	12.8	11.4	54	845	9.28	1.10
TOTAL	89.7	11.6	1147.5	10.7	3533	37543	279.17	0.74

[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 200feet 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).

[3]The impervious subwatershed buffer area WLA (kg/year) divided by the total subwatershed load (kg/year) then multiplied by 100.