Section 6

Massachusetts Estuaries Project

6.1 Introduction

This section describes the Massachusetts Estuaries Project (MEP) and the MEP watershed investigations within the Town of Harwich. The results of the MEP evaluations are the significant driver in the CWMP process. The information presented here has a direct effect on the analysis of potential effluent recharge locations and evaluation of the sewering alternatives presented in Sections 9 and 10. Implementation of the Harwich CWMP will ultimately lead to a reduction in nitrogen within the town's estuaries and aid in the restoration of ecological and community resources. The final recommended plan will reduce nitrogen in the most sensitive watersheds and estuaries to a level that no longer threatens these sensitive waterbodies and will meet the Total Maximum Daily Load (TMDL). This section describes nitrogen impacts to the sensitive MEP watersheds and presents the allowable nitrogen loads for each watershed that cannot be exceeded if existing water quality goals are to be met.

6.2 Massachusetts Estuaries Project (MEP)

As described in Section 1, the MEP is a joint initiative of the Massachusetts Executive Office of Energy and Environmental Affairs (EOEEA), the Massachusetts Department of Environmental Protection (MassDEP), the United States Geological Survey (USGS), and the University of Massachusetts – Dartmouth, School of Marine Science and Technology (SMAST), along with Coastal Zone Management, the Cape Cod Commission (CCC), and numerous Massachusetts coastal communities. Funding support is shared between municipalities, and the State of Massachusetts.

The MEP seeks to assess the degradation of several priority estuaries along the southeast coast of Massachusetts including all of Cape Cod and the Islands which has resulted from rapid population growth throughout the region. The water resources of Cape Cod are a valuable cultural and natural resource for local communities and are essential to maintaining the tourism industry, which is a large source of revenue for the region. Excessive nutrient loading in surface and groundwater has migrated to many estuaries, particularly those downstream of highly developed or populated areas. Over time, nutrient counts build up within an estuary as a result of limited flushing. This degrades water quality and has led to fish kills, algal growth, disruption of benthic communities, and an overabundance of invasive weeds. As a result, beaches are periodically closed, productive shellfish areas have been damaged or destroyed, and the tourist industry and property values are at risk due to aesthetically displeasing water and high bacteria levels. The environmental and socio-economic effects of excessive nutrients and bacterial concentrations in estuaries have direct consequences to the culture, economy, and quality of life in these Massachusetts coastal communities.

Since 2002, the MEP has developed and published a series of reports which assess the nature and extent of nutrient influence within the program area. Comprehensive water quality sampling for these assessments has been conducted in partnership with community groups, and the data have been used to develop quantitative total maximum daily load modeling scenarios for each estuary. Results of these assessments will require municipalities to remediate excessive nutrient input to restore water quality in estuaries, largely through expanded wastewater management.

Conclusions from the MEP reports include nitrogen loadings, and reduction percentages of nitrogen loading required to meet established thresholds in the MEP watershed reports. These thresholds will, upon review by the Massachusetts Department of Environmental Protection, be eventually subject to enforceable nitrogen TMDL permits.

6.2.1 MEP Approach to Estuary Studies

The MEP team, starting in 2002, selected estuaries across Cape Cod and the Islands based on the level of degradation, need for improvement, community engagement in addressing estuary degradation, and available funds for the assessment. Once the estuaries were selected, each location was prioritized according to state and local planning needs, environmental concerns, and local issues.

The MEP approach to estuary studies incorporates estuarine processes into nitrogen loading scenarios to develop a TMDL for each estuary under Section 303(d) of the federal Clean Water Act. The TMDL is based on the link between nitrogen sources in the watershed and relative nitrogen concentrations in receiving embayments. In order to establish a relative TMDL value, MEP collaborators use sophisticated modeling and quantitative analysis to provide municipalities and regulatory agencies with guidance and technical expertise. Modeling tools support the development of alternative scenarios for nutrient controls, typically in the form of enhanced wastewater management. Municipalities use this information to make decisions on estuary management, protection, and restoration practices that will reduce total nitrogen loads.

The MEP assesses the health of each selected estuary ecosystem, determines which nitrogen sources contribute to ecosystem conditions, and determines the reductions in total nitrogen load necessary to restore ecosystem health and meet water quality standards. The following summarizes the MEP process.

The flow chart, Figure 6-1, was developed by the MEP to demonstrate their analytical approach to nutrient assessment.

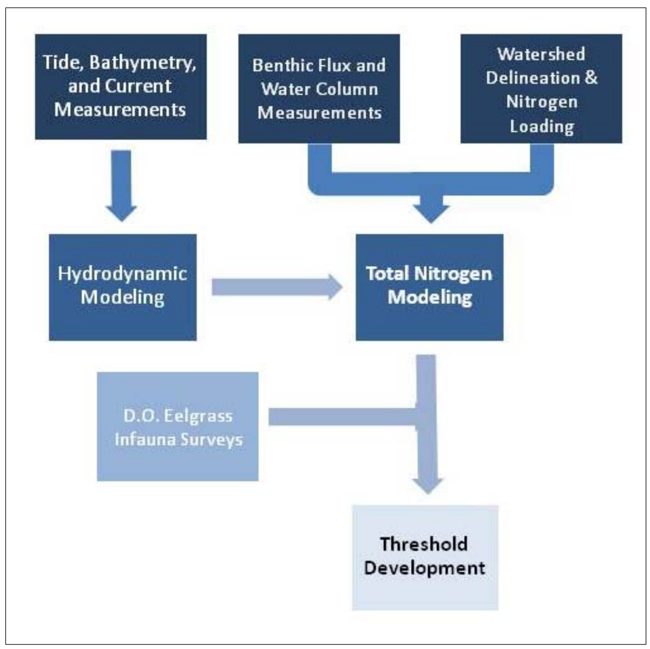


Figure 6-1
Flow Chart of MEP Study Assessment

Environmental Study

The first step in the MEP process is to conduct an environmental study of current land use and aquatic life conditions. Watershed and sub-watershed boundaries were developed by the USGS to delineate land area contributing nutrients to receiving waters for each estuary in the program. A watershed is the contributing land area, including all associated surface and groundwater resources, to an estuary. This includes contributing areas to ponds, water supply wells, tidal rivers, and bays. In Harwich, not all land area in the Town is located within a watershed contributing to an MEP study area.

Watersheds are further divided into subwatershed areas, or sub-areas of land within a watershed. These areas were defined based on groundwater velocity and the resulting time it takes for groundwater to reach a bay or river. A time of travel of 10 years was used to develop subwatershed boundaries.

Once watershed and subwatershed boundaries are delineated, land use is assessed to spatially evaluate the incidence and concentration of nitrogen sources. Typical anthropogenic nitrogen sources include septic systems, stormwater runoff, lawns, and other fertilized landscaped areas. Identifying these areas requires a parcel by parcel assessment linked to a geographic information system (GIS) database which contains data sets that estimate the nature and extent of nutrient sources. When displayed geographically, data patterns highlight targeted areas which require further analysis. In addition, surface water resources are noted for depth, extent, and total stream flow. This information can be used to assess natural nitrogen attenuation in freshwater ponds and predict estuary loading by subwatershed.

Ecosystem health is assessed through three indicators which reflect long-term habitat conditions: eelgrass, macroalgae, and benthic animals, in conjunction with water quality measurements. To assess these indicators each estuary is subject to a minimum of three years of regular sampling. Eelgrass and benthic animals inhabit stationary, long-term communities which react to local environmental changes. Changes in the presence, population, or distribution are an indication of an impaired local environment. Benthic activity, specifically benthic nitrogen flux, is also assessed to gain an understanding of denitrification processes occurring in embayment sediments, which suggests the estuary's ability to process nitrogen and supports determination of healthy nitrogen loading levels.

The aquatic habitat study includes data collection related to benthic community health, dissolved oxygen levels, eelgrass populations, and infaunal animal surveys. This portion of the study may require data spanning several years, based on the extent and complexity of the estuary. Water column monitoring, for example, requires years of nutrient sampling at designated locations to determine fluctuations and seasonal variability. Infaunal animal surveys also require sampling, monitoring, and collection over an extended period of time. Once animals are collected, they are counted, preserved, and categorized. The health, variety, and incidence of these animals are indications of the overall health of the benthic environment within an estuary.

Monitoring Stations

There are typically two types of monitoring stations within each estuary: sentinel stations and check stations. Sentinel stations are designated within each estuary as a discrete point where nitrogen testing will be conducted and where the TMDL will be established. Sentinel stations are situated such that achieving the nitrogen threshold target at each sentinel station should restore the benthic animal habitat. Thus, when this station reaches the target nitrogen concentration established for the estuary, it is assumed that water quality throughout the estuary has improved enough to restore ecological health throughout the estuary.

In addition to the sentinel station, check stations are selected to assist with the goals of restoring healthy eelgrass beds and benthic infaunal habitats and to assess water quality. The target concentrations at these check stations, referred to as secondary criteria, are not used for setting nitrogen thresholds, but rather to provide a check on the acceptability of conditions within the tributary basins at the point that the threshold level is attained at the sentinel station.

Estuary Hydrodynamics

The next part of the MEP process is a hydrodynamic assessment of the estuary, which involves gathering field data to develop a three-dimensional circulation model. In order to produce the model, embayment bathymetry is measured using sonar or remote sensing systems. A site specific tidal record is used to assess the variability of tidal flushing over time. In cases where an estuary is complex, current tidal records may also be used. Once all data is gathered, the three-dimensional hydrodynamic model is developed. This model physically demonstrates tidal flushing within the estuary and assesses embayment basin structure, measurement of basin depth relative to water level, tidal variations, and nutrient dispersion within the water column.

Total Watershed Nitrogen Loading

Nitrogen sources within each subwatershed are determined based on land type, parcel data, water use, and fertilization rates and presented in terms of total and controllable loading. Total loading includes all loads which enter the estuary from groundwater, sediment, and direct atmospheric deposition to the estuary surface. These include all sources of nitrogen within the watershed, such as: septic system discharge, treated wastewater effluent from larger treatment systems, lawn care fertilizers, agricultural fertilizers, and atmospheric deposition collected by runoff from impervious surfaces, waterbody surfaces, and natural surfaces. Controllable loading is the portion of total loading that could potentially be reduced and includes all elements of total loading with the exception of atmospheric deposition. Once nitrogen sources are determined, groundwater flow, subwatershed loading, flushing and hydrodynamic modeling, and natural attenuation are used to estimate total and controllable loading values for a receiving estuary.

The nitrogen concentration in ground and surface water is reduced as it passes through natural systems in streams, ponds, and rivers. This process is known as natural attenuation. In addition, to accurately calculate total load for a receiving water body, nitrogen load must be evaluated for the percent of natural degradation per subwatershed. This occurs through conversion to nitrogen gas, sediment absorption, and other biological processes. Thus, in some cases, a nitrogen load could theoretically be high in one watershed but the actual affect on receiving waters could be much lower due to both attenuation and degradation.

Total Maximum Daily Load (TMDL) Threshold Development

Once the nitrogen cycle is better understood throughout the watershed and its associated estuary, a TMDL is then developed. Criteria for establishing a TMDL are developed through the hydrodynamic models to achieve the desired level of ecosystem health. Modeling allows for optimization of loading reductions based on subwatershed area while gaining a better understanding of hydraulic interactions of flushing between estuaries. TMDLs are developed based on the target concentrations at the water quality monitoring stations described above. These standards are designed to allow for natural concentrations of nitrogen to be at a level which provides water quality that supports a healthy estuary.

6.2.2 Harwich MEP Water Resources

The population of Harwich saw significant growth from 1950 to 2010. There is currently no centralized wastewater treatment system located in the town. Thus, as development has increased, so has nutrient loading as a result of septic system discharge.

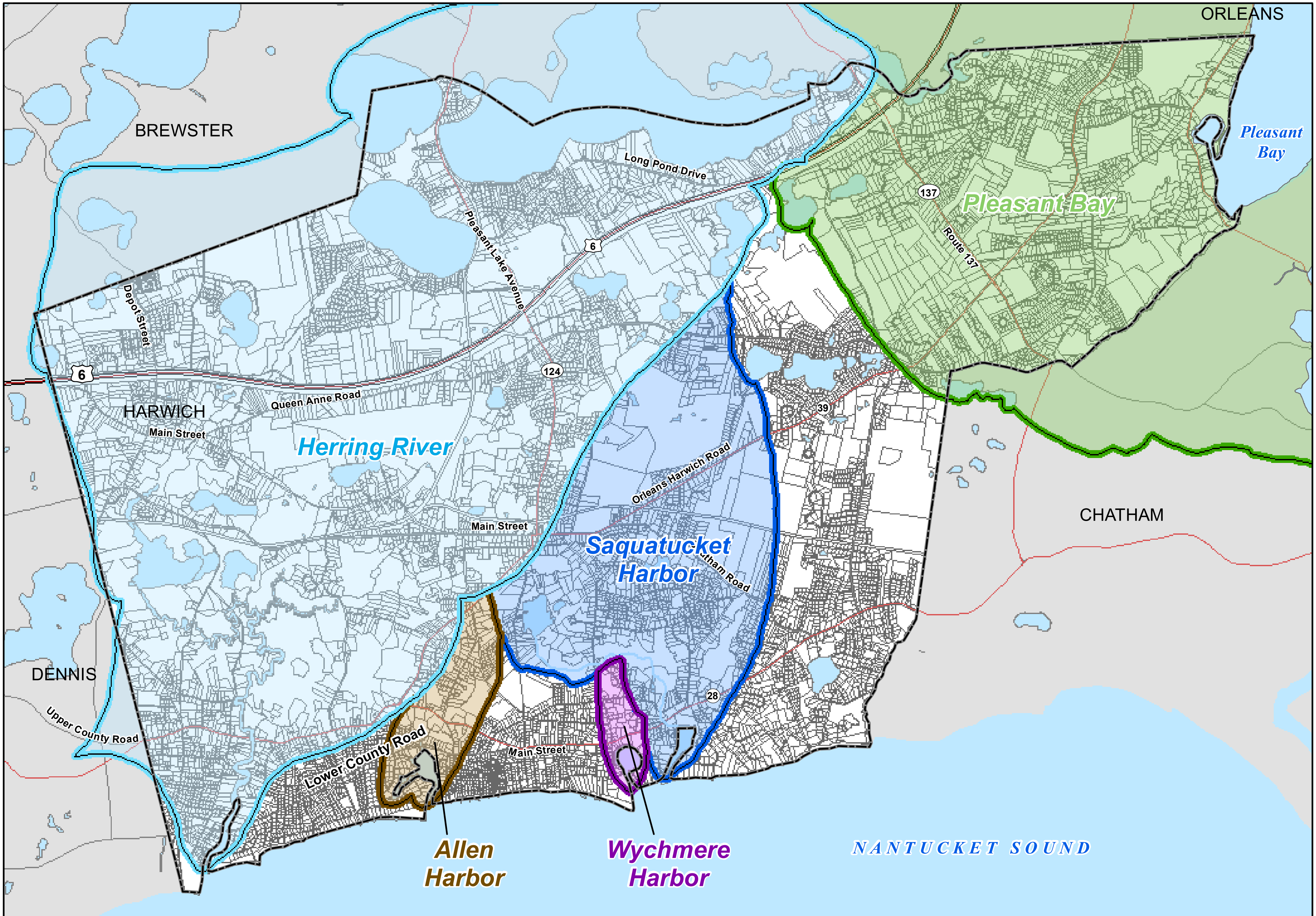
MEP studies have been conducted to evaluate the effects of development and identify nutrient contributing hot spots within Harwich, including all five Town estuaries and the associated contributing watershed land area. Future build-out conditions were calculated as part of the MEP based on current zoning, subdivision of large lots, and increased impervious area including new driveways and roofs. Higher-density village centers and development of the Route 28 corridor in Harwichport were not modeled in locations where they were not within the limits of an MEP studied watershed.

