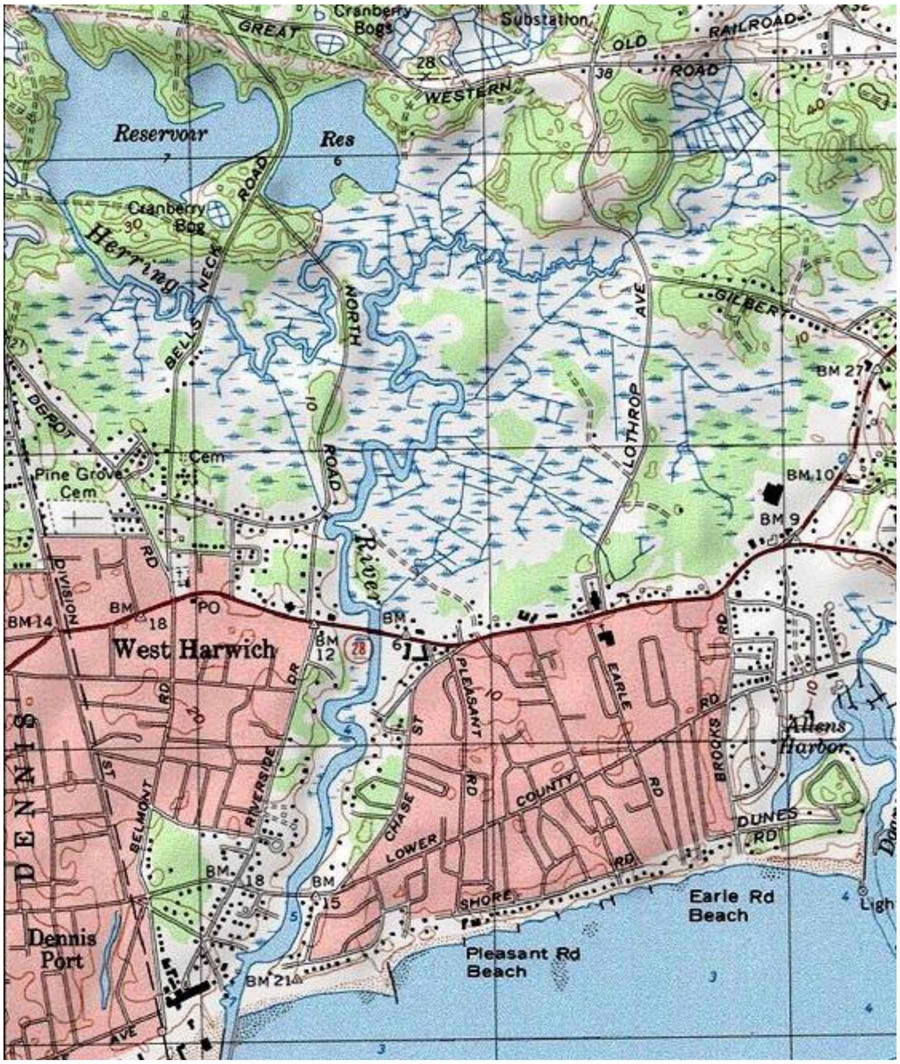
FINAL
Herring River Estuarine System
Total Maximum Daily Load
For Total Nitrogen

CN 395.1



COMMONWEALTH OF MASSACHUSETTS
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February 2016

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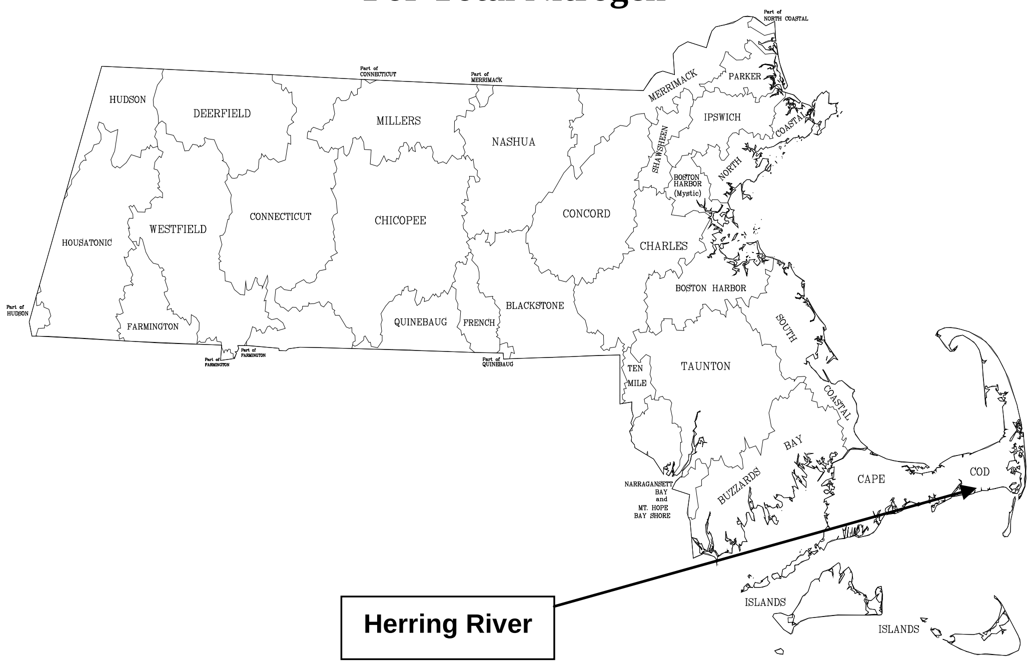


Key Feature: Total Nitrogen TMDL for the Herring River Estuarine System

Location: US Environmental Protection Agency (EPA) Region 1

Land Type: New England Coastal

303d Listing: The Herring River (segment MA96-22) will be listed in a future MA Integrated List of Waters as impaired for aquatic life (loss of eelgrass habitat). The Herring River estuarine system was found to be impaired for nutrients during the MEP study. The segment is also impaired for fecal coliform and is listed in category 4a (TMDL completed) of the 2012 List of Waters.

Data Sources: University of Massachusetts – Dartmouth/School for Marine Science and Technology, US Geological Survey, Applied Coastal Research and Engineering, Inc., Town of Harwich

Data Mechanism: Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Models

Monitoring Plan: Town of Harwich, Water Quality Monitoring Program (with technical assistance from SMAST)

Control Measures: Sewering, Stormwater Management, Attenuation by Impoundments and Wetlands, Fertilizer Use By-laws

Executive Summary

Problem Statement

Excessive nitrogen (N) originating from a range of sources has added to the impairment of the environmental quality of the Herring River estuarine system. In the Herring River estuary the most significant impairment is loss of eelgrass habitat in the lower tidal reach. In general, excessive N is indicated by:

- Undesirable increases in macro algae
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life
- Reductions in the diversity of benthic animal populations
- Significant loss of eelgrass habitat
- Periodic algae blooms

With proper management of N 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 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 could result in an overabundance of 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 Herring River estuarine system will be greatly reduced.

Sources of Nitrogen

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

- The watershed
    - Natural background
    - Septic systems
    - Stormwater runoff from impervious surfaces
    - Fertilizers
    - Agricultural activities
    - Landfills
    - Wastewater treatment facilities;
- Atmospheric deposition;
- Nutrient-rich bottom sediments in the embayments.

Figures ES-A and ES-B illustrate the percent contribution of all the sources of unattenuated N and the controllable unattenuated N sources to the Herring River estuary system, respectfully. Values are based on Table IV-3 and Figure IV-5 from the Massachusetts Estuaries Project (MEP) Herring River Embayment System Technical Report. As evident, most of the present *controllable* load to this system comes from septic systems.

Figure ES-A: Percent Contributions of All Nitrogen Sources to the Herring River Estuarine System

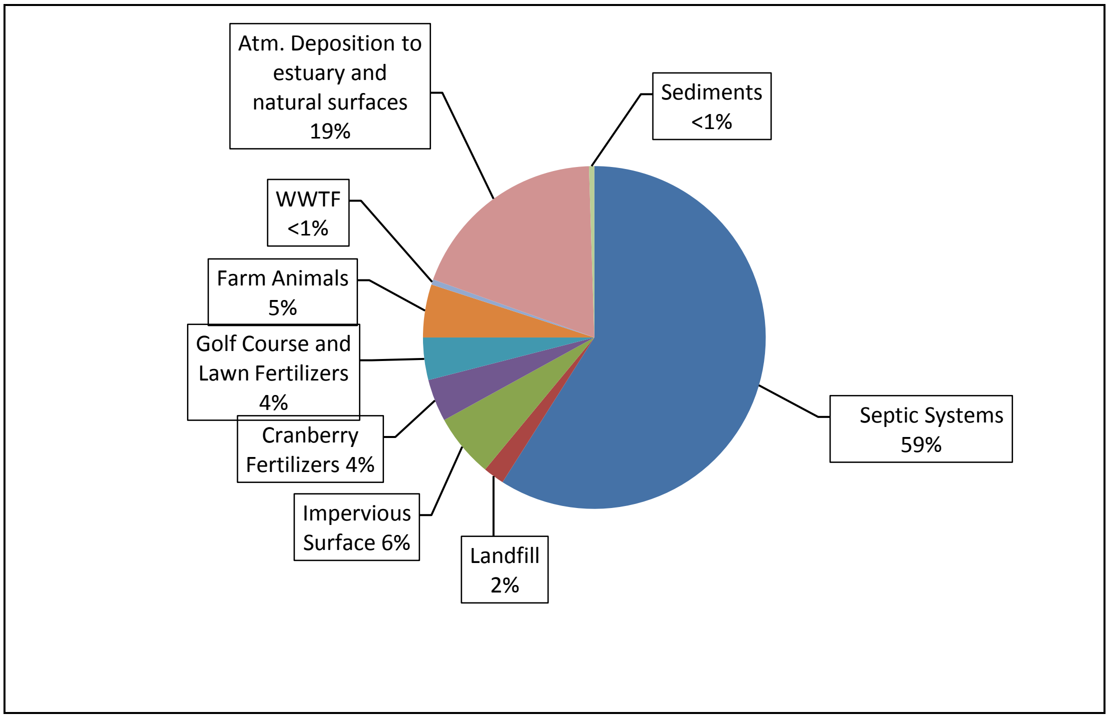
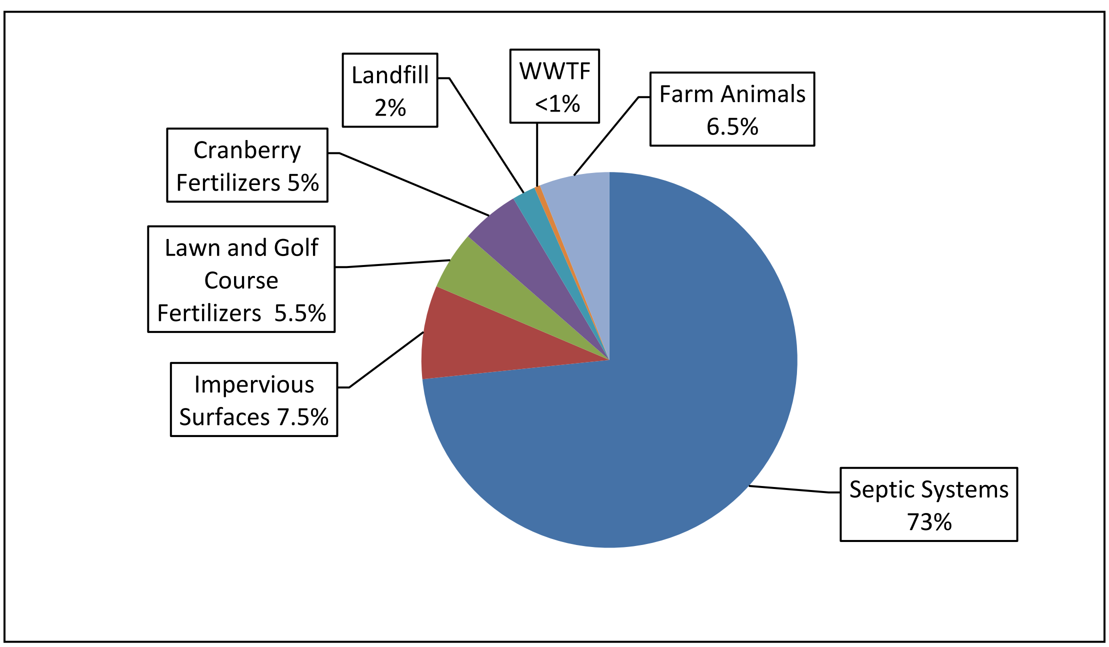


Figure ES-B: Percent Contributions of Controllable Nitrogen Sources to the Herring River Estuarine System



Target Threshold N Concentrations and Loadings

The Herring River estuary lies entirely within the Town of Harwich on Cape Cod, Massachusetts. The watershed of this system is predominately in Harwich but a very small portion is in the Town of Dennis and the northern portion of the watershed is in Brewster. The total N loading (the quantity of N) to the system from the entire watershed is approximately 63 kg N/day. The resultant water column concentrations of N ranged from 0.475-0.968 mg/L throughout the entire system (range of annual means collected from 5 stations during 2001-2011 as reported in Table VI-1 of the MEP Technical Report, and included as Appendix A of this report).