As part of the Harwich estuary studies, the MEP operated under certain assumptions to assess habitat and quality. Eelgrass distribution was based on state surveys conducted in 1951, 1995, and 2001. Watershed delineation was based on long-term steady-state conditions; however boundaries may be affected by water supply pumping rates, particularly during high-volume months. Annual water usage for each parcel included seasonal changes in population, consumptive use of water, and the nitrogen concentration of water which typically enters the groundwater from septic system use. Other nitrogen inputs, such as fertilizers used on golf courses, cranberry bogs, or landscaping and stormwater runoff were quantified using information from past estuary input studies.

6.3 Results of Published MEP Studies

The degrading conditions of estuaries in Harwich are a primary driver for reevaluating the Town's approach to wastewater management. Good water quality is paramount to the environmental and financial health of a resort community such as Harwich. As such, findings presented in the MEP studies are critical to developing a long-term sustainable water resources plan for the community.

As noted previously, Harwich has five estuaries located in the MEP study area: Allen Harbor, Wychmere Harbor, Saquatucket Harbor, Pleasant Bay, and Herring River (see Figure 6-2). The Pleasant Bay watershed is shared with the towns of Brewster, Chatham and Orleans and the Herring River watershed is shared with the towns of Brewster and Dennis. The Pleasant Bay watershed report was completed in May 2006 and the Allen Harbor, Wychmere Harbor, and Saquatucket Harbor report was completed in June 2010. The Herring River report was completed in 2012.The conclusions of each MEP report are described below. Additional MEP report information can be found in Appendix C along with web links to the full reports.



Legend
- Allen Harbor
- Herring River
- Pleasant Bay
- Saquatucket Harbor
- Wychmere Harbor

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 4,000 feet
0 1,500 3,000 Feet

Figure 6-2
Town of Harwich
Estuary Watersheds

CDM Smith

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6.3.1 Allen Harbor Watershed Results

The final report entitled "Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Allen, Wychmere and Saquatucket Harbor Embayment Systems, Harwich, Massachusetts" was published by the Massachusetts Estuaries Project in June 2010. Allen Harbor is located in the Chatham Outwash Plain, which is comprised of sands, gravels, and chiefly pre-Wisconsin deposits. A permeable groundwater aquifer within the watershed contains aerobic waters.

Physical Description

Allen Harbor is a simple estuary located entirely within the Town of Harwich, comprised of a small tributary basin near the inlet, where tidal waters enter from Nantucket Sound. Open water area is 19 acres. Freshwater enters through direct groundwater discharge, precipitation, and a small creek which feeds the salt marsh to the northeast. The Harbor is naturally shallow, approximately 2 meters in depth, and was originally a muddy pond known as Oyster or Gray's Pond before the inlet was expanded to allow marine traffic access to Nantucket Sound. An extended jetty bounds the eastern portion of the access channel and a parallel jetty maintains the natural land barrier and beach to the west. Figure 6-3 shows the Allen Harbor system.

Land Use and Nitrogen Loading

Land use in the Allen Harbor watershed is primarily (54%) residential of which 85% are single family homes. High residential use, coupled with the fact that Harwich has experienced significant population growth since 1950, has resulted in moderate nitrogen loading in the harbor due to watershed inputs, and primarily due to nitrogen from septic system discharge. Figure 6-3 shows the Allen Harbor System.

Allen Harbor Algae Bloom
Summer, 2007

Periodic summer phytoplankton blooms and depleted oxygen in bottom waters (hypoxia) are common. Dredging of the inlet has helped to sustain tidal exchange critical to nitrogen management.

Natural deposition of atmospheric nitrogen on water bodies and natural land surfaces accounts for only 4% of the total loading within the Allen Harbor system. Controllable sources, such as wastewater from septic systems and residential and commercial fertilizer applications, account for approximately 96% of the total nitrogen loading. Because septic system effluent accounts for such a large percent of nitrogen inputs, 86% of controllable nitrogen sources, reducing this source is a priority for improving overall estuary habitat. Figure 6-4 shows total nitrogen loading for the Allen Harbor watershed, including natural deposition, and Figure 6-5 shows the percent of controllable nitrogen loading sources within the watershed.

Watershed
Allen Harbor
Allen Harbor Subsheds

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 800 feet

0 400 800 Feet

Figure 6-3
Allen Harbor System

CDM Smith

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Figure 6-4
Total Nitrogen Loading in the Allen Harbor Watershed, Including Natural Deposition

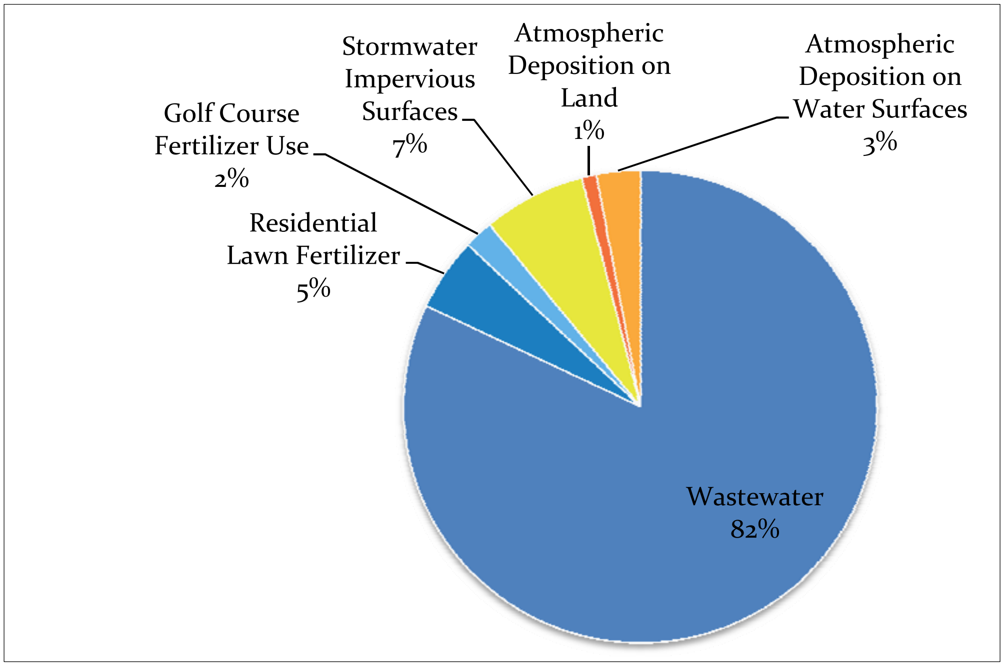
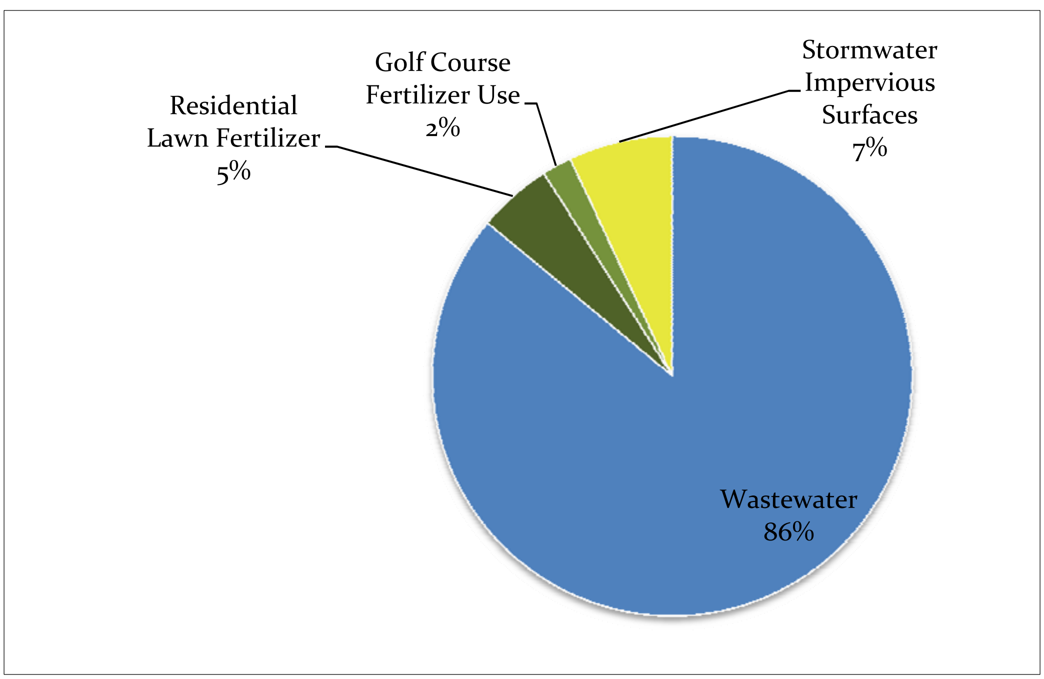


Figure 6-5
Total Controllable Nitrogen Loading in the Allen Harbor Watershed



Amphipods are typically used as an indicator species for benthic community health because of their response to changing conditions in an aquatic environment. In Allen Harbor, infaunal animals were observed with low diversity and high numbers of individual species. The individual species with high numbers were predominantly amphipods, which thrive in high organic enrichment environments. This result indicates intermediate stress and moderate impairment throughout Allen Harbor. In Allen Creek, less diversity and lower total counts indicated high organic enrichment in this tributary. All indicator species results were found to correlate directly with observed levels of low dissolved oxygen, high chlorophyll-a concentrations, and high macroalgal accumulations.

Monitoring Stations and Thresholds

The goal of the Allen Harbor sentinel station (HAR-4) is to identify a location where meeting a target nitrogen concentration would result in water quality throughout the water body sufficient to restore acceptable ecological health. In addition, two check stations (HAR-4A and HAR-5) were selected to assist with the goal of restoring healthy benthic infaunal habitats. The MEP report states that these check station target concentrations were not used for setting nitrogen thresholds in this embayment system. These values merely provide a check on the acceptability of conditions within the tributary basins at the point that the threshold level is attained at the sentinel station. The location of each of station is shown in Figure 6-6.

The threshold nitrogen concentration was determined based on the average concentration of nitrogen in the water column that will support a healthy benthic habitat. Table 6-1 shows present average total nitrogen concentrations observed at monitoring stations as part of the MEP study along with the recommended threshold concentration for Allen Harbor and the percent change necessary to meet the threshold concentration for each monitoring station. All of the available information on eelgrass indicates that the Allen Harbor system did not support eelgrass. The present monitoring data indicates that total nitrogen levels of 0.65 to 0.82 mg/l of nitrogen cannot support healthy benthic communities. The MEP concluded that an upper limit of 0.50 mg/l of nitrogen (tidally averaged) would support healthy infaunal habitat in Allen Harbor. The concentrations at the monitoring stations may be slightly different than the upper limit, but they are chosen so that the upper limit of 0.50 mg/l of nitrogen (tidally averaged) is achieved throughout the system.

Table 6-1
Sentinel and Check Monitoring Stations with Associated Nitrogen Limits For Allen Harbor

Embayment	Monitoring Station	Present total N Concentration* (mg/l)	Threshold average total N Concentration* (mg/l)	% Change
Allen Harbor	HAR-4	0.679	0.498	-26.6%
Allen Harbor	HAR-4A	0.451	0.380	-15.9%
Allen Harbor	HAR-5	0.808	0.545	-32.5%

*Present and threshold average total N values according to Table VIII-5 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems

Values in RED indicate that the value is above the standard and must be reduced.

N

Watershed

Allen Harbor

Water Quality Monitoring Stations

Check Station

Sentinel Station

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 400 feet

0 200 400 Feet

Figure 6-6
Allen Harbor
Monitoring Stations

CDM Smith

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Determination of the threshold septic loading in a watershed is not as simple as determining the threshold concentration in the Allen Harbor. Determination of site-specific nitrogen thresholds for an embayment requires integration of key habitat parameters (infauna and eelgrass), sediment characteristics, and nutrient related water quality information. Nitrogen threshold development builds on these data and links habitat quality to summer water column nitrogen levels. To determine the total loading several factors must be considered including septic system effluent flow into the watershed, natural attenuation throughout the watershed, wastewater treatment facilities (if any exist), estuary flushing, stormwater sources, fertilizers applied throughout the watershed, and finally the threshold concentrations presented in the table above. The MEP evaluation of habitat quality supported by the harbor considers the natural structure of each system and its ability to support that habitat before determining the threshold septic load.

Because septic system loading accounts for most of the controllable nitrogen in the Harbor, septic nitrogen is the primary source which is recommended to be targeted for total reduction within the contributing watershed. Overall, 5.64 kg/day, or roughly 2,058 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. In order to meet threshold total nitrogen loads, it is estimated that the present total septic load in the Allen Harbor watershed would need to be reduced by 74%, as summarized in Table 6-2 below to meet existing conditions.

Table 6-2
Attenuated Septic Loading in the Allen Harbor Watershed*

Sub – Embayment	Present Septic Load (kg/day)	Threshold Septic Load (kg/day)	Septic Load Decrease (% change)
Allen Harbor	4.21	0.841	80.0%
Allen Pond Stream	1.43	0.642	54.9%
Total	**5.64**	**1.483**	**74%**

*Loading information according to Table VIII-2 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems.

Values in RED indicate that the value is above the standard and must be reduced.

The threshold septic loading for the Allen Harbor system is the sum of two threshold loads developed in the MEP report for the Allen Harbor sub embayment and the Allen Pond Stream sub-embayment. The Allen Harbor sub-embayment is the total estuarine reach which receives septic nitrogen inputs through direct groundwater discharge and is separate from surface water inflows. Together these two thresholds combine to give a total threshold septic load for the watershed. To meet the requirements of both the check and sentinel stations, the Allen Harbor sub-embayment will require at least 80% of the present septic load to be reduced, and the Allen Pond Stream sub-embayment will require at least 54.9% of the present septic load to be reduced. Together, the Allen Harbor watershed will require about 74% of the septic load to be reduced.

Part of the MEP watershed nitrogen loading modeling includes a buildout assessment of potential development within the study area watersheds. The buildout performed by the MEP is a straightforward buildout assessment that considers a buildout scenario for both residential and commercial parcels throughout the studied watershed. The buildout assessment is an attempt at estimating buildout in a watershed based on current zoning and any projected changes using local input. The estimates developed for the model allows modelers to run a "what if" scenario that consideres nitrogen loading associated with future development.

Table 6-1A shows buildout average total nitrogen concentrations modeled at monitoring stations as part of the MEP study along with the recommended threshold concentration for Allen Harbor and the percent change necessary to meet the threshold concentration for each monitoring station.

Table 6-1A
Sentinel and Check Monitoring Stations with Associated Buildout Nitrogen Limits for Allen Harbor

Embayment	Monitoring Station	Buildout total N Concentration* (mg/l)	Threshold average total N Concentration* (mg/l)	% Change
Allen Harbor	HAR-4	0.749	0.498	-33.5%
Allen Harbor	HAR-4A	0.478	0.380	-20.5%
Allen Harbor	HAR-5	0.896	0.545	-39.2%

*Buildout and threshold average total N values according to Table IX-5 and VIII-5 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems

Values in RED indicate that the value is above the standard and must be reduced.

In the buildout projection, septic system loading also accounts for most of the controllable nitrogen in the harbor. Thus, septic nitrogen is the primary source which is recommended to be targeted for total reduction within the contributing watershed. Overall, 6.71 kg/day, or roughly 2,449 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. This is about a 19% increase over present loads. In order to meet threshold total nitrogen loads, it is estimated that the current total septic load in the Allen Harbor watershed would need to be reduced by about 78%, as summarized in Table 6-2a below to meet existing conditions.

Table 6-2A
Attenuated Buildout Septic Loading in the Allen Harbor watershed*

Sub – Embayment	Buildout Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease (% change)
Allen Harbor	4.86	0.841	82.6%
Allen Pond Stream	1.85	0.642	65.3%
Total	**6.71**	**1.483**	**78%**

*Loading information according to Table VIII-2 and the MEP Loading Spreadsheets (AKA Rainbow Tables) of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems.

Values in RED indicate that the value is above the standard and must be reduced.

6.3.2 Wychmere Harbor Watershed Results

Wychmere Harbor was evaluated under the same MEP initiative along with Allen Harbor. Results can also be found in the June 2010 final report entitled "Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Allen, Wychmere and Saquatucket Harbor Embayment Systems, Harwich, Massachusetts." Wychmere Harbor is located in the Chatham Outwash Plain, which is comprised of sands, gravels, and chiefly pre-Wisconsin deposits.

Physical Description

Wychmere Harbor is a simple estuary located entirely within the Town of Harwich which is comprised of a small marina and a single outlet. Flushing with Nantucket Sound occurs through a canal bounded by jetties, which was dredged to be navigable in 1887. The harbor was formed as a great salt pond and originally had a small island or emergent bar within the tidal inlet. Open water area is 16 acres.

Freshwater enters through direct groundwater discharge and precipitation. Constructed jetties protect the natural land barriers which bound the channel, and the western jetty extends into Nantucket sound. Figure 6-7 shows the Wychmere Harbor system.

Land Use and Nitrogen Loading

Major sources of nitrogen loading in the Wychmere Harbor watershed include: wastewater from residential septic systems, small onsite (package) wastewater treatment facilities, fertilizers from cranberry bogs, impervious surface stormwater runoff, and direct atmospheric deposition to water surfaces. Land use in the Wychmere Harbor watershed is primarily (55%) residential of which 94% are single family residences.

In the Wychmere Harbor watershed, high residential septic system use coupled with runoff containing fertilizers from residential lawns and cranberry bogs are the predominant sources of nitrogen loading, accounting for 92% of total nitrogen loading in the watershed. Other sources of nitrogen include road and roof stormwater runoff and atmospheric deposition. As a result of the combination of these sources, Wychmere Harbor experiences moderate nitrogen loading which leads to periodic summer phytoplankton blooms and depleted oxygen bottom waters (hypoxia), degraded sediment, and the limited variability and high numbers of benthic animal communities. Dredging of the inlet has helped to sustain tidal exchange critical to nitrogen management; however, continuation of current loading rates will lead to further degradation of the harbor. Because septic system effluent accounts for 83% of the controllable loading in this watershed, reduction of this nitrogen source could reduce total loading to within acceptable limits for the watershed. Figure 6-8 shows total nitrogen loading for the Wychmere Harbor watershed, including natural deposition, and Figure 6-9 shows the percent of controllable nitrogen loading sources within the watershed.

Watershed

Wychmere Harbor

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 500 feet

0 250 500 Feet

Figure 6-7
Wychmere Harbor System

CDM Smith

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Figure 6-8
Total Nitrogen Loading in the Wychmere Harbor Watershed Including Natural Deposition

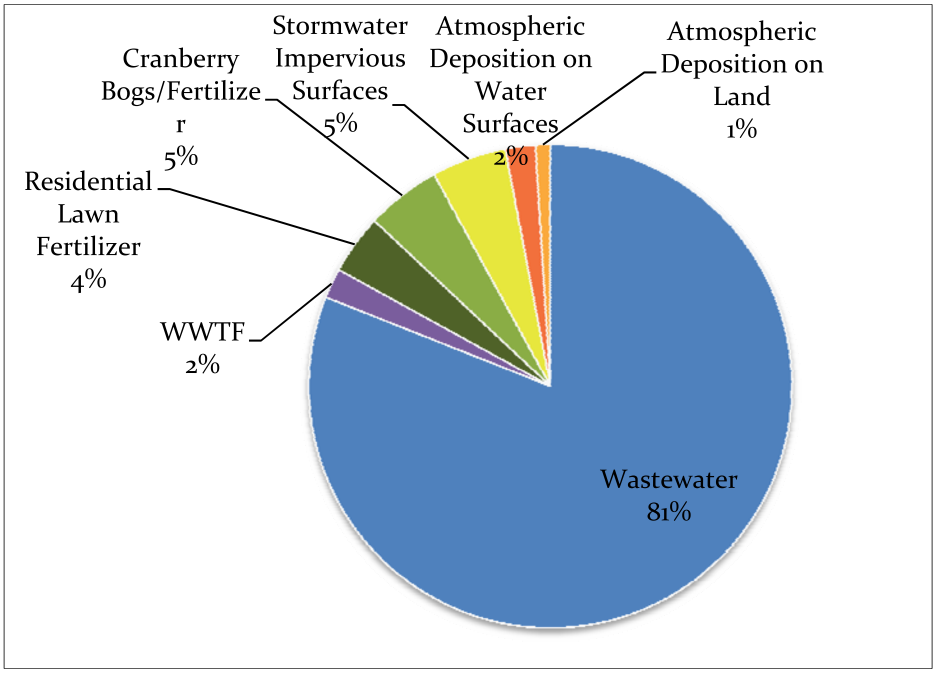
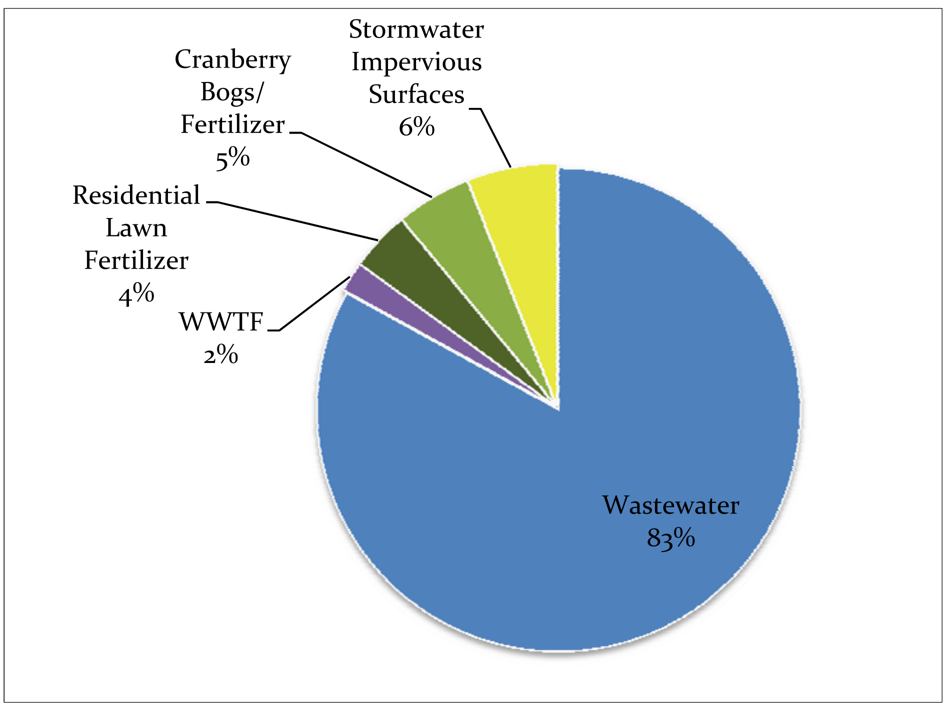


Figure 6-9
Total Controllable Nitrogen Loading in the Wychmere Harbor Watershed



Water Quality Indicators

As noted above, the MEP report identified the Wychmere Harbor as moderately to significantly impaired systems which are beyond their natural capacity to process additional nutrients without further degrading ecological health. While eelgrass is typically used as an indicator species of overall health, there is no evidence it existed historically in Wychmere Harbor. Instead, benthic communities were assessed as the indicator species for overall estuary health.

Infaunal animals were determined to have low diversity with high numbers of individuals, indicating a stressed benthic environment. Further assessment revealed indicator species which respond to high chlorophyll and moderate to high organic enrichment. Results were indicative of moderate nutrient loading in the main basin and moderate to high organic enrichment in the entire Wychmere Harbor system.

Monitoring Stations and Thresholds

Wychmere Harbor contains one sentinel station and one check station, as shown in Figure 6-10. The sentinel station, HAR-3, is positioned within Wychmere Harbor such that meeting the target nitrogen concentration would result in water quality throughout the harbor sufficient to restore ecological health with the goal of restoring healthy benthic infaunal habitats. Observed total nitrogen (TN) concentrations at the sentinel station HAR-3 ranged from an average upper limit of 0.812 mg/L to an average lower limit of 0.530 mg/L between 2001 and 2008.

The threshold nitrogen concentration was determined based on the average concentration of nitrogen in the water column that will support a healthy benthic habitat. Table 6-3 shows present average total nitrogen concentrations observed at monitoring stations as part of the MEP study along with the recommended threshold concentration for the Wychmere Harbor and the percent change necessary to meet the threshold concentration for each monitoring station. All of the available information on eelgrass indicates that the Allen Harbor system did not support eelgrass. The present monitoring data indicates that total nitrogen levels of 0.65 to 0.82 mg/l of nitrogen cannot support healthy benthic communities. The MEP concluded that an upper limit of 0.50 mg/l of nitrogen (tidally averaged) would support healthy infaunal habitat in the Wychmere Harbor. The concentrations at the monitoring stations may be slightly different than the upper limit, but they are chosen so that the upper limit of 0.50 mg/l of nitrogen (tidally averaged) is achieved throughout the system.

Table 6-3
Sentinel and Check Monitoring Stations with Associated Nitrogen Limits for Wychmere Harbor

Embayment	Monitoring Station	Present total N Concentration* (mg/l)	Threshold average total N Concentration* (mg/l)	% Change
Wychmere Harbor	HAR-2A	0.453	0.367	-19.0%
Wychmere Harbor	HAR-3	0.813	0.500	-38.5%

*Present and threshold average total N values according to Table VIII-5 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems

*Values in RED indicate that the value is above the standard and must be reduced.

Watershed

Wychmere Harbor

Water Quality Monitoring Stations

Check Station

Sentinel Station

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 400 feet

0 200 400 Feet

Figure 6-10
Wychmere Harbor
Monitoring Stations

CDM Smith

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Determination of the threshold septic loading in a watershed is not as simple as determining the threshold concentration. Determination of site-specific nitrogen thresholds for an embayment requires integration of key habitat parameters (infauna and eelgrass), sediment characteristics, and nutrient related water quality information. Nitrogen threshold development builds on these data and links habitat quality to summer water column nitrogen levels. To determine the total loading several factors must be considered including septic system effluent flow into the watershed, natural attenuation throughout the watershed, wastewater treatment facilities (if any exist), estuary flushing, stormwater sources, fertilizers applied throughout the watershed, and finally the threshold concentrations presented in the table above. The MEP evaluation of habitat quality supported by the harbor considers the natural structure of each system and its ability to support that habitat before determining the threshold septic load.

Because septic system loading accounts for most of the controllable nitrogen in the harbor, that is the primary source which is recommended to be targeted for nitrogen reduction within the contributing watershed. Overall, 3.208 kg/day, or roughly 1,170 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. In order to meet threshold total nitrogen loads, it is estimated that the current total septic system load in the Wychmere Harbor watershed would need to be reduced by 100 %, as summarized in Table 6-4 below to meet existing conditions.

Table 6-4
Attenuated Septic Loading in the Wychmere Harbor Watershed

Present Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease (% change)
3.208	0.00	100%

*Loading information according to Table VIII-2 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems

*Values in RED indicate that the value is above the standard and must be reduced.

Part of the MEP watershed nitrogen loading modeling includes a buildout assessment of potential development within the study area watersheds. The buildout performed by the MEP is a straightforward buildout assessment that considers a buildout scenario for both residential and commercial parcels throughout the studied watershed. The buildout assessment is an attempt at estimating buildout in a watershed based on current zoning and any projected changes using local input. The estimates developed for the model allows modelers to run a “what if” scenario that considers nitrogen loading associated with future development.

Table 6-3A shows buildout average total nitrogen concentrations modeled at monitoring stations as part of the MEP study along with the recommended threshold concentration for Wychmere Harbor and the percent change necessary to meet the threshold concentration for each monitoring station.