In order to restore and protect this estuarine system, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below those that cause the observed environmental impacts. This N concentration will be referred to as the *target threshold N concentration*. The Massachusetts Estuaries Project (MEP) has determined that by achieving a total N concentration of 0.48 mg/L at sentinel station HAR-7 in the middle of the lower reach of the Herring River (see Figure 5), water and habitat quality will be restored in these systems. The mechanism for achieving the target threshold N concentration is to reduce the N loadings to the watershed of the estuarine system. Based on the MEP sampling and modeling analyses and their Technical Report, the MEP study has determined that the Total Maximum Daily Load (TMDL) of N that will meet the target threshold N concentration of 0.48 mg/L is 50.5 kg N/day. To meet the TMDL this report suggests that a 23.7% reduction of the total watershed nitrogen load for the entire system will be required.

This document presents the TMDL for the Herring River estuarine system and suggests possible options to the watershed towns on how to reduce the N loadings to meet the recommended TMDL and protect the waters of this embayment system.

Implementation

The primary goal of TMDL implementation will be lowering the concentrations of N by targeting loadings from on-site subsurface wastewater disposal (septic) systems. The MEP Technical Report for the Herring River estuarine system indicated that by reducing septic loads by 100% in the Upper Herring River subwatershed and 50 % in the Lothrop Road Stream subwatershed the target thresholds can be met. However, there may be other loading reduction scenarios that could achieve the target threshold N concentrations. These options would require additional modeling to verify their effectiveness.

Local officials can explore other loading reduction scenarios through additional modeling as part of their Comprehensive Wastewater Management Plan (CWMP). Implementing best management practices (BMPs) to reduce N loadings from fertilizers and runoff where possible will also help to lower the total N load to the system. Methods for reducing N loadings from these sources are explained in detail in the "MEP Embayment Restoration Guidance for Implementation Strategies" which is available on the MassDEP website http://www.mass.gov/eea/agencies/massdep/water/watersheds/coastal-resources-and-estuaries.html. 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. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under Clean Water Act Section 208.

Finally, growth within the communities of Harwich, Dennis and Brewster 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 that are not meeting 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 these pollutants of concern, taking into consideration all contributing sources to that water body, while allowing the system to 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 (discernible, 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 assimilative loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of nutrient 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 watershed towns of Harwich, Brewster and Dennis 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 Herring River estuarine system the pollutant of concern for these TMDLs (based on documentation of eutrophication) is the nutrient nitrogen. Nitrogen is the limiting nutrient in coastal and marine waters, which means that as its concentration increases so does the amount of plant matter. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton which impairs the healthy ecology of the affected water bodies.

The TMDLs for total N for the Herring River estuarine system are based primarily on data collected, compiled and analyzed by University of Massachusetts Dartmouth’s School of Marine Science and Technology (SMAST) Coastal Systems Program and the town of Harwich Water Quality Monitoring Program as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from 2001 through 2011, a period which will be referred to as the “present conditions” in the TMDL report 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 MEP Technical Report presents the results of the analyses of the coastal embayment systems using the MEP Linked Watershed-Embayment N Management Model (Linked Model). The analyses were performed to assist the watershed community with making 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 are 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 this embayment. These assessments served as the basis for generating a total N loading threshold for use as a goal for watershed N management. The TMDLs are based on the site specific total N threshold generated for this estuarine system. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision-making process for the watershed communities of Harwich, Brewster and Dennis.

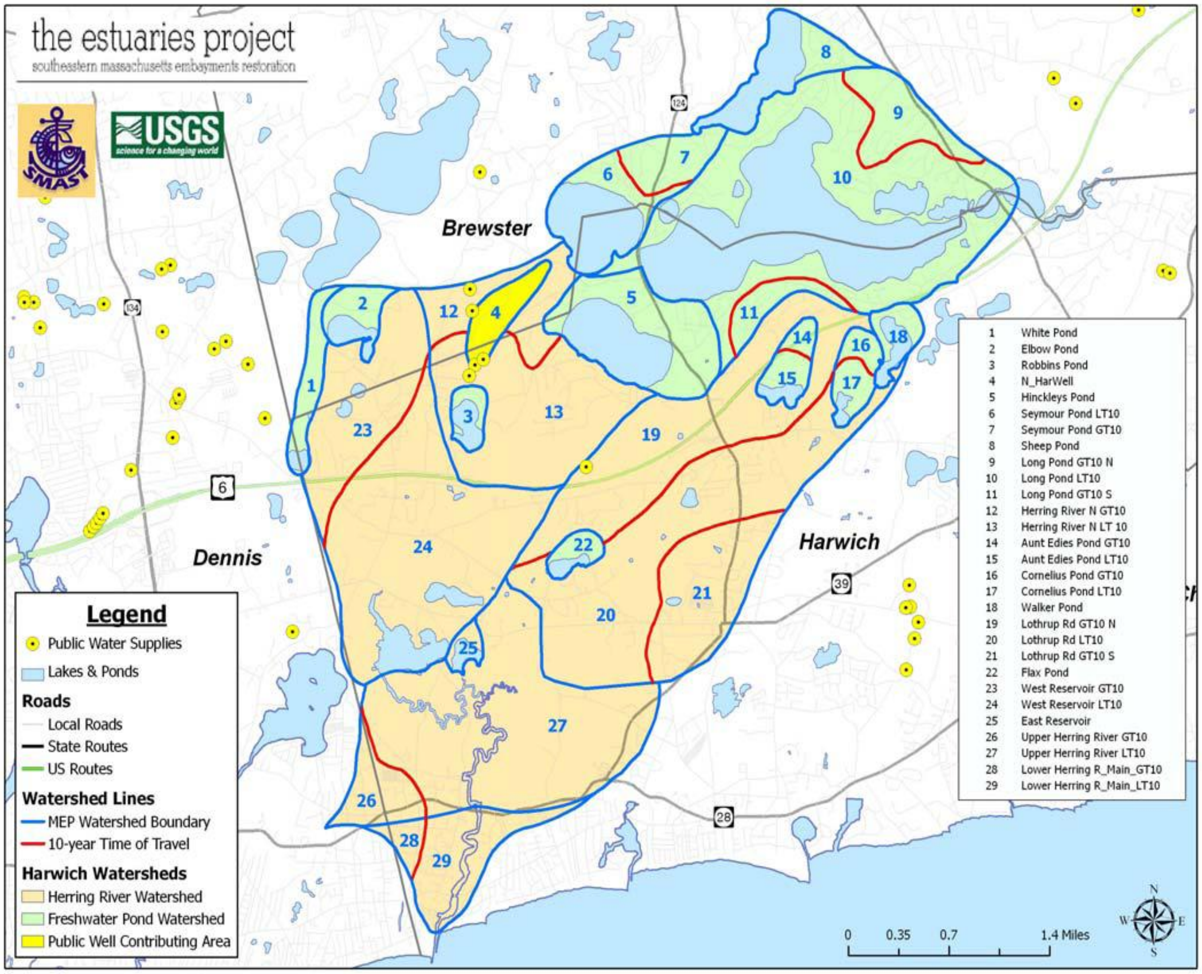
Description of Water Bodies and Priority Ranking

The Herring River system is located within the Towns of Harwich, Brewster and Dennis on Cape Cod. The estuary itself is entirely contained within Harwich but the watershed of the system extends into Brewster and a small portion of Dennis (Figure 1). The MEP Technical Report describes the system as follows:

The Herring River system is comprised of a main tidal river channel, a west branch that extends up to a man-made freshwater reservoir and an east branch that extends up into a small terminal brackish marsh. These two moderately sized streams discharge only a fraction of the aquifer recharge to the estuary, the rest enters from groundwater flow or direct precipitation onto the marsh surface. This large tidal marsh system situated on the southern shore of Cape Cod receives tidal flood water from Nantucket Sound through a single tidal inlet (Figure 2). The inlet is 100 feet wide and has been stabilized by a pair of jetties and is bounded by beach to both the east and west.

The embayment is a salt marsh in the lower and mid reaches and along the major tidal creeks and gradually changes to brackish to predominantly freshwater marsh on the marsh plain in the upper regions. Although the Herring River system functions primarily as a tidal wetland, its lower reach close to the inlet is a tidal river with limited wetland vegetation (from inlet to Route 28 bridge). In this area the tidal channel is relatively wide and navigable thus functioning more like an open water basin than a marsh. Up-gradient of Route 28, the channel narrows and intersects with numerous tidal ditches and smaller tributary marsh creeks. The difference in structure above and below the Route 28 bridge created historic eelgrass habitat and benthic animal communities of more open water basins in the lower tidal reach and wetland dominated habitats in the upper system of salt marsh and tidal channels. This ecological difference results in a greater sensitivity to nitrogen in the lower tidal river portion than in the upper wetland dominated portions. Tidal exchange with the high quality waters of Nantucket Sound is high, given the maintained inlet and the moderate offshore tide range (ca. 6 feet), which has also resulted in tidal creeks which are moderately incised, with near complete drainage of tidal creeks in the upper most portions of the system at low tide.