Table 6-3A
Sentinel and Check Monitoring Stations with Associated Buildout Nitrogen Limits for Wychmere Harbor

Embayment	Monitoring Station	Buildout total N Concentration* (mg/l)	Threshold average total N Concentration* (mg/l)	% Change
Wychmere Harbor	HAR-2A	0.460	0.367	-20.2%
Wychmere Harbor	HAR-3	0.829	0.500	-39.6%

*Buildout and threshold average total N values according to Table IX-5 and VIII-5 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems

Values in RED indicate that the value is above the standard and must be reduced.

In the buildout projection septic system loading also accounts for most of the controllable nitrogen in the Harbor. Thus, septic nitrogen is the primary source which is recommended to be targeted for total reduction within the contributing watershed. Overall, 3.30 kg/day, or roughly 1,206 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. This is about a 3% increase over present loads. In order to meet threshold total nitrogen loads, it is estimated that the current total septic load in the Wychmere Harbor watershed would need to be reduced by 100 %, as summarized in Table 6-4A below to meet existing conditions.

Table 6-4A
Attenuated Buildout Septic Loading in the Wychmere Harbor Watershed*

Buildout Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease (% change)
3.30	0.00	100%

*Loading information according to Table VIII-2 and the MEP Loading Spreadsheets (AKA Rainbow Tables) of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems.

Values in RED indicate that the value is above the standard and must be reduced.

6.3.3 Saquatucket Harbor Watershed Results

Saquatucket Harbor was evaluated under the same MEP initiative along with the Allen and Wychmere Harbors. Results can be found in the June 2010 final report entitled "Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Allen, Wychmere and Saquatucket Harbor Embayment Systems, Harwich, Massachusetts." Saquatucket Harbor is located in the Chatham Outwash Plain, which is comprised of sands, gravels, and chiefly pre-Wisconsin deposits. The harbor was formed by tidal flooding of channels within the outwash deposits of a stream.

Physical Description

Saquatucket Harbor is a simple estuary located in the Town of Harwich which is comprised of a small marina, long channel, and single outlet. Flushing with Nantucket Sound occurs through a dredged canal bounded by jetties. The canal was constructed in 1968. Prior to that, the harbor was a tidal salt marsh with a central tidal river known as Andrews River. The remnants of that tidal river can be found in the western shore of the harbor. Open water area is 12 acres.

Freshwater enters through direct groundwater discharge to the harbor perimeter, precipitation, and two significant surface water sources: Carding Machine Brook from the northwest and Cold (Bottom) Brook from the northeast, both of which feed the remaining salt marshes which bound the basin to the east and west. A moderately sized and relatively healthy salt marsh also exists in the northern region of the basin. Parallel jetties extend the channel into Nantucket sound through shallow water along the barrier beach which bounds Harwich to the south. Figure 6-11 shows the Saquatucket Harbor system.

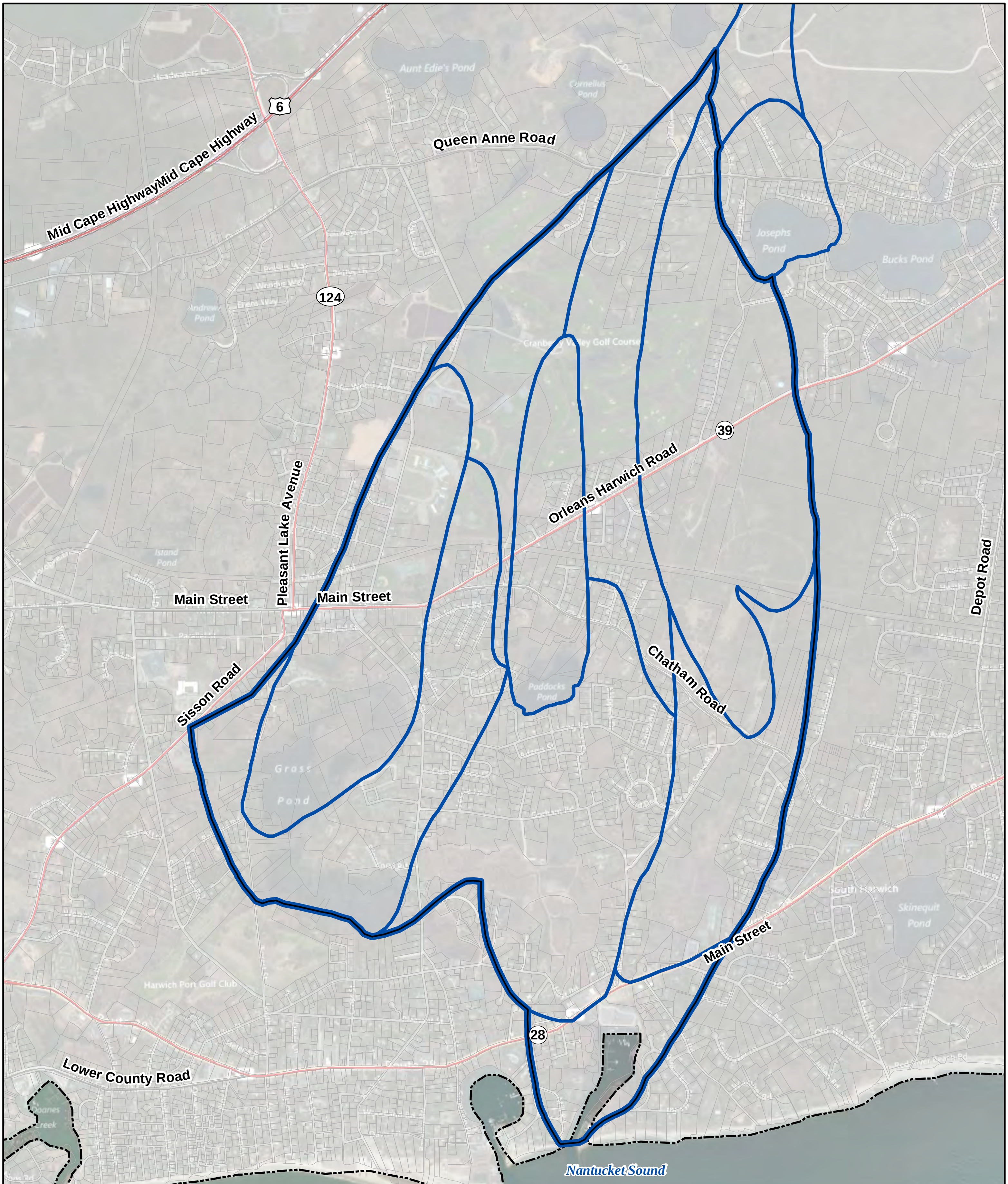
Land Use and Nitrogen Loading

Land use in the Saquatucket Harbor watershed is 41% public service, due to Town-owned preservation land, the publicly-owned Cranberry Valley Golf Course, and the former cranberry bog system now owned by Harwich Conservation Trust. Residential use is comparable at 36%, of which 97% is single family residences. It is estimated that there are approximately 30 private drinking water wells in use at single family residences in the Saquatucket watershed.

In the Saquatucket watershed, residential septic system use coupled with runoff containing fertilizers from golf courses, residential lawns, and cranberry bogs are the predominant sources of nitrogen loading, accounting for 92% of total nitrogen loading. Other sources of nitrogen loading include farm animals, road and roof runoff, and atmospheric deposition.

As a result of the combination of these sources, Saquatucket Harbor experiences moderate nitrogen loading which leads to periodic summer phytoplankton blooms and depleted bottom water oxygen (hypoxia), degraded sediment, and a limited variability and high numbers of benthic animal communities. Dredging of the inlet has helped to sustain tidal exchange which is critical to nitrogen management, however current loading will lead to continued degradation of the harbor. Septic systems accounts for 75% of total nitrogen loading in the watershed and 79% of controllable loading.

This will be the focus of future efforts to bring the harbor conditions to balanced levels such that benthic habitat may be restored. Figure 6-12 shows total nitrogen loading for the Saquatucket Harbor watershed, including natural deposition, and Figure 6-13 shows the percent of controllable nitrogen loading sources within the watershed.



Watershed

Saquatucket Harbor

Saquatucket Harbor Subsheds

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 1,800 feet

0 900 1,800 Feet

Figure 6-11
Saquatucket Harbor System

CDM Smith

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Figure 6-12
Total Nitrogen Loading in the Saquatucket Harbor Watershed, Including Natural Deposition

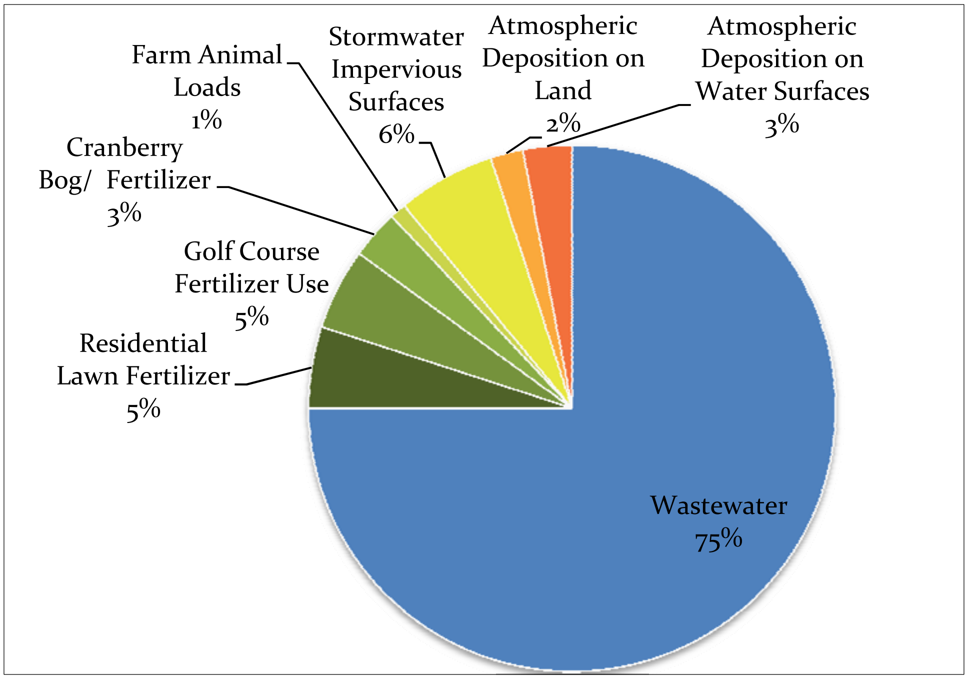
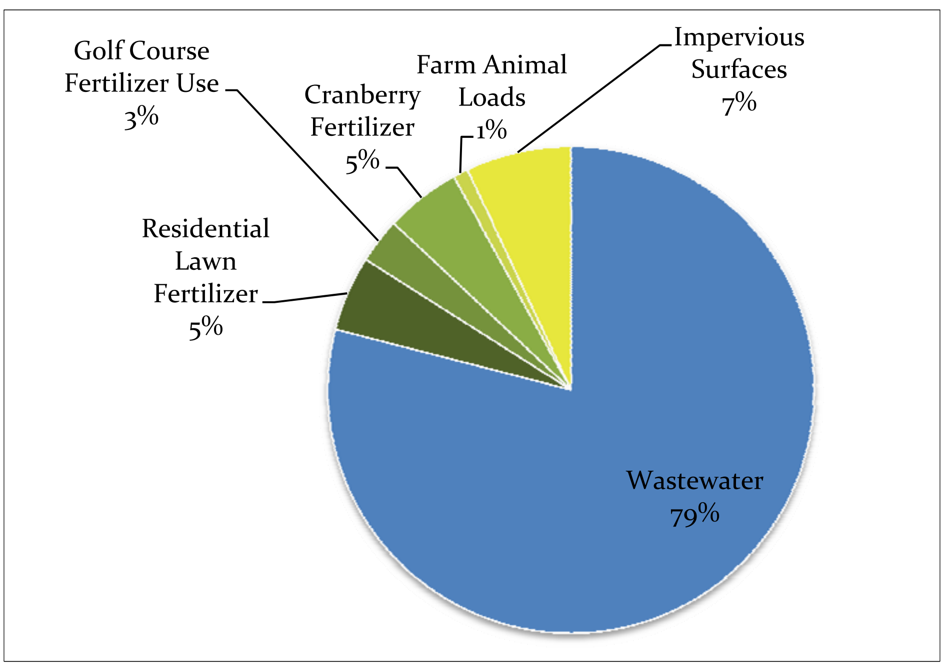


Figure 6-13
Total Controllable Nitrogen Loading in the Saquatucket Harbor Watershed



Water Quality Indicators

The MEP report identified the Saquatucket Harbor estuary as a moderate to significantly impaired system beyond its natural capacity to process additional nutrients without further degrading ecological health. While eelgrass is typically an indicator species of overall health, there is no evidence that the basin has ever supported it. In addition, current water quality conditions and nutrient levels would not support eelgrass populations. As a result, the MEP used the infaunal animal population as an indicator of overall health for this harbor.

In place of eelgrass, benthic animals were again used as the indicator species of overall harbor water quality. Low diversity of infaunal animals with high numbers of individuals, specifically amphipods, was observed. This observation is indicative of nitrogen enrichment and intermediate stress on the habitat; however, it is not indicative of severe degradation. The main basin maintained moderate numbers of species with high numbers of individuals, also indicative of habitat impairment. High chlorophyll and moderate to high organic enrichment indicator species are all indicative of moderate nutrient loading in the main basin and moderate to high organic enrichment in the overall Saquatucket Harbor system.

Dissolved oxygen was also used to indicate water quality. Frequent oxygen depletion was noted in the main basin of Saquatucket Harbor at values consistent with a nitrogen-enriched water body that is moderately to significantly impaired.

Monitoring Stations and Thresholds

In Saquatucket Harbor, one sentinel station entitled HAR-2 is located at the end of the marina, before the main harbor area, as shown in Figure 6-14. This location is positioned such that meeting the target criteria in this location will signify improve water quality throughout the harbor area sufficient to restore ecological health and restore healthy benthic infaunal habitats.

The threshold nitrogen concentration for Saquatucket Harbor sentinel station HAR-2 is 0.494 mg/L. Investigations between 2001 and 2008 have shown that the harbor has average concentration of 0.652mg/L, and nitrogen loading increasing marginally between 2006 and 2008, though generally remaining relatively stable. Similar to the other two harbors (Allen and Wychmere), the available information on eelgrass indicates that the Saquatucket Harbor system did not support eelgrass and cannot support healthy benthic communities. The MEP concluded that an upper limit of 0.50 mg/l of nitrogen (tidally averaged) would support healthy infaunal habitat in Saquatucket Harbor. The concentrations at the monitoring stations may be slightly different than the upper limit, but they are chosen so that the upper limit of 0.50 mg/l of nitrogen (tidally averaged) is achieved throughout the system. This is summarized in Table 6-5 below.

Watershed

Saquatucket Harbor

Water Quality Monitoring Stations

Sentinel Station

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 400 feet

0 200 400 Feet

Figure 6-14
Saquatucket Harbor
Monitoring Stations

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Table 6-5
Sentinel and Check Monitoring Stations with Associated Nitrogen Limits for Saquatucket Harbor

Embayment	Monitoring Station	Present total N Concentration* (mg/l)	Threshold average total N Concentration* (mg/l)	% Change
Saquatucket Harbor	HAR-2	0.652	0.494	-24.2%

*Present and threshold average total N values according to Table VIII-5 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems

Values in RED indicate that the value is above the standard and must be reduced.

Determination of site-specific nitrogen thresholds for an embayment requires integration of key habitat parameters (infauna and eelgrass), sediment characteristics, and nutrient related water quality information. Nitrogen threshold development builds on these data and links habitat quality to summer water column nitrogen levels. To determine the total loading several factors must be considered including septic system effluent flow into the watershed, natural attenuation throughout the watershed, wastewater treatment facilities (if any exist), estuary flushing, stormwater sources, fertilizers applied throughout the watershed, and finally the threshold concentrations presented in the table above. The MEP evaluation of habitat quality supported by the harbor considers the natural structure of each system and its ability to support that habitat before determining the threshold septic load.

The primary source of nitrogen in the Saquatucket Harbor watershed is septic system effluent, which accounts for a majority of total and controllable nitrogen loading. For this reason, this source is the primary focus of nitrogen reduction to meet the threshold values. Overall, 13.25 kg/day, or roughly 4,836 kg/year, total nitrogen is estimated to originate from septic systems within the watershed. In order to meet threshold nitrogen loads, it is estimated that the current total septic load in the Saquatucket Harbor watershed would need to be reduced by 60 percent, as shown in Table 6-6.

Table 6-6
Attenuated Septic Loading in the Saquatucket Harbor watershed*

Sub – Embayment	Present Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease (% change)
Saquatucket Harbor	2.545	0.507	80.1%
Cold Spring Brook	7.775	3.499	55.0%
E. Saquatucket Stream	2.926	1.274	56.5%
Total	**13.246**	**5.280**	**60%**

*Loading information according to Table VIII-2 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems

Values in RED indicate that the value is above the standard and must be reduced.

The threshold septic loading for the Saquatucket Harbor system is the sum of three threshold loads developed in the MEP report for the Saquatucket Harbor sub embayment, The Cold Brook (also known locally as Cold Spring Brook and/or Carding Machine Brook) sub- embayment and the East Saquatucket Stream sub-embayment. The Saquatucket Harbor sub-embayment is the total estuarine reach which receives septic nitrogen inputs through direct groundwater discharge and is separate from surface water inflows. Together these three thresholds combine to give a total threshold septic load for the watershed. To meet the requirements of both the check and sentinel stations, the Saquatucket Harbor sub-embayment will require at least 80.1% of the present septic load to be reduced, the Cold Brook sub-embayment will require at least 55.0% of the present septic load to be reduced and the East Saquatucket Stream sub-embayment will require at least 56.5% of the present septic load to be reduced. Together, the Saquatucket Harbor watershed will require 60% of the septic load to be reduced.

The buildout assessment performed by the MEP is a straightforward buildout assessment that considers a buildout scenario for both residential and commercial parcels throughout the studied watershed. The buildout assessment is an attempt at estimating buildout in a watershed based on current zoning and any projected changes using local input. The estimates developed for the model allows modelers to run a “what if” scenario that considers nitrogen loading associated with future development.

Table 6-5A shows buildout average total nitrogen concentrations modeled at monitoring stations as part of the MEP study along with the recommended threshold concentration for Saquatucket Harbor and the percent change necessary to meet the threshold concentration for each monitoring station.

Table 6-5A
Sentinel and Check Monitoring Stations with Associated Buildout Nitrogen Limits for Saquatucket Harbor

Embayment	Monitoring Station	Buildout total N Concentration* (mg/l)	Threshold average total N Concentration* (mg/l)	% Change
Saquatucket Harbor	HAR-2	0.691	0.494	-28.5%

*Buildout and threshold average total N values according to Table IX-5 and VIII-5 of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems

Values in RED indicate that the value is above the standard and must be reduced.

In the buildout projection, septic system loading also accounts for most of the controllable nitrogen in the Harbor. Thus, septic nitrogen is the primary source which is recommended to be targeted for total reduction within the contributing watershed. The buildout model run for saquatucket septic load is actually lower than the present load because an enhanced attenuation factor was utilized in the Bank Street Bogs that changed the attenuation rate from 35% to 50% in the buildout assumptions. Overall, 12.51 kg/day, or roughly 4,566 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. This is about a 5.5% *decrease* over present loads. In order to meet threshold total nitrogen loads, it is estimated that the current total septic load in the Saquatucket Harbor watershed would need to be reduced by 58 %, as summarized in Table 6-6A below to meet existing conditions.

Table 6-6A
Attenuated Buildout Septic Loading in the Saquatucket Harbor Watershed*
with Enhanced Attenuation

Buildout Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease (% change)
12.51	5.28	58%

*Loading information according to Table VIII-2 and the MEP Loading Spreadsheets (AKA Rainbow Tables) of the June 2010 MEP Final Report for Allen, Wychmere and Saquatucket Harbor Embayment Systems.

Values in RED indicate that the value is above the standard and must be reduced.

6.3.4 Pleasant Bay Watershed and Sub-Embayment Results

The final MEP report for the Pleasant Bay embayment, "Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Orleans, Chatham, Brewster and Harwich, Massachusetts," was published in May 2006. Two additional memoranda were issued in October and June of 2010. These two memoranda update specific attenuation and flushing assumptions. The first memorandum was issued June 25, 2010 and updates the attenuation assumptions in Muddy Creek and nitrogen loading to Pleasant Bay. The second memorandum was issued October 5, 2010 and evaluates the additional scenario to the water quality impacts with the addition of a 24-foot opening to the Muddy Creek inlet. The updates in these memoranda and are considered to be part of the final MEP report for the Pleasant Bay System and are used throughout this section.

Pleasant Bay is the largest embayment system on Cape Cod, comprised of large open water areas and small tributary sub-embayments. Four subwatersheds out of the 59 contributing subwatersheds assessed for the Pleasant Bay system are located within the town of Harwich. Those subwatersheds are Round Cove, Lower Muddy Creek, Upper Muddy Creek, and the Harwich portion of the Pleasant Bay subwatershed. This analysis focuses only on the portions of the Pleasant Bay system within Harwich.

The MEP report identified sub-embayments throughout Pleasant Bay as near or beyond their natural capacity to process additional nutrients without further degrading ecological health. Embayments often indicate the overall health of a watershed because water sources, both groundwater and surface water, carry nutrients from developed areas and deposit those nutrients into a water body. When nutrients are deposited in an estuary, or a water body with limited flow, they often build up faster than the natural systems can break them down, resulting in elevated nitrogen levels. Eutrophication and decreased eelgrass populations throughout the Pleasant Bay system have resulted in moderate impairment, according to the MEP. Because of groundwater and surface water from developed areas, the resulting eutrophication indicates that nutrient overload is not present just in the embayment, but throughout the watershed.

This MEP study, and subsequent updates as part of this CWMP, sought to identify and further investigate the contributing factors which led to current conditions. For Pleasant Bay, nitrogen management is vital to ensure restoration of its natural systems. The solution must include source mitigation local to Pleasant Bay, as well as nitrogen management within the larger regional basins by limiting on-site disposal of wastewater. In order to address this, it is important to first understand the current conditions through ongoing assessment and then establish criteria for improvements.

Physical Description

The Pleasant Bay embayment system is comprised of drowned river valley estuaries, barrier beaches and islands, salt marshes, and flats which exchange tidal waters with a large lagoonal estuary. The large lagoonal estuarine basins, or open water areas, include Little Pleasant Bay, Pleasant Bay, and Chatham Harbor. The Pleasant Bay sub-embayment is bounded by Harwich and Brewster to the southwest and northwest, respectively, Orleans and Little Pleasant Bay to the North, and Chatham to the south. Nauset Spit is a natural sandy barrier island and marine protected area which bounds Chatham Harbor to the east and limits flushing between the embayment and the Atlantic Ocean. Figure 6-15 shows the Pleasant Bay embayment system and its associated estuarine basins. This also shows the sub-watersheds located in Harwich.

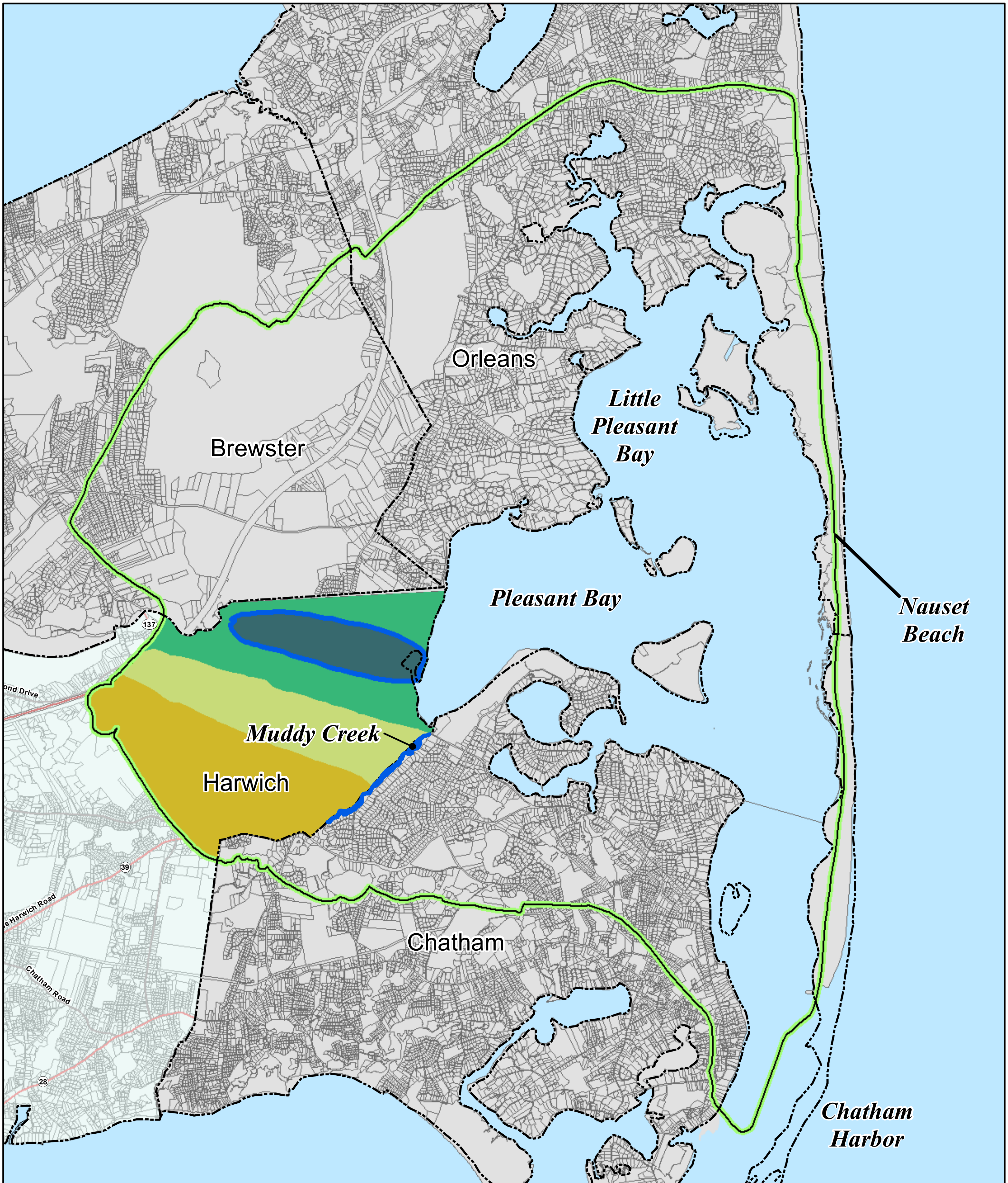
Land Use and Nitrogen Loading

Determination of the amount of nitrogen transported by freshwater sources to the Pleasant Bay embayment was made in three main steps: assessment of nitrogen accumulation and nitrogen sources; assessment of nitrogen transport through natural systems; and evaluation of natural denitrification processes which degrade concentrations over time.

The following subsection presents loading in Harwich for Upper and Lower Muddy Creek, Round Cove and the Pleasant Bay subwatersheds. Subwatershed nitrogen loading in Pleasant Bay and Round Cove is shared with the town of Brewster, and subwatershed nitrogen loading in both Upper Muddy Creek and Lower Muddy Creek is shared with the town of Chatham.

Determination of the existing nitrogen load for each subwatershed included regional loading factors and parcel by parcel land and water use data. Watershed-specific information regarding wastewater, fertilizers, stormwater runoff from impervious surfaces, and atmospheric deposition were also used.

Digital parcel and tax assessor data from 1999 and 2005 and updated land use coverages from 2006 were used for the Town of Harwich. These data generally consisted of land use information as well as Town-generated information. Land use was broken down into nine common and comparable categories: 1) residential, 2) commercial, 3) industrial, 4) undeveloped, 5) agricultural, 6) mixed use, 7) golf course and recreational, 8) public service/government, and 9) freshwater ponds. Across Pleasant Bay, the most common land uses were residential (38% of watershed area) and public service including government-owned lands, roads, and rights-of-way (37%).



N

Watershed

Pleasant Bay System

Sub-Watersheds in Harwich

Round Cove

Pleasant Bay

Lower Muddy Creek

Upper Muddy Creek

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 5,280 feet

0 2,640 5,280 Feet

Figure 6-15
Pleasant Bay
Sub-Watersheds in Harwich

CDM Smith

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Water use information by parcel was obtained from the Harwich Water Department for the year 2004. Wastewater-based nitrogen loading from the individual parcels using on-site septic systems was based upon the measured water use, estimated nitrogen concentration, and assumed consumptive loss of water (i.e. irrigation, drinking water, etc.) before the remainder is treated in a septic system. Typical septic system removal of nitrogen is around 20%, however further nitrogen loss during aquifer transport is negligible. Average water use throughout the Pleasant Bay watershed was 166 gpd at the time of the MEP assessment.