Figure 1: Watershed Delineations for the Herring River Estuarine System

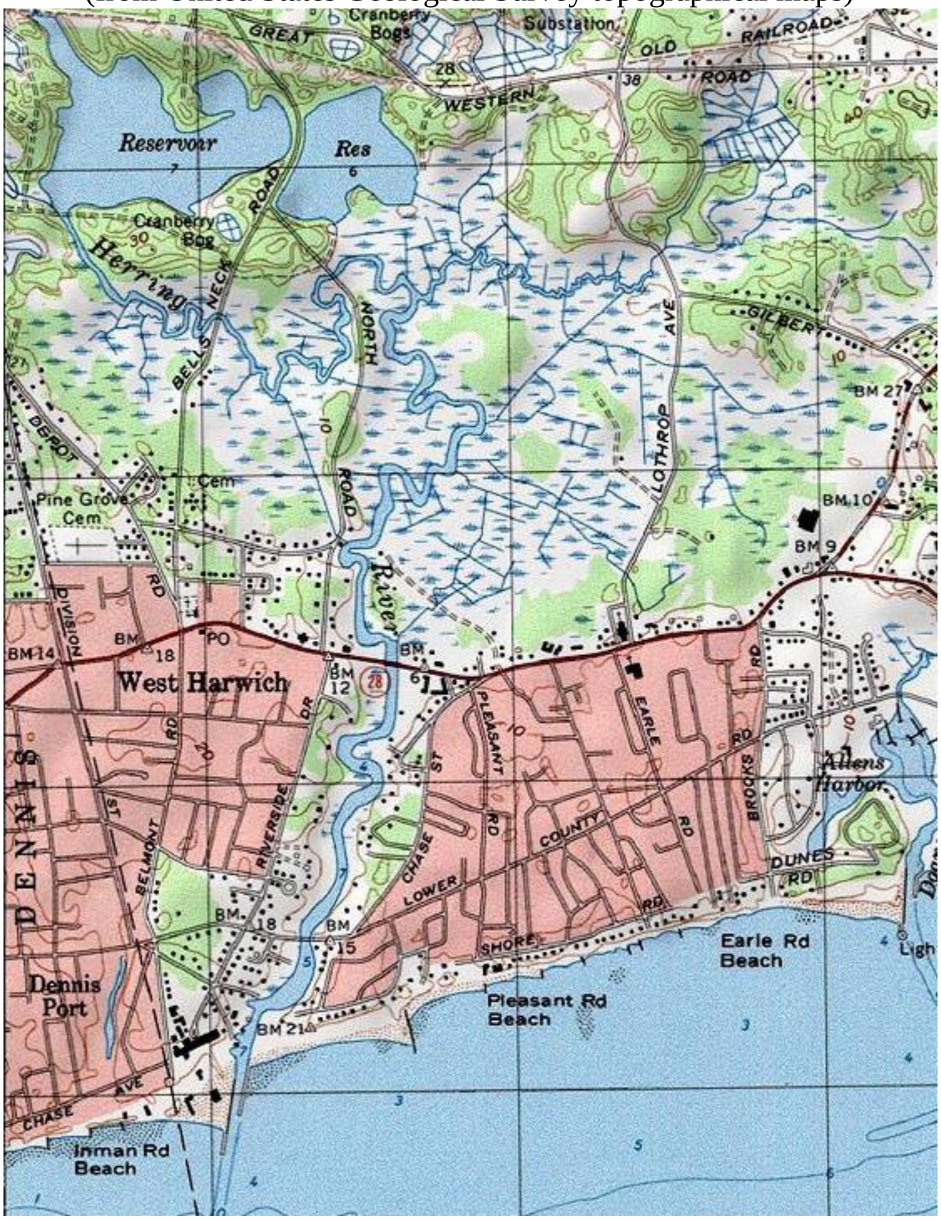


Overall, the Herring River marsh is typical of a large New England tidal marsh system, with the lower regions composed of predominantly salt marsh dominated by a central tidal creek and the marsh plain colonized by *Spartina alterniflora* (low marsh) and *Spartina patens and Distichlis spicata* (high marsh). The upper regions, furthest from the tidal inlet show the influence of the freshwater inflows from the surrounding watershed with species grading to brackish marsh dominated by *Phragmites* finally shifting to freshwater marsh dominated by *Typha* and other freshwater species on the marsh plain.

The primary ecological threat to the Herring River system as a coastal resource is degradation resulting from nutrient enrichment. Loading of the critical eutrophying nutrient, nitrogen, to the Herring River estuarine system has been increasing over the past few decades and has impaired eelgrass habitat in the estuary's lower tidal basin. Since the upper basin of the Herring River system was determined by the MEP study to be wetland dominated and therefore less sensitive to nitrogen enrichment than the tidally dominated lower basin it was characterized as a high quality habitat that had not been impaired by the naturally high levels of nitrogen. However, the MEP

Technical Report concluded that further increases of nitrogen to the estuary and increased habitat degradation are certain unless nitrogen management is implemented.

Figure 2: Map of the Herring River Estuarine System
(from United States Geological Survey topographical maps)



Nitrogen enrichment occurs through two primary mechanisms, 1) high rates of nitrogen entering from the surrounding watershed and/or 2) low rates of flushing due to "restricted" tidal exchange with the low nitrogen waters of Nantucket Sound.

The nitrogen loading to the Herring River estuary, like almost all embayments in southeastern Massachusetts, results primarily from on-site disposal of residential (and some commercial) wastewater. The Town of Harwich, like most of Cape Cod, has seen rapid growth over the past several decades and does have two small wastewater treatment facilities located within the town boundaries (the town Middle/Elementary School complex and the Cranberry Pointe nursing home facility). Even so, most areas of the Herring River watershed rely almost entirely on privately maintained on-site septic treatment and disposal of wastewater. As existing and probable increasing levels of nutrients impact the coastal embayments of the Town of Harwich, water quality degradation will accelerate, with further harm to valuable environmental resources.

Fortunately for the resource protection of the upper basin of the Herring River (north of Route 28), its function as a tidal wetland system makes it more tolerant of watershed nitrogen inputs than coastal open-water embayments, like nearby Allens Harbor or Wychmere Harbor. The greater sensitivity of embayments versus wetlands results from their lower rates of water turnover, the fact that there is limited to no exposure of the sediments to the atmosphere at low tide (like the marsh plain), and the fact that these systems have evolved under much lower levels of productivity and organic matter loading than wetlands.(MEP Technical Report)

Table 1 lists the various categories of the waterbody segments in this system that appear in the 2012 Integrated List of Waters. Herring River is listed in Category 4a as impaired for pathogens with an approved TMDL however it is not listed as impaired for nutrients because, for the assessment period (2004 – 2008), eelgrass was still present in the lower estuary. Since the MEP analysis did show nutrient impairment due primarily to complete eelgrass loss by 2010, this segment will be listed as impaired in a future MA Integrated List of Waters. Fecal Coliform is listed in Table 1 for completeness. Further discussion of fecal coliform is beyond the scope of this TMDL. Also, Long Pond and Hinkley’s Pond are included for completeness in this table since they part of the Herring River Watershed and appear in the 2012 integrated list, but they are not included in this TMDL.

Table 1: Herring River System Waterbodies in the 2012 Integrated List of Waters

Name	Segment ID	Description	Size	Category*	Impairment Cause	EPA TMDL Number
Herring River	MA96-22	Outlet of Herring River Reservoir (at North Harwich Reservoir Dam) west of Bells Neck Road, Harwich to mouth at Nantucket Sound, Harwich.	0.07 Miles^2	4a	Fecal Coliform	36772
Long Pond	MA96183	Brewster/Harwich	715 Acres	5	Dissolved Oxygen	--
Hinckleys Pond	MA96140	Harwich	164 Acres	2	--	--

*Category 4a – TMDL is completed
Category 5 – Waters requiring a TMDL
Category 2 – Attaining some uses, other uses not assessed

A majority of the information presented here is drawn from the MEP Technical Report. A complete description of the embayment system is presented in Chapters I, III and IV of this report. Chapters VI and VII of the MEP Technical Report provide assessment data that show that the Herring River estuarine system is impaired primarily because of degraded eelgrass habitat and nutrients.

Table 2 compares the DEP listed impaired parameter and the MEP impairments found during the technical study by SMAST for the Herring River.

Table 2: Comparison of Impaired Parameters for the Herring River System

Name/Segment	DEP Listed Parameter	SMAST Impaired Parameter
Herring River (MA96-22)	Fecal Coliform	Eelgrass Loss, Nutrients (in lower Herring River, portion MA96-22)

The embayment addressed by this document has been determined to be "high priority" based on three significant factors: (1) the initiative that the town of Harwich has taken to assess the conditions of the entire embayment system; (2) the commitment made by the town to restore the Herring River estuarine system; and (3) the extent of impairment in the Herring River estuarine system. 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. 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.

Problem Assessment

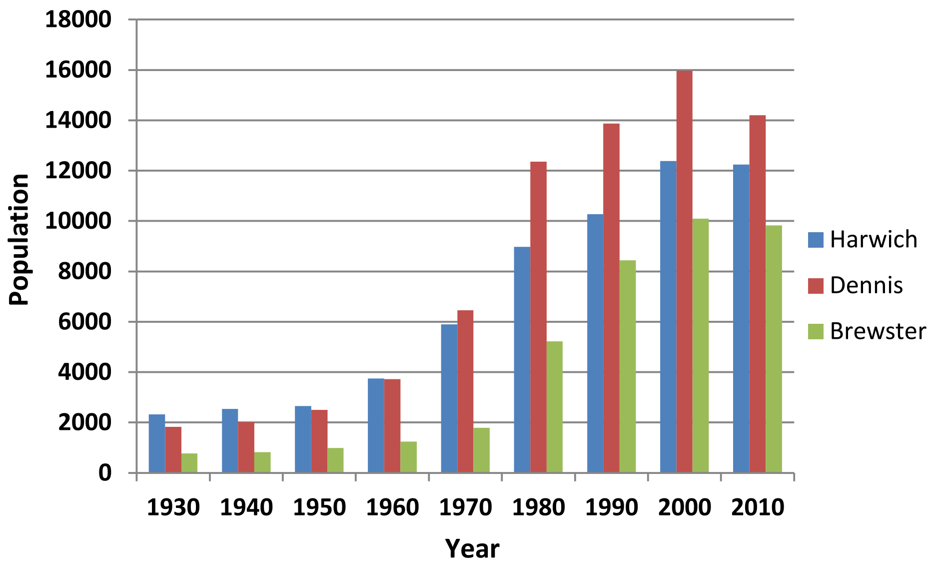
Water quality problems associated with development within the watershed result primarily from septic systems and much less from the landfill, runoff and fertilizers. The water quality problems affecting nutrient-enriched embayments generally include periodic decreases of dissolved oxygen, loss of eelgrass habitat, decreased diversity and quantity of benthic animals and periodic algae blooms. 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 Harwich, 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 shell fishing. The continued degradation of this coastal embayment as described above will significantly reduce the recreational and commercial value and use of these important environmental resources.

Figure 3 shows how the populations of the watershed towns of Harwich, Dennis and Brewster have increased dramatically in the last 50 years or so - about 4 times as much for Harwich and Dennis and almost 10 times for Brewster (http://www.census.gov/popest/data/index.html). Increases in N loading to estuaries are directly related to increasing development and population in the watershed. The increase in population contributes to a decrease in undeveloped land and an increase in septic systems, runoff from impervious surfaces and fertilizer use. All the residences in the Herring River watershed are serviced by privately maintained conventional on-site septic systems with the exception of two wastewater treatment facilities with groundwater discharge permits that service the Harwich Middle/Elementary School and the Cranberry Pointe Nursing Home. There are also four innovative/alternative septic systems on record in the watershed. There is no centralized wastewater treatment system in the watershed. These unsewered areas contribute significant nitrogen to the system through transport in direct groundwater discharges to estuarine waters and through surface water flows from freshwater tributaries and ponds.

Habitat and water quality assessments were conducted on this estuarine system based upon water quality monitoring data, changes in eelgrass distribution, time-series water column oxygen measurements and benthic community structure. As a basis for a nitrogen threshold determination, the MEP study focused on major habitat quality indicators: (1) bottom water dissolved oxygen and chlorophyll-*a* concentrations; (2) eelgrass distribution over time and (3) benthic animal communities (see Chapter VII of the Technical Report).

The Herring River estuarine system is a complex estuary composed of two functional types of component basins: a tidal river (lower Herring River estuary - inlet to Route 28 bridge) which is functioning as an open-water basin, and tidal wetlands (upper Herring River estuary - above Route 28 bridge) with the upper reaches supporting extensive salt marsh area and fresh/brackish tidal wetlands with tidal creeks. The difference in structure above and below the Route 28

Figure 3: Resident Population Trend for Herring River Watershed Towns



bridge created historic eelgrass habitat and benthic animal communities of more open water basins in the lower tidal reach and wetland dominated habitats in the upper wetland basin. This ecological difference results in a greater sensitivity to nitrogen in the lower tidal river portion than in the upper wetland dominated portions. In addition, the extensive salt marsh introduces a level of natural organic enrichment.

At present, the Herring River estuarine system is showing differences in nitrogen enrichment and habitat quality among its two component basins with regions of clearly impaired habitat as well as healthy habitat. (Table 3, taken from the MEP Technical Report) Eelgrass habitat has not historically existed within the creeks of the upper wetland dominated basin of the Herring River estuary, consistent with other large wetland systems. Tidal creeks do not generally support eelgrass habitat, particularly when the creek drains significantly during each ebb tide. Further, the naturally high organic matter and nitrogen levels and low oxygen in large wetlands are not generally supportive of eelgrass development and growth. In contrast, the lower tidal reach of the Herring River estuary, which functions as a tidal river carrying tidal exchange between the large upper wetland basin and Nantucket Sound has historically supported eelgrass. Nitrogen enrichment through direct groundwater inputs as well as naturally high nitrogen contributions from the upstream tidal wetlands has resulted in a near complete loss of eelgrass from the lower estuary from 2004 to 2010. However, at present there is no clear impairment of benthic habitat within the Herring River estuary at existing levels of organic matter and nitrogen loading.

The measured levels of oxygen depletion and enhanced chlorophyll a levels are consistent with the observed habitat quality within the functional basin types (wetland/open water) throughout the Herring River estuary. Overall the oxygen levels observed within the creeks of the upper basin are typical of wetland dominated creeks and are comparable to other similarly structured healthy wetland areas on Cape Cod. However, the higher oxygen levels and lower phytoplankton biomass in the tidal river are consistent with an open water basin that until recently supported eelgrass and presently supports high quality benthic habitat. Tidal river oxygen conditions did exhibit daily excursions in oxygen levels, but the range of daily oxygen excursion and level of depletion was moderate. Based upon the level of depletion (periodically to 4 mg/L), there should be concern that should nitrogen enrichment increase, causing even greater oxygen depletion, the high quality benthic habitat in the tidal river will become impaired.

Table 3: Summary of Conditions Related to the Major Indicators of Habitat Impairment Observed in the Herring River Estuarine System

Health Indicator	Herring River Estuary			
	Tidal Wetlands (Upper Estuary)			Tidal River (Lower Estuary)
	West	Main Creek	East	
Dissolved Oxygen	H	H	H	MI
Chlorophyll	H-MI	H	H	H
Macroalgae	-	-	-	-
Eelgrass	--	--	--	SI
Infaunal Animals	H	H	H	H
Overall	H	H	H	SI

H - Healthy Habitat Conditions*
MI – Moderately Impaired*
SI – Significantly Impaired- considerably and appreciably 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/eea/agencies/massdep/water/watersheds/the-massachusetts-estuaries-project-mep.html
-- no evidence this basin is supportive of eelgrass
- sparse or absent

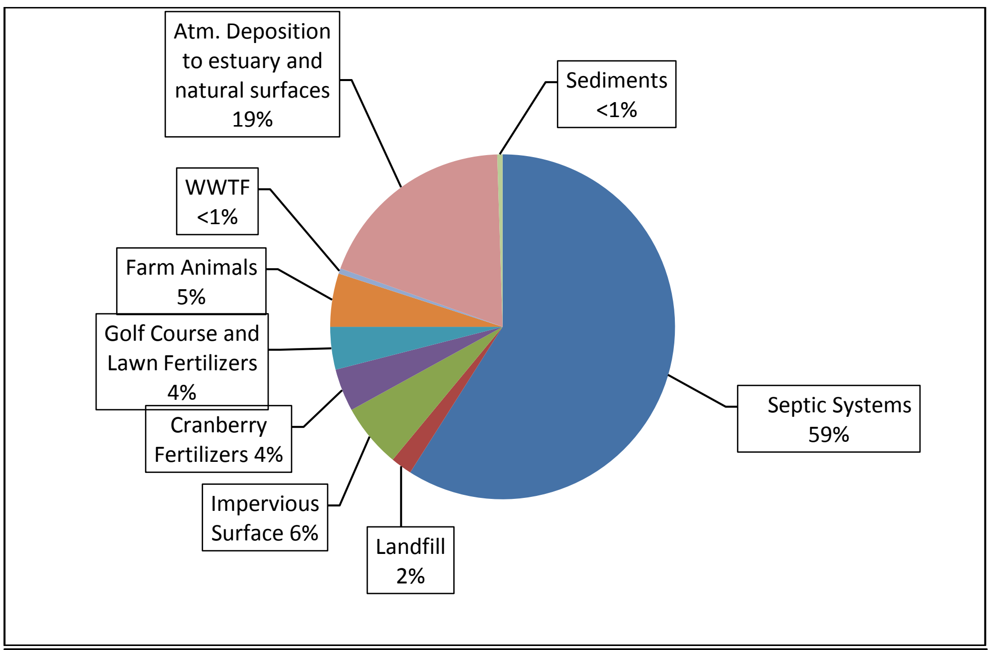
Pollutant of Concern, Sources, and Controllability

In the coastal embayments of the town of Harwich as in most marine and coastal waters the limiting nutrient is N. 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.

The embayment addressed in this TMDL report has had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the Town of Harwich, SMAST, 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.

Figure 4 illustrates the sources of N to the Herring River estuarine system. Most of the controllable N affecting these systems originates from on-site subsurface wastewater disposal systems (septic systems).

Figure 4: Percent Contribution of Nitrogen Sources to the Herring River Estuarine System



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

<u>Atmospheric deposition to estuary and natural surfaces (forests, fields, etc.)</u> – Although helpful, local controls are not adequate – it is only through region- and nation-wide air pollution control initiatives that significant reductions are feasible, however the N from these sources might be subjected to enhanced natural attenuation as it moves towards the estuary.

<u>Farm animals</u> – related N loadings can be controlled through agricultural BMPs.

Fertilizer –Fertilizer and related N loadings can be reduced through best management practices (BMPs), bylaws and public education.

Impervious surfaces and stormwater runoff - sources of N can be controlled by BMPs, bylaws and stormwater infrastructure improvements and public education.

Landfill – the Town of Harwich owns a closed and capped landfill and there is also a wood waste reclamation facility located within the Herring River watershed and the nitrogen load from these landfill drains to the watershed. Related N loadings can be controlled through appropriate BMP and management techniques.

Nitrogen from sediments - 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 N from fluxing.

Septic system - sources of N 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 N-reducing on-site wastewater treatment systems.

WWTF – the Harwich Elementary/Middle School and the Cranberry Pointe Nursing Home wastewater treatment plants are small, groundwater discharge facilities within the watershed. Sources of N can be reduced via implementation of nitrogen removal technologies.

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

Description of the Applicable Water Quality Standards

The water quality classifications of the saltwater portions of the Herring River estuarine system are SA (all surface waters subject to the rise and fall of the tide), and the freshwater portions of the system are classified as B. Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen (DO), nutrients, aesthetics, and 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 or combinations 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)(b) states: "Bottom Pollutants or Alterations. All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the

physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms."

314 CMR 4.05(5)(c) states, "Nutrients - Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established…"

314 CMR 4.05(b) 1:

Class SA: 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.

Class B: Dissolved Oxygen

a. Shall not be less than 6.0 mg/L in cold water fisheries and not less than 5.0 mg/L in warm water fisheries;

b. Where natural background conditions are lower, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

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 EPA 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 tend to have unique characteristics and development of individual water body criteria is typically required.

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 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 harmful or excessive algal blooms;
3) preserve healthy benthic communities;
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.

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 50 embayments thus far 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. Also, 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. It should be noted that this approach includes high-order, watershed and sub-watershed scale modeling necessary to develop critical nitrogen targets for each major sub-embayment. The models, data and assumptions used in this process are specifically intended for the purposes stated in the MEP Technical Report, upon which this TMDL is based. As such, the Linked Model process does not contain the type of data or level and scale of analysis necessary to predict the fate and transport of nitrogen through groundwater from specific sources. In addition, any determinations related to direct and immediate hydrologic connection to surface waters are beyond the scope of the MEP's Linked Model Process.

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-4 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
    - chlorophyll *a* record
    - eelgrass 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 embayments, for the purpose of developing target N loading rates, includes:

1) Selecting one or two stations within the embayment system located close to the inland-most reach or reaches which typically have 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 that 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 relate to **N concentration:**

1) the present N concentrations in the sub-embayments;
2) site-specific target threshold N concentrations.

And, two outputs relate to **N loadings:**

1) the present N loads to the sub-embayments;

2) load reductions necessary to meet the site specific target N concentrations.

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

A brief overview of each of the outputs follows:

Nitrogen concentrations in the embayment

1) Observed "present" conditions:

Table 4 presents the average concentrations of N measured in this estuarine system from data collected by the Town of Harwich water quality monitoring program during the period 2001-2011. The overall means and standard deviations of the averages are presented in Appendix A (taken from Table VI-1 of the MEP Technical Report). Water quality sampling stations are shown in Figure 5 below. The sentinel station is HAR-7 located at the Route 28 bridge.

2) Modeled site-specific target threshold N 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. This is called the *target threshold nitrogen concentration*. 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 target threshold N concentrations by using the specific physical, chemical and biological characteristics of each sub-embayment.

The target threshold nitrogen concentration for the Herring River Estuary is 0.48 mg/L (Table 4). The approach for determining nitrogen loading rates, which will maintain acceptable habitat quality throughout an embayment system is to first identify a sentinel location within the embayment and second to determine the nitrogen concentration within the water column,which will restore that location to the desired habitat quality. The sentinel location is selected such that the restoration of that one site will necessarily bring the other regions of the system to acceptable habitat quality levels. Once the sentinel site and its target threshold nitrogen concentration are determined, the MEP study modeled nitrogen loads until the targeted nitrogen concentration was achieved.

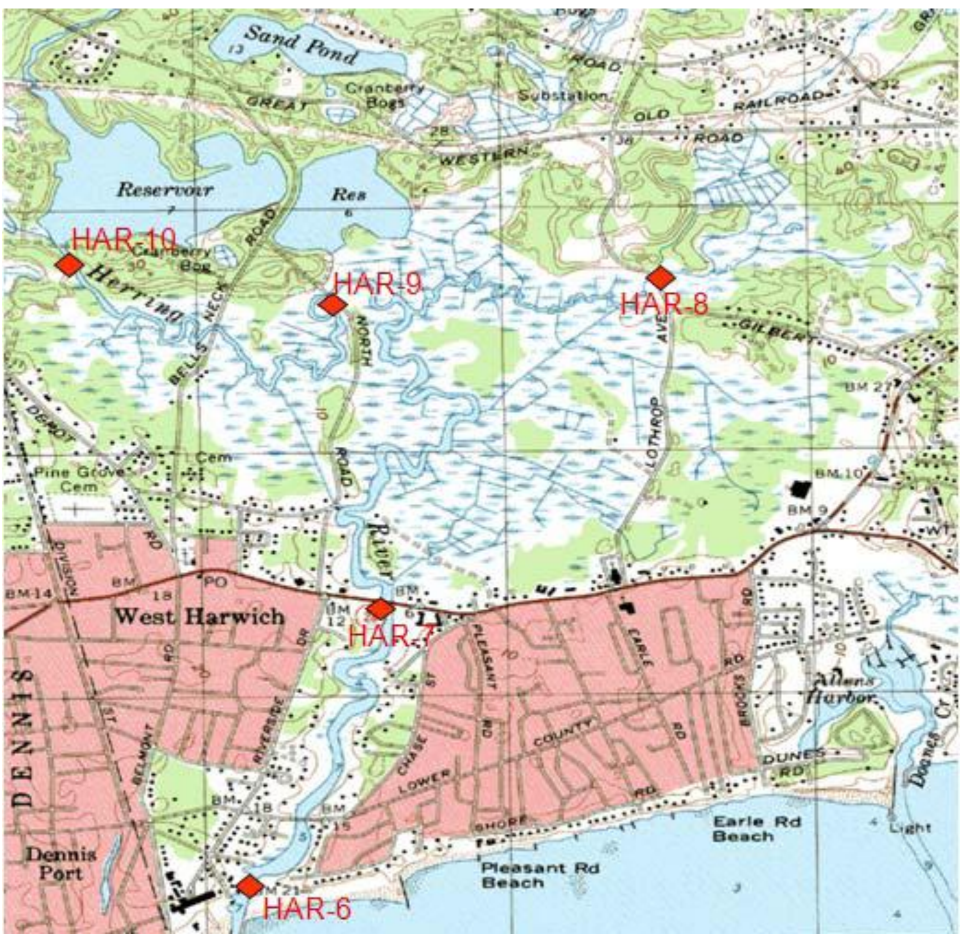
The determination of the critical target threshold nitrogen concentration for maintaining high quality habitat with the Herring River estuarine system is based on the nutrient and oxygen levels, temporal trends in eelgrass distribution and benthic community indicators. The primary habitat issues within the Herring River estuarine system relate to the loss of the eelgrass beds from the lower Herring River estuary. The loss of eelgrass classifies the lower Herring River estuary as "significantly impaired". However, the higher oxygen levels and lower phytoplankton biomass in the tidal river are consistent with an open water basin that until recently supported

Table 4: Observed Present Nitrogen Concentrations and Sentinel Station Target Threshold Nitrogen Concentration for the Herring River Estuarine System

Sub-embayment	Monitoring Station	Observed Nitrogen Concentration [1](mg/L)	Target Threshold Nitrogen Concentration (mg/L)
Lower Herring River Estuary (Wixen Dock)	HAR-6	0.628	
Mid Estuary (Route 28)	HAR-7	0.685	0.48
Upper Herring River Estuary (North Road)	HAR-9	0.810	
Lothrop Road (East Branch H.R.)	HAR-8	0.827	
West Reservoir	HAR-10	0.700	

[1] Average total N concentrations from present loading based on an average of the annual N means from 2001-2011.