Similar to the watersheds previously discussed, the Pleasant Bay watershed also has a high residential septic system use coupled with stormwater runoff containing fertilizers from golf courses and residential lawns. These sources are the predominant sources of nitrogen loading, accounting for 51% of total nitrogen loading within the watershed. Other sources of nitrogen loading include road and roof runoff and atmospheric deposition.

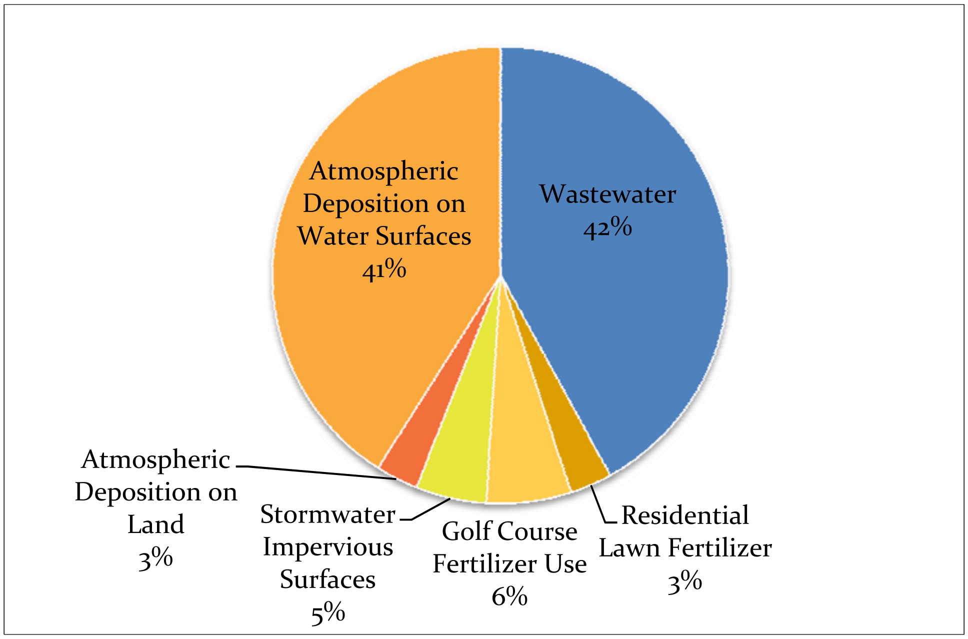
The primary ecological threat to Pleasant Bay resources is degradation resulting from nutrient enrichment. Loading of the critical eutrophying nutrient, nitrogen, to the embayment waters has been greatly increased over the past few decades with further increases certain unless nitrogen management is implemented.

The Pleasant Bay system is more complicated than many of the other embayments studied by the MEP because of the presence of a large shoreline with numerous sub-embayments. The large number of subembayments greatly increases the potential for direct discharges from homes situated on the shore and decreases the travel time of groundwater from the watershed recharge areas to bay regions of discharge.

The presence of enclosed embayments in areas with relatively high population densities creates a nutrient loading problem that is important since the protected marine shorelines are the same shorelines that are popular for boating, recreation, and land development. These enclosed bodies of water are often inadequately flushed of the pollutants that they receive due to the proximity and density of development near and along their shores.

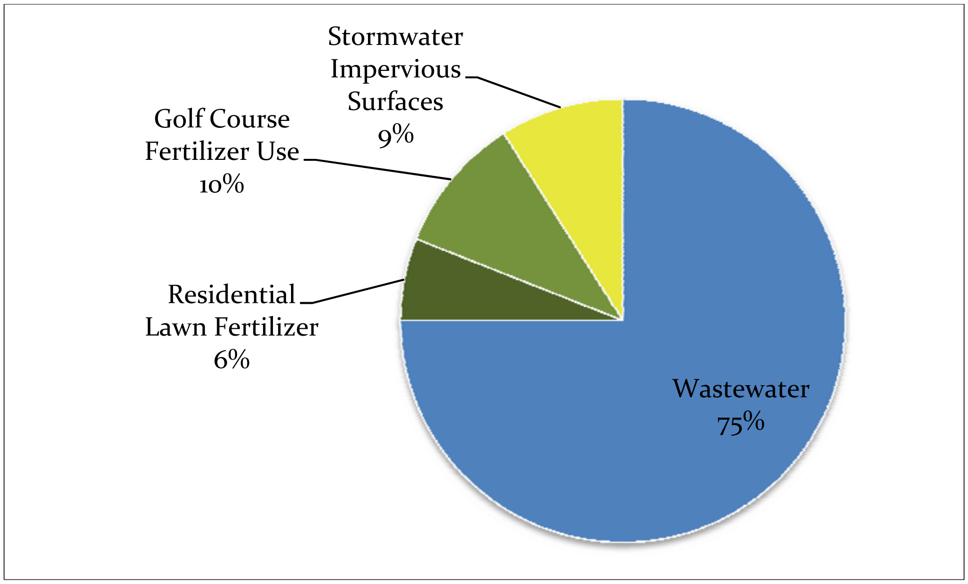
Septic system effluent, which accounts for 42% of total nitrogen loading in the Pleasant Bay watershed and 75% of controllable nitrogen loading, will be the focus of future efforts to bring the harbor conditions to balanced levels such that benthic habitat may be restored. Figure 6-16 shows total nitrogen loading for the entire Pleasant Bay watershed, including natural deposition, and Figure 6-17 shows the percent of controllable loading sources within the watershed.

Figure 6-16
Total Nitrogen Loading in the Pleasant Bay Watershed, Including Natural Deposition



For this system, wastewater is the primary contributor of total nitrogen to the Pleasant Bay system. Other controllable sources contribute approximately 17% of the total load.

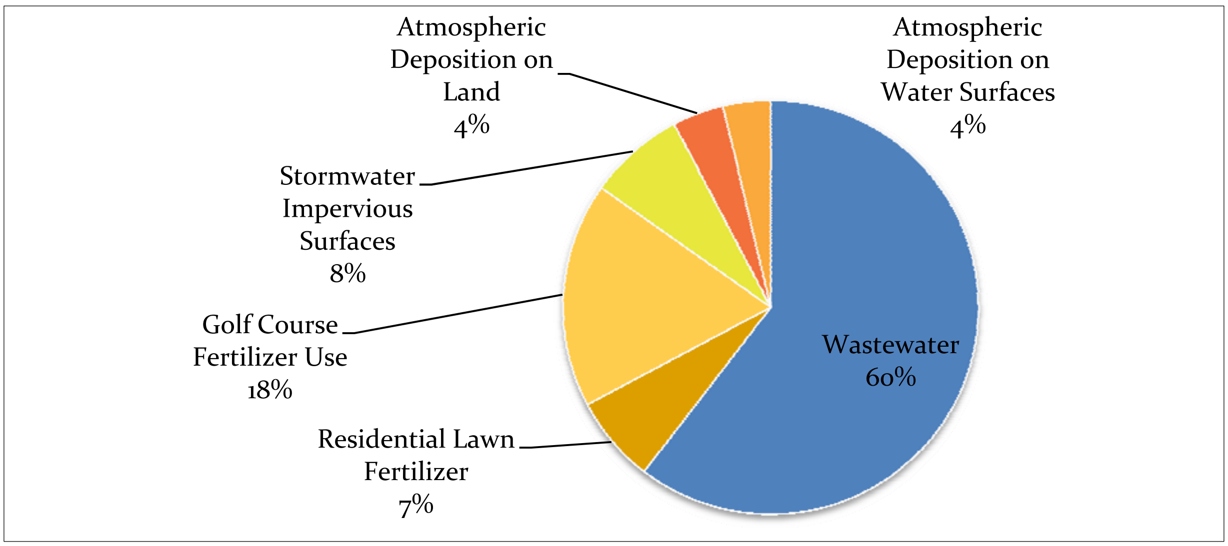
Figure 6-17
Total Controllable Nitrogen Loading in the Pleasant Bay Watershed



While wastewater is the major contributor to the controllable nitrogen load, fertilizers contribute another 16% to the system and stormwater contributes approximately 9% to the controllable load.

Since the Pleasant Bay system is so complex, the subwatersheds to the Pleasant Bay system such as Round Cove and Muddy Creek have slightly different distributions of nitrogen inputs due to the different types of development throughout the sub-watersheds. As an example, wastewater in Muddy Creek contributes 72% of total nitrogen loading and 79% of controllable loading. As a result of these differences, each subwatershed must be considered individually when deciding the appropriate amount of nitrogen that should be managed. Figure 6-18 shows total nitrogen loading for the Muddy Creek subwatershed, including natural deposition, and Figure 6-19 shows the percent of controllable loading sources within the subwatershed.

Figure 6-18
Total Nitrogen Loading in the Muddy Creek Subwatershed, Including Natural Deposition

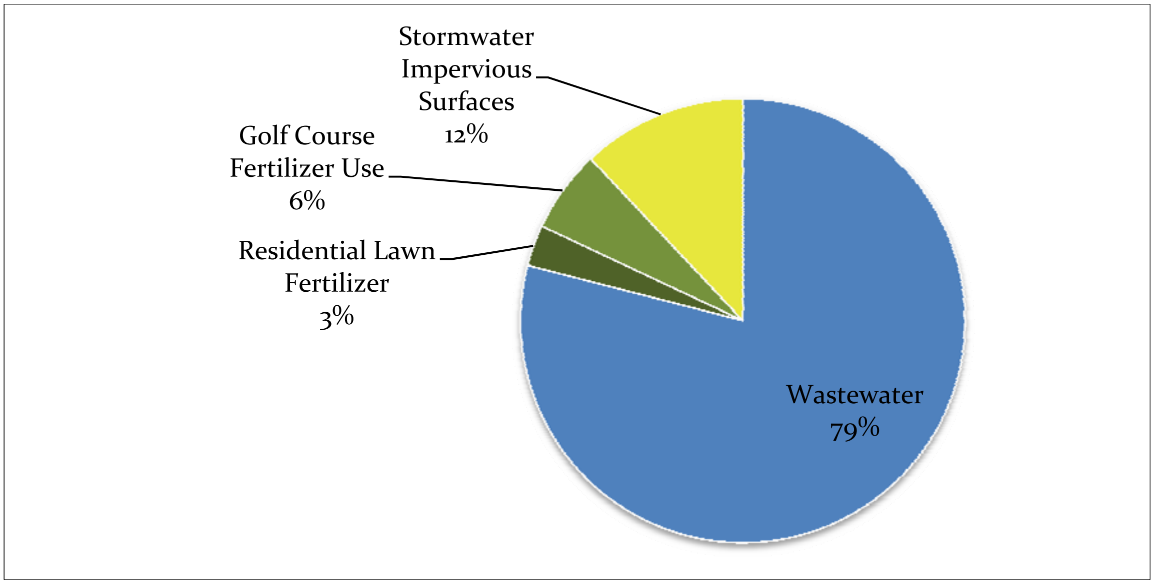


As noted above, for the Muddy Creek system, wastewater is the majority contributor 60 %, and fertilizers contribute another 25% of total nitrogen to the Muddy Creek subwatershed. Other sources contribute approximately 16% of the total load.

For controllable nitrogen loads, wastewater is again the major contributor and fertilizers contribute another 9% and other sources contribute approximately 12% of the controllable load to the Muddy Creek system.

Once nitrogen sources are determined, the amount which they contribute to receiving waters depends on the time and method of transport as well as natural attenuation through freshwater ponds. For instance, nitrogen inputs which enter or pass through a pond are reduced by approximately 50% due to natural attenuation, while denitrification during groundwater transmissivity is considered negligible. For that reason, loads are further assessed according to subwatershed.

Figure 6-19
Total Controllable Nitrogen Loading in the Muddy Creek Subwatershed



Water Quality Indicators

Water quality within the Pleasant Bay system varies from healthy to degraded, depending on the level of nitrogen enrichment at a particular location. For the purposes of assessing water quality indicators, Upper Muddy Creek and Round Cove were classified as small enclosed basins and received similar results for key habitat indicators, while Lower Muddy Creek was categorized as a moderate sized tributary sub-embayment.

Key habitat indicators include infaunal animals, eelgrass population, and dissolved oxygen/chlorophyll-a levels. In Upper Muddy Creek, the benthic animal population is significantly depleted, indicating high nitrogen loading and oxygen stress. Results from Round Cove indicated intermediate stress species, including amphipods, however nutrient loading was considered to be only moderately beyond nitrogen loading limits.

Historically, eelgrass has not been supported in most of the small enclosed basins within Pleasant Bay, including Round Cove. However there is a small patch of eelgrass in the Lower Muddy Creek area. As a result, the MEP used the infaunal animal population as well as eelgrass populations as an indicator of overall health.

A High level of oxygen stress was observed in small enclosed basins, including Upper Muddy Creek and Round Cove watersheds. These basins were also found to maintain higher nitrogen levels due to limited flushing. Round Cove was reported with mild hypoxia, a condition where dissolved oxygen levels are below 2 mg/L; however levels were typically above 4 mg/L or 5 mg/L during the field data collection period. In contrast, Upper Muddy Creek was frequently observed to be anoxic, where dissolved oxygen was not present. The area within Pleasant Bay between Round Cove and Upper Muddy Creek was typically reported to maintain dissolved oxygen levels of about 5 mg/L; however one event was reported as partially hypoxic, with dissolved oxygen levels reported between 2 and 4 mg/L.

Overall, Upper Muddy Creek, Lower Muddy Creek, and Round Cove were each separately ranked for level of stress according to several nutrient related health indicators, including: dissolved oxygen, chlorophyll-a, macroalgae, eelgrass, and infaunal animals. Round Cove was ranked moderately impaired to significantly impaired for dissolved oxygen levels, chlorophyll-a levels, and infaunal animal species, resulting in an overall ranking of significantly impaired to moderately impaired. Upper Muddy Creek was ranked significantly impaired to severely degraded in terms of dissolved oxygen levels, chlorophyll-a levels, and infaunal animal species, resulting in an overall ranking of severely degraded. Lower Muddy Creek was consistently ranked significantly impaired.

Muddy Creek Culvert Project

The Pleasant Bay Alliance recognized that the tidal flushing in Muddy Creek was both man made and limited by the presence of a tidal restriction (culvert) to Muddy Creek. Since both the Upper and Lower Muddy Creek were impaired, the Alliance realized that increased flushing in these subwateresheds could have a significant impact in the threshold concentrations. As a result, discussions were held with SMAST and a new scenario was developed that evaluated the Pleasant Bay system with a 24-foot wide culvert (opening) to Muddy Creek. The size of the 24-foot culvert was chosen because it was believed by SMAST that a culvert larger than that would not significantly increase flushing or have an effect on the thresholds based on the modeling results.