Figure 5: Water Quality Sampling Stations in the Herring River Estuarine System



eelgrass and presently supports high quality benthic habitat. Based upon all lines of evidence it appears that the upper wetland basin of the Herring River estuary is presently supporting high quality infaunal habitat, is structurally unable to support eelgrass, and has not exceeded its threshold nitrogen level for assimilating additional nitrogen without impairment. Therefore, nitrogen management should focus on the recent losses of eelgrass habitat from the lower estuary's tidal river basin, as the upper wetland basin appears to be well below its nitrogen loading threshold level. As infaunal habitat is less sensitive to the effects of nitrogen enrichment than is eelgrass, reducing the level of nitrogen enrichment to restore the impaired eelgrass habitat will also enhance infaunal habitat within the tidal river portion of the estuary.

The MEP study results indicate that eelgrass has been lost from the Herring River estuary in areas that presently support tidally averaged TN levels of 0.57 mg N L-1. In other similar systems "healthy" beds have been observed at <0.428 mg N L-1 and 0.421 mg N L-1 in the East and West Branches of the Westport River Estuary, which also has extensive up gradient wetlands. It appears that in the Westport River Estuary, the TN level to support high quality eelgrass habitat may be greater than 0.43 mg N L-1, but less than 0.50 mg N L-1. However, in systems with shallow water or where the tidal exchange places clear low nutrient water over the eelgrass for half of the tide, like in the tidal river reach of the Herring River Estuary, eelgrass beds are sustainable at higher tidally averaged TN levels. At shallow depths in Bournes Pond, eelgrass can still be found (although heavy with epiphytes) at the mouth of the upper tributary at a tidally averaged TN concentration of 0.481 mg TN L-1, while the more stable beds in the lower region of Israel’s Cove have at a tidally averaged TN of 0.429 mg TN L-1. All of the eelgrass information for the Herring River estuary indicates that the nitrogen threshold level supportive of high quality eelgrass habitat is close to, but less than 0.50 mg N L- 1. The threshold is significantly affected by the very high water quality during flood tides (0.32 - 0.34 mg N L-1) which is supportive of eelgrass coverage versus the relatively poor water quality (for open water systems) during the ebbing tides (0.68 - 0.77 mg N L-1) due to out-flow from the extensive upper wetland basin. The result is that the threshold must take into account the daily variation in conditions not just the average condition.

Given the structure of the tidal river, particularly the existence of the extensive upper wetland system, and the recent loss and current TN levels, it appears that TN levels need to be lowered to 0.48 mg L-1 at the sentinel station (HAR-7) at the Route 28 bridge. This site was selected based upon its location at the upper most extent of the documented eelgrass coverage in this estuary.

The findings of the analytical and modeling investigations for the Herring River estuarine system are discussed and explained below.

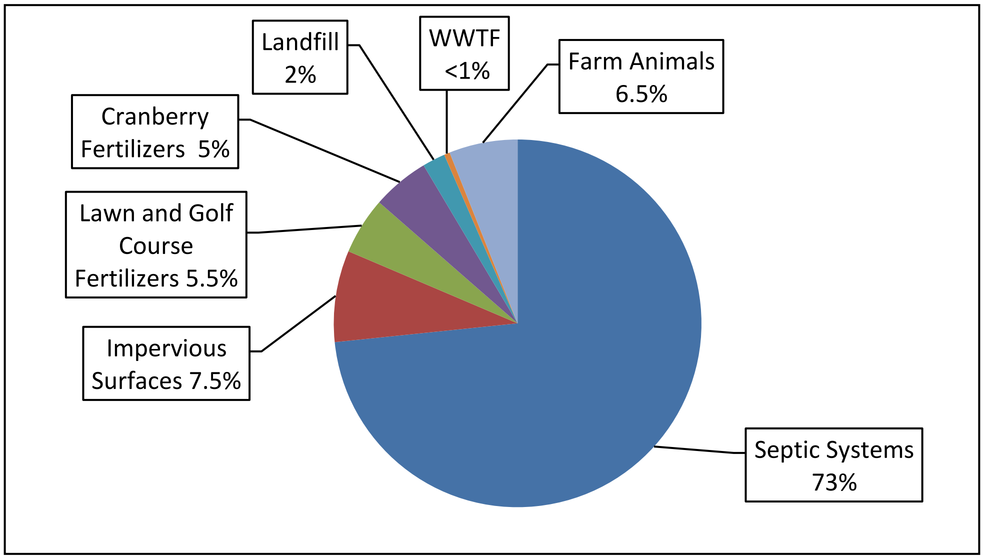
The target threshold N concentration for an embayment represents the average water column concentration of N that will support the habitat quality and dissolved oxygen concentrations being sought. The water column N level is ultimately controlled by the integration of the watershed N load, the N concentration 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.Target threshold N concentrations in this study were developed to restore or maintain SA waters or high habitat quality. In this system, high habitat quality was defined as stable eelgrass beds in the lower reach of Herring River and healthy infaunal habitat throughout the system.

Nitrogen loadings to the embayment

1) Present Loading rates:

In the Herring River estuarine system overall, the highest N loading from ***controllable*** sources is from on-site wastewater treatment systems. The MEP Technical Report calculates that septic systems account for 73% of the controllable N load to the overall system. Other controllable sources include fertilizers from lawns, golf courses and cranberry bogs(10.5%), runoff from impervious surfaces (7.5%), farm animals (6.5%), the landfill (2%), and two small wastewater treatment facilities (<1%). (Figure 6) Nitrogen rich sediments are not considered feasibly controllable but are a minor source in this system. However, reducing the N load to the estuary will also reduce N in the sediments since the magnitude of the benthic contribution is related to the watershed load. Atmospheric nitrogen deposition to the estuary and watershed surface area was also an uncontrollable source to this system.

Figure 6: Percent Contribution of Locally Controllable Sources of Nitrogen to the Herring River Estuarine System



A subwatershed breakdown of N loading, by source, is presented in Table 4. The data on which Table 5 is based can be found in Table ES-1 and Table IV-3 of the MEP Technical Report. As previously indicated, the present N loadings to this estuary system must be reduced in order to restore the impaired 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 that will achieve the target threshold N concentrations.

2) Nitrogen loads necessary for meeting the site-specific target threshold N concentrations:

Table 6 lists the present watershed N loadings from the Herring River estuarine system and the percent watershed load reductions necessary to achieve the target threshold N concentration at the sentinel station (see following section).

Table 5: Present Nitrogen Loadings to the Herring River Estuarine System

Sub-embayment	Present Land Use Load[1] (kg N/day)	Present Septic System Load (kg N/day)	Present Watershed Load[2] (kg N/day)	Atmospheric Deposition[3] (kg N/day)	Present Benthic Flux (kg N/day)	Total Nitrogen Load from All Sources[4] (kg N/day)
Lower Herring River	1.973	7.063	9.036	0.252	1.427	10.715
East Reservoir	0.246	0.047	0.293	0	0.752	1.045
Upper Herring River	2.828	10.468	13.296	0.395	-1.742	11.949
West Reservoir	15.427	12.137	27.564	-	-	27.564
Lothrop Road Stream	3.317	8.877	12.627	-	-	12.627
Herring System Total	23.791	38.592	62.816	0.647	0.437	63.9

[1]Includes fertilizers, runoff, farm animals, landfill and atmospheric deposition to lakes and natural surfaces
[2]Includes fertilizers, runoff, farm animals, landfill, atmospheric deposition to lakes and natural surfaces and wastewater inputs
[3]Atmospheric deposition to the estuarine surface only.
[4]Composed of fertilizers, runoff, landfill, wastewater, atmospheric deposition and benthic nitrogen input

Table 6: Present 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-embayment	**Present Total Watershed Load [1] (kg/day)**	**Target Threshold Watershed Load[2] (kg/day)**	**% Watershed Load Reductions Needed to Achieve Target**
Lower Herring River	9.036	9.036	0
East Reservoir	0.293	0.293	0
Upper Herring River	13.296	2.827	-78.7%
West Reservoir	27.564	27.564	0
Lothrop Road Stream	12.627	8.255	-34.6%
Herring System Total	62.816	47.975	-23.7%

[1] Includes fertilizers, runoff, farm animals, landfill, atmospheric deposition to lakes and natural surfaces and wastewater inputs
[2]Target threshold watershed load is the N load from the watershed (including natural background) needed to meet the target threshold N concentration identified in Table 4, above.
*From Tables ES-2and VIII-3 in the MEP Technical Report

It is very important to note that load reductions can be produced through a variety of strategies: reduction of any or all sources of N; increasing the natural attenuation of N within the freshwater systems; and/or modifying the tidal flushing through inlet reconfiguration (where appropriate). This scenario establishes the general degree and spatial pattern of reduction that will be required for restoration of the N impaired portions of this system. The watershed towns of Harwich, Dennis and Brewster should take any reasonable actions to reduce the controllable N 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 Herring River estuarine system are aimed at establishing the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems.

The development of a TMDL requires detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time) for each waterbody system. 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 *a* 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 is included in the loading estimates, but is not quantified or presented separately. Background loading was calculated on the assumption that the entire watershed is forested with no anthropogenic sources of N. It is accounted for in this TMDL but not defined as a separate component. Readers are referred to Table ES-1 of the MEP Technical Report for estimated loading due to natural conditions.

Waste Load Allocations

Waste load allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. In the Herring River estuarine system there are no permitted surface water discharges in the watershed with the exception of stormwater. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of stormwater be included in the waste load component of the TMDL.

For purposes of the Herring River TMDLs, MassDEP also considered the nitrogen load reductions from regulated MS4 sources necessary to meet the target nitrogen concentrations. In estimating the nitrogen loadings from regulated stormwater sources, MassDEP considered that most stormwater runoff in the MS4 communities is not discharged directly into surface waters, but, rather, percolates into the ground. The geology on Cape Cod and the Islands consists primarily of glacial outwash sands and gravels, and water moves rapidly through this type of soil profile. A systematic survey of stormwater conveyances on Cape Cod and the Islands was never undertaken prior to the MEP study used in the development of this TMDL. Nevertheless, most catch basins on Cape Cod and the Islands are known to MassDEP to have been designed as leaching catch basins in light of the permeable overburden. MassDEP, therefore, recognized that most stormwater that enters a catch basin in the regulated area will percolate into the local groundwater table rather than directly discharge to a surface waterbody.

As described in the Methodology Section (above), the Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source. However, MassDEP also considered that some stormwater collected in the regulated area is discharged directly to surface waters through outfalls.

In the absence of specific data or other information to accurately quantify stormwater discharged directly to surface waters, MassDEP assumed that all impervious surfaces within 200 feet of the shoreline, as calculated from MassGIS data layers, would discharge directly to surface waters, whether or not it in fact did so. MassDEP selected this approach because it considered it unlikely that any stormwater collected farther than 200 ft. from the shoreline would be directly discharged into surface waters. Although the 200 foot approach provided a gross estimate, MassDEP considered it a reasonable and conservative approach given the lack of pertinent data and information about MS4 systems on Cape Cod. For the Herring River estuarine system this calculated stormwater WLA based on the 200 foot buffer is 0.07 kg/day N. This WLA amounts to 0.06 % of the total N load to the Herring River system (see Appendix C for details). This conservative load is a negligible amount of the total nitrogen load to this embayment when compared to other sources.

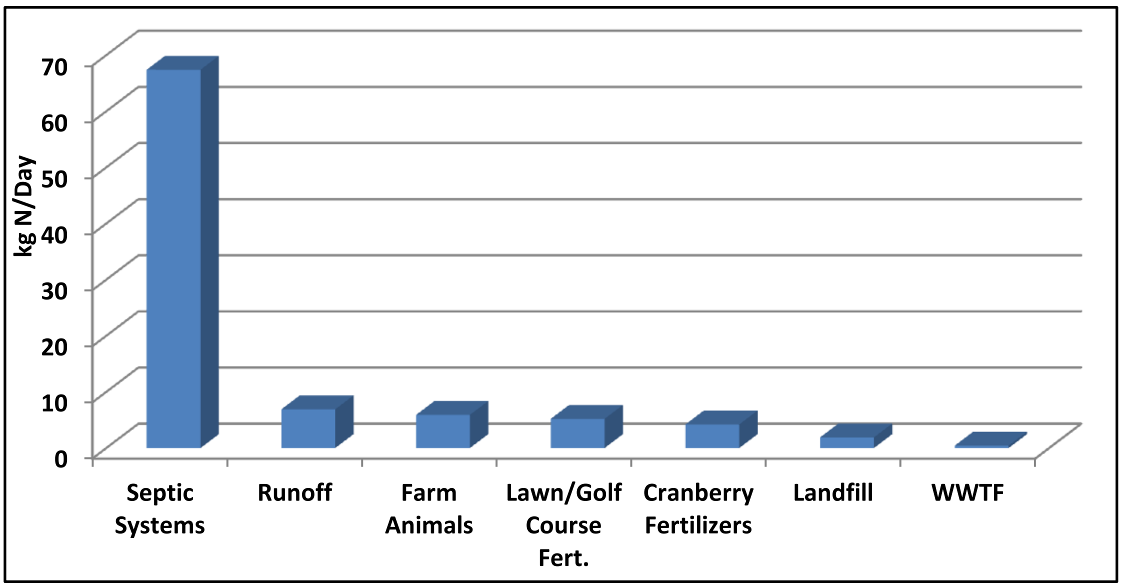
Load Allocations

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Herring River estuarine system the locally controllable nonpoint source loadings are from on-site subsurface wastewater disposal systems (septic systems) and other land uses, which include stormwater runoff, (except from impervious cover within 200 feet of the waterbody which is defined above as part of the waste load) fertilizers, farm animals, two small WWTFs which discharge to groundwater, and the landfill. Figure 6 (above) and Figure 7 (below) illustrate that septic systems are the most significant portion of the controllable N load (73% or 67 kg N/day), with contributions from runoff, farm animals and fertilizers much less (6.9, 5.9 and 9.4 kg N/day, respectively). Loads from the landfill and the WWTPs are even less

(1.9 and .43 kg N/day, respectively). In addition, there are nonpoint sources of N from sediments, natural background and atmospheric deposition that are not feasibly controllable.

Stormwater that is subject to the EPA Phase II Program is considered a part of the waste load allocation, rather than the load allocation (see waste load allocation discussion). As discussed above and presented in Chapter IV, V, and VI, of the MEP Technical Report, on Cape Cod and the Islands the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater. Therefore, the TMDL accounts for stormwater and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and stormwater for the purpose of developing control strategies. As the Phase II Program is implemented in the watershed communities, new studies, and possibly further modeling, will identify what portion of the stormwater load may be controllable through implementation of Best Management Practices (BMPs).

Figure 7: Herring River Estuarine System Locally Controllable N Loads by Source



The sediment loading rates incorporated into the TMDL are lower than the existing benthic input listed in Table 4 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 N (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 Herring River estuarine system is reduced from existing conditions based on the load reduction and the observed PON concentrations within each sub-embayment relative to Nantucket 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. There was one exception to this rule. Since there was a negative benthic flux (nutrient uptake) recorded in the Upper Herring River under present conditions, a more conservative approach was used for this segment in the TMDL by assuming zero benthic flux for this segment in the future. This conservative approach was used and is considered part of the margin of safety in the TMDL.

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.

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 MOS must be designed to ensure that any uncertainties in the data or calculations used to link pollutant sources to water quality impairment modeling will be accounted for in the TMDL and ensure protection of the beneficial uses. 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. An explicit MOS quantifies an allocation amount separate from other Load and Wasteload Allocations. An explicit MOS can incorporate reserve capacity for future unknowns, such as population growth or effects of climate change on water quality. An implicit MOS is not specifically quantified but consists of statements of the conservative assumptions used in the analysis. The MOS for the Herring River estuarine system TMDLs is implicit. MassDEP used conservative assumptions to develop numeric model applications that account for the MOS. These assumptions are described below, and they account for all sources of uncertainty, including the potential impacts of changes in climate.

While the general vulnerabilities of coastal areas to climate change can be identified, specific impacts and effects of changing estuarine conditions are not well known at this time (http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html). Because the science is not yet available, MassDEP is unable to analyze climate change impacts on streamflow, precipitation, and nutrient loading with any degree of certainty for TMDL development. In light of these uncertainties and informational gaps, MassDEP has opted to address all sources of uncertainty through an implicit MOS. MassDEP does not believe that an explicit MOS approach is appropriate under the circumstances or will provide a more protective or accurate MOS than the implicit MOS approach, as the available data simply does not lend itself to characterizing and estimating loadings to derive numeric allocations within confidence limits. Although the implicit MOS approach does not expressly set aside a specific portion of the load to account for potential impacts of climate change, MassDEP has no basis to conclude that the conservative assumptions that were used to develop the numeric model applications are insufficient to account for the lack of knowledge regarding climate change.

Conservative assumptions that support an implicit MOS:

1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayment. 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. In this context, "direct groundwater discharge" refers to the portion of fresh water that enters an estuary as groundwater seepage into the estuary itself, as opposed to the portion of fresh water that enters as surface water inflow from streams, which receive much of their water from groundwater flow. Nitrogen from the upper watershed regions, which travels through ponds or wetlands, almost always enters the embayment via stream flow, and 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%. 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 for the Herring River system based on measurements for four of the 12 freshwater ponds and conservatively estimated at 50% for the remaining ponds. These attenuation factors were higher than that used in the land-use model. All other ponds lacked sufficient data to calculate an attenuation factor so a more conservation value of 50% was applied as more protective and defensible. Nitrogen attenuation in freshwater ponds has generally been determined by the MEP analysis to be at least 50%, so the watershed model assigns a conservative attenuation of 50% to all nitrogen from freshwater pond watersheds unless there is sufficient information to develop a pond-specific attenuation rate to incorporate into the loading analysis.

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 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 predicted 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. It was also conservatively assumed that the present benthic flux uptake measured in the Upper Hearing River (-1.742 kg/day) does not exist under future loading conditions and as such was designated as "0" for purposes of the TMDL.

Benthic regeneration of N is dependent 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 stations and target threshold N concentrations. The 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 concentration. Meeting the target threshold N concentrations at the sentinel stations 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 and therefore this approach is conservative.

Finally, the linked model accounted for all stormwater loadings and groundwater loadings in one aggregate allocation as a non point source and this aggregate load is accounted for in the load allocation. The method of calculating the WLA in the TMDL for regulated stormwater was conservative as it did not disaggregate this negligible load from the modeled stormwater LA, hence this approach further enhances the margin of safety.

In addition to the margin of safety within the context of setting the N threshold levels as described above, a programmatic margin of safety also derives from continued monitoring of these 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 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 N on a seasonal basis and N sources can take considerable time to migrate to impacted waters.

TMDL Values for the Herring River Estuarine 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 7 below.

In this table the non-controllable N loadings from the atmosphere and 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, WWTPs, farm animals, the landfill, stormwater runoff and fertilizer sources. For the Herring River system the TMDLs were calculated by projecting reductions in locally controllable septic systems in the subwatersheds of the upper Herring River estuary and Lothrop Road Stream (Table 8). The goals of these TMDLs are to achieve the identified target threshold N concentration at the identified sentinel station. The target loads identified in Table 6 represent one alternative-loading scenario to achieve that goal but other scenarios may be possible and approvable as well.

Table 7: The Total Maximum Daily Loads (TMDL) for the Herring River Estuarine System

Sub-embayment	Target Threshold Watershed Load[1] (kg N/day)	Atmospheric Deposition (kg N/day)	Nitrogen Load from Sediments[2] (kg N/day)	TMDL[3] (kg N/day)
Lower Herring River	9.036	0.252	1.249	10.54
East Reservoir	0.293	0	0.628	0.92
Upper Herring River	2.827	0.395	0	3.22
West Reservoir	27.564	-	-	27.56
Lothrop Road Stream	8.255	-	-	8.26
Herring River System Total	47.975	0.647	1.877	50.50

[1] Target threshold watershed load (including natural background) is the load from the watershed needed to meet the embayment target threshold nitrogen concentration identified in Table 4.
[2] Projected sediment N loadings obtained by reducing the present benthic flux loading rates (Table 4) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON. (Negative fluxes set to zero.)
[3] Sum of target threshold watershed load, sediment load and atmospheric deposition load.

Implementation Plans

The critical element of this TMDL process is achieving the specific target threshold N concentration for the sentinel station presented in Table 4 above that is necessary for the restoration and protection of water quality and eelgrass habitat within the Herring River estuarine system. In order to achieve these target threshold N concentrations, N loading rates must be reduced throughout the harbor embayment system. Table 6, above, lists the target watershed threshold loads for this embayment. If this threshold load is achieved, this embayment will be protected.

Septic Systems:
Table 8 presents a load reducing scenario based solely on reducing the septic loads from the Herring River estuary watershed. However, as previously noted, there is a variety of loading reduction scenarios that could achieve the target threshold N concentrations. Local officials can explore other loading reduction scenarios through additional modeling as part of their Comprehensive Wastewater Management Plan (CWMP). It must be demonstrated however, that any alternative implementation strategies will be protective of the entire embayment system and that none of the embayment will be negatively impacted. To this end, additional linked model runs can be performed by the MEP to assist the planning efforts of the town in achieving target N loads that will result in the desired target threshold N concentration.

Table 8: Summary of the Present On-Site Subsurface Wastewater Disposal System Loads, and the Loading Reductions Necessary to Achieve the TMDL by Reducing On-Site Subsurface Wastewater Disposal System Loads Only

Herring River System/Subwatershed	Present Septic System Load (kg N/day)	Threshold Septic System Load (kg N/day)	Threshold Septic System Load % Change
Lower Herring River	7.063	7.063	0
East Reservoir	0.047	0.047	0
Upper Herring River	10.468	0.00	-100.0%
West Reservoir	12.137	12.137	0
Lothrop Road	8.877	4.504	-49.3%

(Note: Taken from Table VIII-2 of the MEP Technical Report. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, WWTF, landfill, or fertilizer loading terms.)