The effect of increasing the inlet opening to Muddy Creek on nitrogen throughout Pleasant Bay was evaluated using the Pleasant Bay model, as requested by the Pleasant Bay Alliance. This evaluation was conducted under both existing and buildout watershed loadings. The evaluation showed that replacing the existing inlet to Muddy Creek with a 24-foot culvert has little effect on the nitrogen levels throughout the Pleasant Bay System, since Muddy Creek represents only about 12% of the watershed load to the overall system, and the inlet has little effect on the amount of nitrogen leaving Muddy Creek. According to the evaluation, a small, but insignificant, lowering of concentrations will be realized from the larger tide range in Muddy Creek with the new inlet.

While there is a clear reduction in the nitrogen level at the Muddy Creek check station due to the wider opening, there is little or no change in the nitrogen concentrations at the other check stations and sentinel stations. The wider culvert results in a 20% drop in the difference between the existing conditions modeled nitrogen concentration and the threshold concentration (0.21 mg/l) at the Lower Muddy Creek check station (PBA-05). Additional nitrogen reductions are still necessary in the Muddy Creek watershed to meet the threshold concentration in Lower Muddy Creek, but the magnitude is reduced through the installation of the wider opening. All other stations throughout Pleasant Bay have insignificant changes in concentration (i.e., less than one percent). These results suggest that installing a 24-foot opening at the head of Muddy Creek will improve water quality in Muddy Creek and will not result in any significant changes in the rest of the Pleasant Bay system. The subsection below presents threshold concentrations and nitrogen reduction goals which were developed with the assumption that the 24-foot Muddy Creek opening will be implemented as part of the overall wastewater management program.

Monitoring Stations and Thresholds

Due to the relative size and extent of the Pleasant Bay estuary, the comprehensive MEP evaluation involved sampling at more than 20 monitoring stations throughout this complex estuary. Sampling locations were selected based on the subject data being evaluated and its relative location in comparison to the subject subwatershed. Figure 6-20 shows the selection of water quality check stations which were sampled during warm weather months from 2000 to 2005 that are discussed in this section, in addition to the three sentinel stations for Pleasant Bay.

As described previously, sentinel stations are locations within the embayment which, once restored, "will necessarily bring the other regions of the system to acceptable habitat quality levels." In the Pleasant Bay sub-embayment, three sentinel locations were used to determine the critical nitrogen threshold necessary to maintain a high-quality eelgrass habitat. Sentinel stations for Pleasant Bay included PBA-12 at the head of Little Pleasant Bay, PBA-03 at upper Ryders Cove, and CM-13 at lower Ryders Cove. These locations were selected because comparative conditions in other sub-embayments, where depth was similar, supported eelgrass growth. While each of these locations is positioned to capture the overall performance of the Pleasant Bay estuary, none are located near the subject sub-watersheds of concern in Harwich.

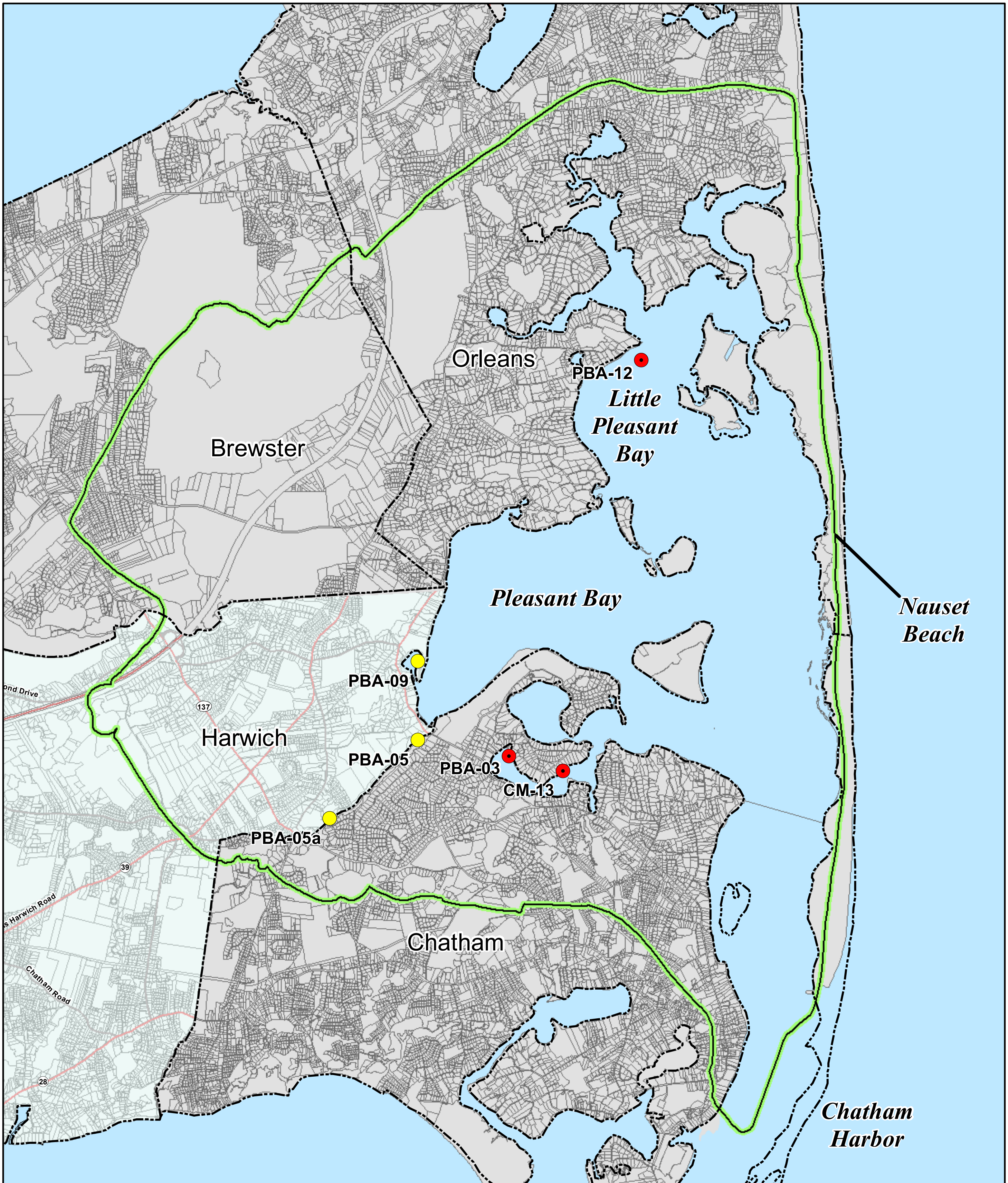
The sentinel station for the Pleasant Bay System is based on a nitrogen threshold that targets the restoration of eelgrass. This station was placed within the uppermost reach of Little Pleasant Bay (PBA-12). The total nitrogen level at the sentinel station (PBA-12) is 0.723 mg/l of nitrogen which was set to improve the eelgrass habitat throughout Little Pleasant Bay and the historic distribution in Pleasant Bay, which will see lower nitrogen levels when the threshold is reached.

While eelgrass restoration is the primary nitrogen management goal within the Pleasant Bay System, there are small basins which do not appear to have historically supported eelgrass habitat. For these sub-embayments, restoration and maintenance of healthy animal communities is the management goal. It should be noted that restoration of eelgrass is not the only criteria for restoration of habitat health throughout the Pleasant Bay System. Based upon the 1951 eelgrass analysis there are eight (8) sub-embayments to Pleasant Bay that are not likely to support eelgrass habitat for structural reasons. While these systems may not be supportive of eelgrass habitat, they are generally capable of supporting healthy benthic animal habitat. Infaunal animals are sensitive to the organic matter loading and resulting periodic oxygen depletions associated with nitrogen overloading.

Since these conditions typically occur at higher nitrogen loads than does the shading of the bottom by increased phytoplankton production (principal cause of eelgrass loss), the nitrogen threshold level for healthy benthic animal habitat is higher than for healthy eelgrass habitat. This has been found to be the case throughout the MEP study area.

Since the Pleasant Bay system is so complex and is shared by several towns, each individual community must understand how to reduce excess nutrients in the sub-embayment that falls within its towns boundaries.

In order for Harwich to monitor progress in reducing its nitrogen contribution to Pleasant Bay, the town will need to monitor the check stations closest to the sub-embayment for which they are responsible. There are three check stations located near Harwich. These stations include PBA-09 at Round Cove, PBA-05a at Upper Muddy Creek, and PBA-05 at Lower Muddy Creek. The sentinel station PBA-12 should be monitored for the Pleasant Bay sub-embayment that discharges directly to Pleasant Bay. Table 6-7 summarizes the present and threshold nitrogen concentrations at these stations.



Watershed

Pleasant Bay System

Water Quality Monitoring Stations

Check Station

Sentinel Station

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 5,280 feet

0 2,640 5,280 Feet

Figure 6-20
Water Quality Monitoring Stations in Pleasant Bay

CDM Smith

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Present concentrations for each station were determined using total nitrogen concentration data collected during warm weather months from 2000 to 2005. The present concentration is the mean of the five annual average nitrogen concentrations collected during that time period. A summary of each monitoring station present and total nitrogen loading was captured for each sub-watershed. Table 6-7 shows present average total nitrogen concentrations observed at monitoring stations as part of the MEP study along with the recommended threshold concentration for the four sub-embayments.

Table 6-7
Sentinel and Check Monitoring Stations with Associated Nitrogen Limits for the Pleasant Bay System

Sub -embayment	Monitoring Station	Present Total N Concentration* With Existing Muddy Creek Opening (mg/l)	Threshold Concentration (mg/l)	% Change
Round Cove	PBA-09	0.255	0.207	18.8%
Upper Muddy Creek	PBA-05A	0.674	0.405	39.9%
Lower Muddy Creek	PBA-05	0.298	0.208	30.2%
Little Pleasant Bay - head	PBA – 12	0.178	0.160	10.1%

*Present and threshold average total N values according to Table 3 of the October 5th, 2010 MEP Technical Memo, and Table VIII-6 of the May 2006 Pleasant Bay Linked Embayment Model.

Values in RED indicate that the value is above the standard and must be reduced.

For comparison, Table 6-7A summarizes the present and threshold nitrogen concentrations at these stations with the enlarged culvert at Muddy Creek.

Table 6-7A
Sentinel and Check Monitoring Stations with Associated Nitrogen Limits for the Pleasant Bay System

Subwatershed	Monitoring Station	Present Total N Concentration* With Enlarged Muddy Creek Opening (mg/l)	Threshold Concentration (mg/l)	% Change
Round Cove	PBA-09	0.253	0.207	18.1%
Upper Muddy Creek	PBA-05A	0.674	0.405	39.9%
Lower Muddy Creek	PBA-05	0.255	0.208	18.4%
Little Pleasant Bay - head	PBA – 12	0.178	0.160	10.1%

*Present and threshold average total N values according to Table 4 of the October 5th, 2010 MEP Technical Memo, and Table VIII-6 of the May 2006 Pleasant Bay Linked Embayment Model.

Values in RED indicate that the value is above the standard and must be reduced.

Determination of site-specific nitrogen thresholds for an embayment requires integration of key habitat parameters (infauna and eelgrass), sediment characteristics, and nutrient related water quality information. Nitrogen threshold development builds on these data and links habitat quality to summer water column nitrogen levels. To determine the total loading several factors must be considered including septic system effluent flow into the watershed, natural attenuation throughout the watershed, wastewater treatment facilities (if any exist), estuary flushing, stormwater sources, fertilizers applied throughout the watershed, and finally the threshold concentrations presented in the table above. The MEP evaluation of habitat quality supported by the harbor considers the natural structure of each system and its ability to support that habitat before determining the threshold septic load.

Because septic effluent accounts for the majority of total loading to each watershed, septic system nitrogen loading is the primary focus of reduction efforts moving forward. The Round Cove watershed maintains an average septic load of 5.18 kg/day. A 63% reduction in total septic loading is required in the Round Cove watershed to meet threshold nitrogen loading and restore habitat in that sub-embayment. The Upper Muddy Creek watershed maintains an average septic load of 4.72 kg/day. A 45% reduction in total septic loading is required in the Upper Muddy Creek watershed to meet threshold nitrogen loading and restore habitat in that sub-embayment. The Lower Muddy Creek watershed maintains an average septic load of 8.60 kg/day. A 50% reduction in total septic loading is required in the Lower Muddy Creek watershed to meet threshold nitrogen loading and restore habitat in that sub-embayment.

The Pleasant Bay sub-embayment requires a 61% reduction in present septic load, therefore the watersheds contributing directly to the Pleasant Bay system should, at minimum, reduce septic nitrogen loading by 61%. Table 6-8 summarizes the septic loading concentrations and thresholds for Harwich sub-watersheds in Pleasant Bay. The individual reductions from each community contributing to a watershed will need to be coordinated on a sub-embayment by sub-embayment basis and as required by each community's long term planning needs.

Table 6-8
Attenuated Septic Loading in the Harwich Portion of the Pleasant Bay Watershed*
with Revised Muddy Creek Opening

Sub-Embayment	Present Septic Load (kg/day)	Threshold Septic Load With Enlarged Muddy Creek Opening (kg/day)	Septic Load Decrease (% change)
Round Cove	5.18	1.87	64%
Upper Muddy Creek	4.72	2.59	45%
Lower Muddy Creek	8.60	4.30	50%
Pleasant Bay	16.69	6.51	61%

*Loading information according to Table 2 of the October 5th ,2010 MEP Technical Memo : MEP scenarios to evaluate water quality impacts of the addition of a 24-foot culvert in Muddy Creek inlet.

Values in RED indicate that the value is above the standard and must be reduced.

As shown in this section, the primary source of nitrogen in the Pleasant Bay system watershed is septic system effluent, which accounts for the highest percentage of total and controllable nitrogen loading. For this reason, this source is the primary focus of nitrogen reduction to meet the threshold values. Overall, 35.19 kg/day, or roughly 12,844 kg/year, total nitrogen is estimated to originate from septic systems within the above mentioned sub-embayments of the Pleasant Bay watershed.

Table 6-9
Attenuated Septic Loading in the Pleasant Bay Watersheds (within the Town of Harwich Boundaries)

Present Septic Load (kg/day)	Threshold Septic Load With Enlarged Muddy Creek Culvert (kg/day)	Septic Load Decrease to Meet Threshold (% change)
35.19	15.27	57%

*Loading information according to Table 2 of the October 5th ,2010 MEP Technical Memo : MEP scenarios to evaluate water quality impacts of the addition of a 24-foot culvert in Muddy Creek inlet.