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. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under the Clean Water Act Section 208.

If a community chooses to implement TMDL measures without a CWMP it must demonstrate that these measures will achieve the target threshold N concentration. (Note: Communities that choose to proceed without a CWMP will not be eligible for State Revolving Fund loans.)

Because the vast majority of controllable N load is from septic 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.

Stormwater:
The 2003 NPDES permits which EPA has issued in Massachusetts to implement the Phase II Stormwater program do not establish numeric effluent limitations for stormwater discharges, rather, they establish narrative requirements, including best management practices, to meet the following six minimum control measures and to meet State Water Quality Standards.

1. Public education and outreach particularly on the proper disposal of pet waste,
2. Public participation/involvement,
3. Illicit discharge detection and elimination,
4. Construction site runoff control,

5. Post construction runoff control, and
6. Pollution prevention/good housekeeping.

As part of their applications for Phase II permit coverage, communities must identify the best management practices they will use to comply with each of these six minimum control measures and the measurable goals they have set for each measure. Therefore, compliance with the requirements of the Phase II stormwater permit in the Town of Harwich will contribute to the goal of reducing the nitrogen load as prescribed in this TMDL for the Herring River estuarine system watershed. In their 2014 annual Phase II MS4 Stormwater report to EPA (http://www.epa.gov/region1/npdes/stormwater/2003-permit-archives.html) Harwich reports that 100% of the mapping of the stormdrain system and outfalls in the town has been completed and field verification is ongoing. The annual reports indicate that they continue to update stormwater drainage systems to Phase II standards. In addition, the Town conducts an ongoing public outreach campaign that includes website, posters, handouts, mailers and flyers with information on various pollution prevention activities (e.g., hazardous waste collections) and regulations.

Other activities being conducted by Harwich as reported in their most recent (2014) NPDES Phase II MS4 Annual Report include: membership in the Pleasant Bay Resource Management Alliance (The Alliance has over 100 volunteers who collect water samples throughout the Bay from June through September); hosting COASTSWEEP which organizes volunteer beach cleaning events in Harwich; and working with Americorps of Cape Cod to clean streams related to herring runs in Harwich.

The Town of Brewster which drains the uppermost portion of the watershed has implemented a number of activities relative to their Phase II MS4 permit (as reported in their 2014 Annual Stormwater Report to EPA). These include: several water quality projects funded under a CZM nonpoint source pollution grant for the Stoney Brook Watershed, various education and outreach projects, replacing an undersized culvert under Route 6A, work on the town's Integrated Water Resource management Plan which includes addressing stormwater issues, updating the Town's GIS system relative to stormwater infrastructure, approval of a IDDE by-law, and completion of a comprehensive IDDE plan.

There is a small amount of Phase II stormwater regulated area (<100 acres) in Dennis's portion of the watershed. In its 2014 Annual Stormwater Report to EPA Dennis has implemented a number of activities relative to their Phase II MS4 Permit that may impact the Herring River watershed. These include: good housekeeping actions for municipal operations, requiring applicable commercial projects and all subdivisions to meet the Town's stormwater requirements, enforcement of the stormwater by-law, various education and outreach projects, and ongoing update of stormwater outfall maps.

Climate Change:
MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are possible based on known science. Massachusetts Executive Office of Energy and Environmental Affairs 2011Climate Change Adaptation Report: http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html predicts that by 2100 the sea level could be from 1 to 6 feet higher than the current position and

precipitation rates in the Northeast could increase by as much as 20 percent. However, the details of how climate change will affect sea level rise, precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. The ongoing debate is not about whether climate change will occur, but the rate at and the extent to which it will occur and the adjustments needed to address its impacts. EPA's 2012 Climate Change Strategy http://water.epa.gov/scitech/climatechange/upload/epa_2012_climate_water_strategy_full_report_final.pdf states: "Despite increasing understanding of climate change, there still remain questions about the scope and timing of climate change impacts, especially at the local scale where most water-related decisions are made." For estuarine TMDLs in southeastern Massachusetts, MassDEP recognizes that this is particularly true, where water quality management decisions and implementation actions are generally made and conducted at the municipal level on a sub-watershed scale.

EPA's Climate Change Strategy identifies the types of research needed to support the goals and strategic actions to respond to climate change. EPA acknowledges that data are missing or not available for making water resource management decisions under changing climate conditions. In addition, EPA recognizes the limitation of current modeling in predicting the pace and magnitude of localized climate change impacts and recommends further exploration of the use of tools, such as atmospheric, precipitation and climate change models, to help states evaluate pollutant load impacts under a range of projected climatic shifts.

In 2013, EPA released a study entitled, "Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds." (National Center for Environmental Assessment, Washington D.C.; EPA/600/R-12/058F). The closest watershed to southeastern Massachusetts that was examined in this study is a New England coastal basin located between Southern Maine and Central Coastal Massachusetts. These watersheds do not encompass any of the watersheds in the Massachusetts Estuary Project (MEP) region, and it has vastly different watershed characteristics, including soils, geography, hydrology and land use – key components used in a modeling analysis. The initial "first order" conclusion of this study is that, in many locations, future conditions, including water quality, are likely to be different from past experience. However, most significantly, this study did not demonstrate that changes to TMDLs (the water quality restoration targets) would be necessary for the region. EPA's 2012 Climate Change Strategy also acknowledges that the Northeast, including New England, needs to develop standardized regional assumptions regarding future climate change impacts. EPA's 2013 modeling study does not provide the scientific methods and robust datasets needed to predict specific long-term climate change impacts in the MEP region to inform TMDL development.

MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind. Adjustments can be made as environmental conditions, pollutant sources, or other factors change over time. Massachusetts Coastal Zone Management (CZM) has developed a StormSmart Coasts Program (2008) to help coastal communities address impacts and effects of erosion, storm surge and flooding which are increasing due to climate change. The program, www.mass.gov/czm/stormsmart offers technical information, planning strategies, legal and regulatory tools to communities to adapt to climate change impacts.

As more information and tools become available, there may be opportunities to make adjustments in TMDLs in the future to address predictable climate change impacts. When the science can support assumptions about the effects of climate change on the nitrogen loadings to the Herring River Estuarine System the TMDL can be reopened, if warranted.

The towns of Harwich, Dennis and Brewster 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.

MassDEP's MEP Implementation Guidance report: http://www.mass.gov/eea/agencies/massdep/water/watersheds/coastal-resources-and-estuaries.html provides N loading reduction strategies that are available to Harwich, Dennis and Brewster and 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

*Harwich, Dennis and Brewster are three of the 237 communities in Massachusetts covered (at least in part) by the Phase II stormwater program requirements.

Monitoring Plan

MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. MassDEP's position is that implementation will be conducted through an iterative process where adjustments maybe needed in the future. The two forms of monitoring include 1) tracking implementation progress as approved in the CWMP and 2) monitoring water quality and habitat conditions in the estuaries, including but not limited to, the sentinel stations identified in the MEP Technical Report.

The CWMP will evaluate various options to achieve the goals set out in the TMDL report and the MEP 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 values are not fixed, the target threshold N concentrations at the sentinel stations are fixed. 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 on a case-by-case basis, MassDEP believes 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 watershed communities 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. The watershed towns of Harwich, Brewster and Dennis 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 and stormwater 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. Stormwater NPDES permit coverage will address discharges from municipally owned stormwater 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 the 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 implements these TMDLs, the loading values (kg/day of N) will be used by MassDEP for guidance for permitting activities and should be used by the community as a management tool.

Public Participation

Public meetings to present the results of and answer questions on this TMDL were held on August 26, 2015 in the Selectmen's meeting room, Harwich Town Hall. Patti Kellogg (MassDEP) summarized the Mass Estuaries Project and described the Draft Nitrogen TMDL Report findings. Public comments received at the public meetings and comments received in writing within a 30-day comment period following the public meeting were considered by the Department. No written comments were received by the Department during the 30-day comment period. This final version of the TMDL report includes both a summary of the public meeting comments together with the Department's response to the comments and Frequently Ask Questions, and scanned images of the attendance sheets from the meeting (Appendix D). MEP representatives at the public meeting included Kimberly Groff, Brian Dudley, Barbara Kickham, and Matt Reardon.

Appendix A

Table A-1 Summary of the Nitrogen Concentrations for the Herring River Estuarine System

(from Chapter VI of the MEP Technical Report)

Town of Harwich water quality monitoring data and modeled Nitrogen concentrations for the Herring River Estuarine System. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means.

Sub-embayment	Station	2001 Mean	2002 Mean	2003 Mean	2004 Mean	2005 Mean	2006 Mean	2007 Mean	2008 Mean	2009 Mean	2010 Mean	2011 Mean	Mean	s.d. all data	N	Model Min	Model Max	Model Avg.
Wixen Dock	HAR-6	0.760	0.696	0.716	0.567	0.537	0.686	0.475	0.654	0.566	0.853	0.567	0.628	0.143	36	0.323	0.677	0.425
Route 28 Bridge	HAR-7	0.755	0.756	0.814	0.742	0.768	0.581	0.566	0.625	0.529	0.693	0.712	0.685	0.147	51	0.338	0.767	0.567
North Road	HAR-9	0.793	0.853	0.919	0.968	0.794	0.873	0.667	0.783	0.636	0.873	0.776	0.810	0.181	51	0.711	0.793	0.776
Lothrop Road	HAR-8	0.705	0.891	0.910	0.814	0.786	--	--	--	--	--		0.827	0.153	24	0.822	0.852	0.840
W. Reservoir	HAR-10	0.732	0.968	0.836	0.654	0.607	0.605	--	--	--	--		0.700	0.152	26	0.710	0.712	0.710

Appendix B:

Table B-1: Herring River Estuarine System Total Nitrogen TMDL and 4 Pollution Prevention TMDLs

Sub-embayment	Segment ID/Description	Impairment/TMDL Status	TMDL (kgN/day)
Lower Herring River	MA96-22_2012: Outlet of Herring River Reservoir (at North Harwich Reservoir Dam) west of Bells Neck Road, Harwich to mouth at Nantucket Sound, Harwich. Lower portion from Route 28 to mouth at Nantucket sound.	Determined to be impaired for nutrients during the development of this TMDL.	10.54
East Reservoir	--	Not impaired for total nitrogen, but TMDL needed since embayments are linked. (Pollution Prevention TMDL)	0.92
Upper Herring River	MA96-22_2012: Outlet of Herring River Reservoir (at North Harwich Reservoir Dam) west of Bells Neck Road, Harwich to mouth at Nantucket Sound, Harwich. Upper portion from Route 28 to outlet of Herring River Reservoir.	Not impaired for total nitrogen, but TMDL needed since embayments are linked. (Pollution Prevention TMDL)	3.22
West Reservoir	--	Not impaired for total nitrogen, but TMDL needed since embayments are linked. (Pollution Prevention TMDL)	27.56
Lothrop Road Stream	--	Not impaired for total nitrogen, but TMDL needed since embayments are linked. (Pollution Prevention TMDL)	8.26
Herring River System Total			50.50

* Pollution Prevention TMDL for community planning and to prevent further downstream impairment.

Appendix C

Table C-1: The Herring River Estuarine System estimated waste load allocation (WLA) from runoff of all impervious areas within 200 feet of its waterbodies

System Name	Impervious Area in 200ft buffer (acres)[1]	Total Impervious Area in Watershed (acres)	Total Watershed Area (acres)	% Impervious of Total Watershed Area	Impervious Area in 200ft buffer as Percentage of Total Watershed Impervious Area	MEP Total Unattenuated Watershed Impervious Load (kg N/day)[2]	MEP Total Unattenuated Watershed Load (kg N/day)[3]	Impervious buffer 200ft WLA (kg N/day)[4]	Buffer area WLA as percentage of MEP Total Unattenuated Watershed Load[5]
Herring River	11.34	1,113	9,558	11.6%	1.0%	6.94	113.3	0.07	0.06%

[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 unattended N load from impervious surfaces from the MEP Technical report, Table IV-3

[3]This includes the unattenuated nitrogen loads from wastewater from septic systems, one wastewater treatment facility, landfill, fertilizers, runoff from both natural and impervious surfaces, farm animals and atmospheric deposition to the waterbody surfaces from Table IV-3 in the MEP Technical report.

[4]The impervious watershed 200 ft buffer area (acres) divided by total watershed impervious area (acres) then multiplied by total impervious watershed load (kg N/day).

[5]The impervious watershed buffer area WLA (kg N/day) divided by the total watershed load (kg N/day) then multiplied by 100.

Appendix D

Massachusetts Estuaries Project (MEP) Response to Comments

DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR
HERRING RIVER SYSTEM (CONTROL #395.0)
(REPORT DATED APRIL 16, 2015)

DRAFT TMDL REPORT FOR
ALLEN, WYCHMERE, AND SAQUATUCKET HARBORS ESTUARINE SYSTEMS
(CONTROL # 312.0)
(REPORT DATED APRIL 16, 2015)

No written comments were received by MassDEP during the public comment period. However, we have included some answers to Frequently Asked Questions on the MEP, TMDLs, and CWMPs

General frequently asked questions:

1) **Can a CWMP include the acquisition of open space, and if so, can State Revolving Funds (SRF) be used for this?**
DEP Response: State Revolving funds can be used for open space preservation if a specific watershed property has been identified as a critical implementation measure for meeting the TMDL. The SRF solicitation should identify the land acquisition as a high priority project for this purpose which would then make it eligible for the SRF funding list. However, it should be noted that preservation of open space will only address potential future nitrogen sources (as predicted in the build-out scenario in the MEP Technical report) and not the current situation. The town will still have to reduce existing nitrogen sources to meet the TMDL.

2) **Do we expect eelgrass to return if the nitrogen goal is higher than the concentration that can support eelgrass?**
DEP Response: There are a number of factors that can control the ability of eelgrass to re-establish in any area. Some are of a physical nature (such as boat traffic, water depth, or even sunlight penetration) and others are of a chemical nature like nitrogen. Eelgrass decline in general has been directly related to the impacts of eutrophication caused by elevated nitrogen concentrations. Therefore, if the nitrogen concentration is elevated enough to cause symptoms of eutrophication to occur, eelgrass growth will not be possible even if all other factors are controlled and the eelgrass will not return until the water quality conditions improve.

3) **Who is required to develop the CWMP? Can it be written in-house if there is enough expertise?**
DEP Response: The CWMP can be prepared by the town. There are no requirements that it must be written by an outside consultant; however, the community should be very confident

that its in-house expertise is sufficient to address the myriad issues involved in the CWMP process. MassDEP would strongly recommend that any community wishing to undertake this endeavor on its own should meet with MassDEP to develop an appropriate scope of work that will result in a robust and acceptable plan.

4) **Have others written regional CWMPs (i.e. included several neighboring towns)?**
DEP Response: Joint CWMPs have been developed by multiple Towns particularly where Districts are formed for purposes of wastewater treatment. Some examples include the Upper Blackstone Water Pollution Abatement District that serve all or portions of the towns Holden, Millbury, Rutland West Boylston and the City of Worcester and the Greater Lawrence Sanitary District that serves the greater Lawrence area including portions of Andover, N. Andover, Methuen and Salem NH.. There have also been recent cases where Towns have teamed up to develop a joint CWMP where districts have not been formed. The most recent example are the Towns discharging to the Assabet River. They include the Towns of Westboro and Shrewsbury, Marlboro and Northboro, Hudson, and Maynard. The reason these towns joined forces was they received higher priority points in the SRF coming in as a group than they otherwise would have individually.

5) **Does nitrogen entering the system close to shore impair water quality more? If we have to sewer, wouldn't it make sense to sewer homes closer to the shore?**
DEP Response: Homes closer to the waterbody allow nitrogen to get to that waterbody faster. Those further away may take longer but still get there over time and are dependent upon the underlying geology. However, what is more important is the density of homes. Larger home density means more nitrogen being discharged thus the density typically determines where to sewer to maximize reductions. Also there are many factors that influence water quality such as flushing and morphology of the water body.

6) **Do you take into account how long it takes groundwater to travel?**
DEP Response: Yes, the MEP Technical report has identified long term (greater than 10 years) and short term time of travel boundaries in the ground-watershed.

7) **What if a town can't meet its TMDL?**
DEP Response: A TMDL is simply a nutrient budget that determines how much nitrogen reduction is necessary to meet water quality goals as defined by state Water Quality Standards. It is unlikely that the TMDL cannot be achieved however in rare occasions it can happen. In those rare cases the Federal Clean Water Act provides an alternative mechanism which is called a Use Attainability Analysis (UAA). The requirements of that analysis are specified in the Clean Water Act but to generalize the process, it requires a demonstration would have to be made that the designated use cannot be achieved. Another way of saying this is that a demonstration would have to be made that the body of water cannot support its designated uses such as fishing, swimming or protection of aquatic biota. This demonstration is very difficult and must be approved by the U.S. Environmental Protection Agency. As long as a plan is developed and actions are being taken at a reasonable pace to achieve the goals of the TMDL, MassDEP will use discretion in taking enforcement steps. However, in the event that reasonable progress is not being made, MassDEP can take enforcement action through the broad authority granted by the Massachusetts Clean Waters

Act, the Massachusetts Water Quality Standards, and through point source discharge permits.

8) **What is the relationship between the linked model and the CWMP?**
DEP Response: The model is a tool that was developed to assist the Town to evaluate potential nitrogen reduction options and determine if they meet the goals of the TMDL at the established sentinel station in each estuary. The CWMP is the process used by the Town to evaluate your short and long-term needs, define options, and ultimately choose a recommended option and schedule for implementation that meets the goals of the TMDL. The models can be used to assist the Towns during the CWMP process.

9) **Is there a federal mandate to reduce fertilizer use?**
DEP Response: No, it is up to the states and/or towns to address this issue.

10) **Will monitoring continue at all stations or just the sentinel stations?**
DEP Response: At a minimum, DEP would like to see monitoring continued at the sentinel stations monthly, May-September in order to determine compliance with the TMDL. However, ideally, it would be good to continue monitoring all of the stations, if possible. The benthic stations can be sampled every 3-5 years since changes are not rapid. The towns may want to sample additional locations if warranted. DEP plans to continue its program of eelgrass monitoring.

11) **What is the state's expectation with CWMPs?**
DEP Response: The CWMP is intended to provide the Towns with potential short and long-term options to achieve water quality goals and therefore provides a recommended plan and schedule for sewering/infrastructure improvements and other nitrogen reduction options necessary to achieve the TMDL. The state also provides a low interest loan program called the state revolving fund or SRF to help develop these plans. Towns can combine forces to save money when they develop their CWMPS.

12) **Can we submit parts of the plan as they are completed?**
DEP Response: Submitting part of a plan is not recommended because no demonstration can be made that the actions will meet the requirements of the TMDL. With that said however the plan can contain phases using an adaptive approach if determined to be reasonable and consistent with the TMDL.

13) **How do we know the source of the bacteria (septic vs. cormorants, etc.)?**
DEP Response: This was not addressed because this is a nitrogen TMDL and not a bacteria TMDL.

14) **Is there a push to look at alternative new technologies?**
DEP Response: Yes, the Massachusetts Septic System Test Center is located on Cape Cod and operated by the Barnstable County Department of Health and Environment. This Center tests and tracks advanced innovative and alternative septic system treatment technologies. DEP evaluates pilot studies for alternative technologies but will not approve a system unless it has been thoroughly studied and documented to be successful.

15) **How about using shellfish to remediate and reduce nitrogen concentrations?**
DEP Response: Although MassDEP is not opposed to this approach in concept and the approach is gaining favor in some areas of the country presently this is not an approved method because of a lack of understanding regarding how much nitrogen is removed over a specified period of time. Some examples of systems where research is being conducted include Long Island Sound (LIS), , Wellfleet, and Chesapeake Bay where oysters are being evaluated for remediation but the complete science is still not well defined. There are also many unknowns that can affect nitrogen uptake associated with proper management of the beds and it is likely that very large areas of shellfish may be needed to see measureable improvements.

16) **The TMDL is a maximum number, but we can still go lower.**
DEP Response: The state's goal is to achieve designated uses and water quality criteria. There is nothing however that prevents a Town from implementing measures that go beyond that goal. It should also be noted that the TMDL is developed conservatively with a factor of safety included

17) **Isn't it going to take several years to reach the TMDL?**
DEP Response: It is likely that several years will be necessary to achieve reductions and to see a corresponding response in the estuary. However, the longer it takes to implement solutions, the longer it is going to take to achieve the goals.

18) **The TMDL is based on current land use but what about future development?**
DEP Response: The MEP Study and the TMDL also takes buildout into account for each community.

19) **What about innovative technologies?**
DEP Response: Through the CWMP there is a push to look at innovative alternatives but they need to be tested and approved by DEP. Other options to explore besides conventional sewering include: improving flushing and increasing opportunities for freshwater attenuation further up in the watershed (without worsening water quality).

Verbal comments from the audience noted by MassDEP during the Herring River and Allen, Wychmere, and Saquatucket Harbors TMDL Public Meeting, August 26, 2015, Harwich Town Hall:

Audience member: "I don't see any updates by MassDOT on stormwater. Towns have been asked to do all this work, what is MassDOT doing on stormwater?"

MassDEP response: "There is a separate stormwater permit for MassDOT through the Phase II program."

David Young, CDM: "Herring River gets threshold of 0.48 mg/L while Allen, Wychmere and Saquatucket get 0.50 mg/L. This is higher by 0.02 although a small difference would mean millions of dollars of additional treatment at the wastewater treatment plant. How are thresholds calculated?"

Brian Howe, SMAST responded: "Threshold for Herring River is lower due to the goal to restore eelgrass. This is one of the highest/lenient thresholds for eelgrass amongst the 70 MEP projects. The MEP looks at areas with eelgrass today in comparable estuaries to set the threshold. When tide is in, very good, high quality water comes in from Vineyard Sound."

SIGN IN SHEET 8/26/2015
Herring River and Allens, Saquatucket and Wychmere Harbors
TMDL PUBLIC HEARING

	Signature	Print Name	Affiliation
1.	Kim Tower	KIM TOWER	TOWN OF PLYMOUTH
2.	Ann Howe	ANN HOWE	HARWICH - VOTER
3.	Allin P. Thompson	ALLIN P. THOMPSON.	WASTEWATER Com.
4.	[illegible]	Michael MacAskill	Harwich BOS
5.	Matthew Reardon	Matthew Reardon	MassDEP
6.	Diane T. Chamberlain	Diane T. Chamberlain	DENNIS CWMTF
7.	Sue Leven	SUE LEVEN	TOWN OF BREWSTER
8.	Christopher Clark	[illegible]	TOWN OF HARWICH T.A.
9.	[illegible]	DAVID F YOUNG	CDM SMITH
10.	[illegible]	Heinz Proft	HARWICH NATURAL RESOURCES

SIGN IN SHEET 8/26/2015

Herring River and Allens, Saquatucket and Wychmere Harbors

TMDL PUBLIC HEARING

	Signature	Print Name	Affiliation
11.	Ed Eichner		SMAST - UMASSD
12.	[illegible]	[illegible]	SMAST - UMASSD
13.	Tom Cambareri	Tom Cambareri	Cape Cod Commission
14.	Walter Berry	WALTER BERRY	USEPA - NARRAGANSETT
15.	Kate Mulvaney	Kate Mulvaney	USEPA - ORISE
16.	Jeremy Gingras	Jeremy Gingras	Town of Harwich WIC
17.	E Sullivan	Elizabeth Sullivan	Town of Dennis
18.	[illegible]	Mark NELSON	Horsley Witten Group, Inc.
19.			
20.			