Values in RED indicate that the value is above the standard and must be reduced.

The buildout performed by the MEP for the Pleasant Bay is a straightforward buildout assessment that considers a buildout scenario for both residential and commercial parcels throughout the studied watershed. The buildout assessment is an attempt at estimating buildout in a watershed based on current zoning and any projected changes using local input. The estimates developed for the model allows modelers to run a "what if" scenario that consideres nitrogen loading associated with future development.

Table 6-8A shows buildout average total nitrogen loads for Harwich sub-watersheds in the Pleasant Bay and the percent change necessary to meet the threshold concentration in each subembayment.

Table 6-8A
Attenuated Buildout Septic Loading in the Harwich Portion of the Pleasant Bay watershed*

Sub-Embayment	Buildout Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease to Meet Threshold (% change)
Round Cove	5.78	1.87	68%
Upper Muddy Creek	6.12	2.59	58%
Lower Muddy Creek	10.16	4.30	58%
Pleasant Bay	21.84	6.51	70%

*Loading information according to Table 2 of the October 5th ,2010 MEP Technical Memo : MEP scenarios to evaluate water quality impacts of the addition of a 24-foot culvert in Muddy Creek inlet.

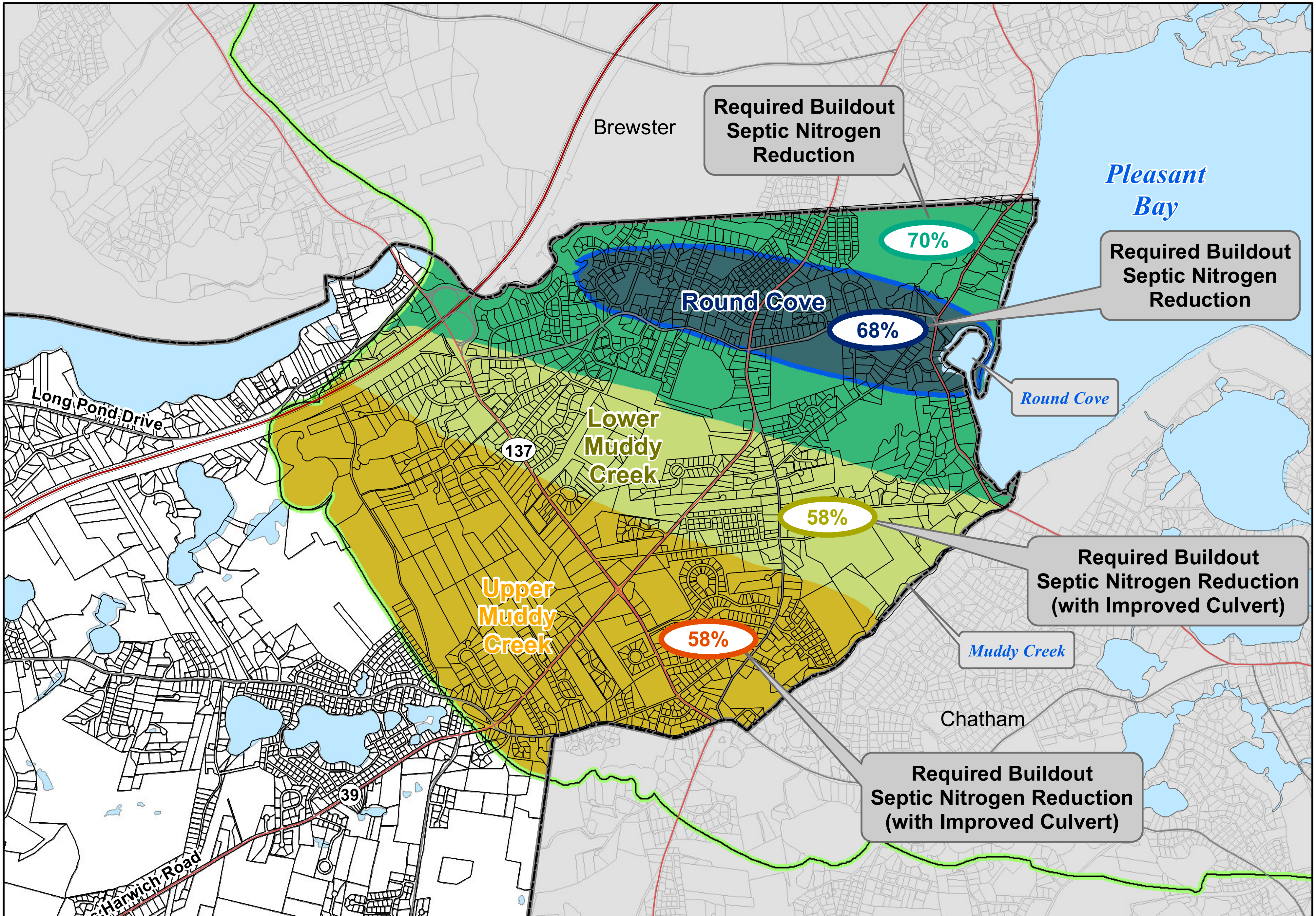
Values in RED indicate that the value is above the standard and must be reduced.

Overall, 43.90 kg/day, or roughly 16,023 kg/year, total nitrogen is estimated to originate from septic systems at buildout within the Harwich sub-watersheds of Pleasant Bay. This is about a 25% increase over present loads. In order to meet threshold nitrogen loads, it is estimated that the buildout total septic load in the Pleasant Bay watersheds would need to be reduced by 65%, as shown in Table 6-9A. See Figure 6-21 for subwatershed boundaries in Harwich and the total buildout percent reduction required for each.

Table 6-9A
Attenuated Septic Buildout Loading in the Pleasant Bay Watersheds (within the Town of Harwich Boundaries)

Buildout Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease to Meet Threshold (% change)
43.90	15.27	65%

Values in RED indicate that the value is above the standard and must be reduced.



Watershed
Pleasant Bay System

Sub-Watershed
Round Cove
Muddy Creek
Lower Muddy Creek
Upper Muddy Creek

Map of Pleasant Bay Watersheds
in Harwich

1 inch = 2,500 feet
0 1,250 2,500 Feet

Figure 6-21
Harwich Sub-Watershed Boundaries in Pleasant Bay

CDM Smith

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6.3.5 Herring River Watershed Results

The final MEP report for the Herring River embayment, "Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Herring River Embayment System, Harwich, Massachusetts," was published as a DRAFT in June of 2012.

Physical Description

The Herring River Marsh / Embayment System is located within the Town of Harwich, however the watershed to the overall system extends into the Towns of Brewster and Dennis. The Herring River System is comprised of a main tidal channel and includes a west branch that extends up to a man-made freshwater reservoir and an east branch that extends up into a small brackish marsh.

The Herring River System is one of the largest functional wetlands on Cape Cod. This wetland is predominantly a freshwater marsh in the upper reaches and a salt marsh system in the lower reaches. Although most of the Herring River system is a tidal wetland system, the lower reaches closer to the inlet are considered to be a tidal river with limited wetland vegetation. Below the Route 28 bridge, the tidal channel is relatively wide and functions more like an open water basin than a marsh. Above Route 28, the channel narrows and then intersects with smaller tributary marsh creeks.

The differences in structure above and below the Route 28 bridge are very different. Historic eelgrass habitat and benthic animal communities of more open water basins exist in the lower tidal reach. However, minimal eelgrass is currently present in this area. Wetland dominated habitats exist 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.

The Herring River System receives water from Nantucket Sound through a single tidal inlet. The inlet is relatively wide and navigable and functions more like an embayment rather than a marsh. Above Route 28, the channel narrows and quickly changes to a system that is dominated by salt marsh.

Overall, the Herring River Marsh/Embayment system 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. The upper regions, furthest from the tidal inlet show the influence of the freshwater inflows from the surrounding watershed. Tidal exchange with the Nantucket Sound is high with near complete drainage of tidal creeks in the upper most portions of the system at low tide. Observations by the USGS and the MEP indicate that the Herring River is healthy functioning New England tidal wetland system north of the Route 28 bridge. The Herring River Marsh provides both wildlife habitat and a nursery to offshore fisheries, as well as serving as a storm buffer and nutrient sink for watershed derived nitrogen.

The primary ecological threat to the Herring River system is degradation from nutrient enrichment. This is particularly true within the lower tidal river reach. Nitrogen loading is primarily from on-site disposal of wastewater or disposal of treated effluent from municipal treatment facilities. Most areas of the Herring River watershed rely almost entirely on privately maintained on-site septic treatment and disposal of wastewater. As existing and likely increasing levels of nutrients impact the coastal embayments of the Town of Harwich, water quality degradation is expected to increase.

Land Use and Nitrogen Loading

Land use in the Herring River Harbor watershed is primarily (56%) residential of which 66% are single family homes. High residential use, coupled with the fact that Harwich has experienced significant population growth since 1950, has resulted in moderate nitrogen loading in the watershed due to watershed inputs, and primarily due to nitrogen from septic system discharge. Figure 6-22 shows the Herring River System.

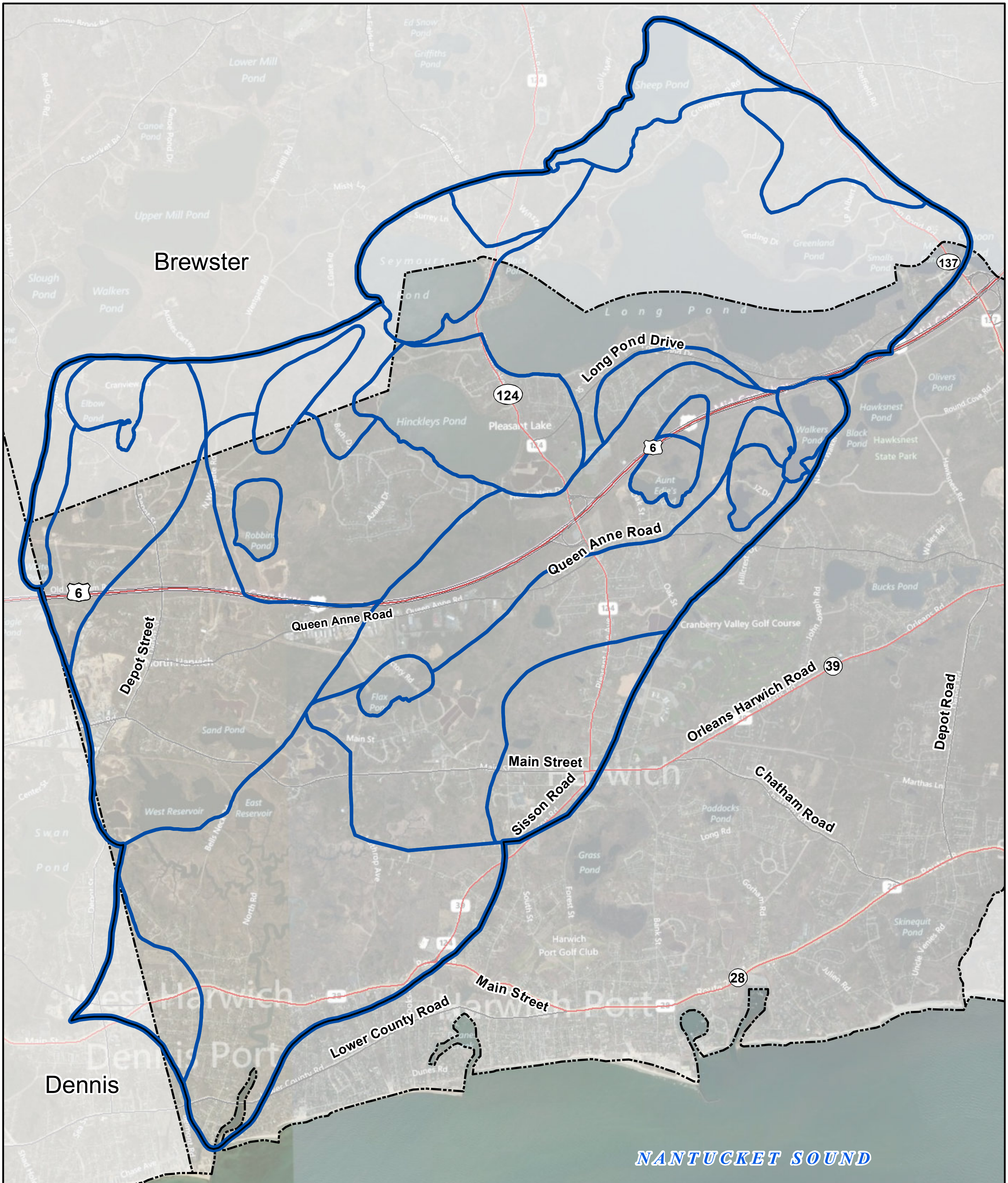
Natural deposition of atmospheric nitrogen on water bodies and natural land surfaces accounts for 18% of the total loading within the Herring River system. Controllable sources, such as wastewater from septic systems and residential and commercial fertilizer applications, account for approximately 63% of the total nitrogen loading. Because septic system effluent accounts for such a large percent of nitrogen inputs, 68% of controllable nitrogen sources, reducing this source is a priority for improving overall estuary habitat. Figure 6-23 shows total nitrogen loading for the Herring River watershed, including natural deposition, and Figure 6-24 shows the percent of controllable nitrogen loading sources within the watershed.

Water Quality Indicators

High quality habitat in open water basins support different communities than high quality habitat in tidal wetlands. These important differences are described in the MEP assessment of the wetland dominated upper region and open water dominated tidal river comprising the lower region of the Herring River system. This 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 wetland basin. Based upon the available information, tidal creeks of the upper reach do not appear to be able to support eelgrass habitat. The lower estuarine reach below Route 28 is structured to support eelgrass habitat.

The MEP report identified the Herring River system as one that can support high quality habitat. It is not presently impaired by their naturally high levels of nitrogen and organic matter enrichment. The open water basin of the tidal river is presently supporting high quality benthic animals which is consistent with its level of dissolved oxygen, organic matter, nutrient enrichment and flushing. This open water basin does, however, appear to be at or slightly below its threshold level of enrichment relative to benthic animal habitat in its upper most reaches. Any additional nutrient inputs are expected to further degrade ecological health.

Since the results of the infauna survey do not indicate clear impairment of benthic habitat within the Herring River system, the MEP recommends a nitrogen management analysis that focuses primarily on the recent losses of eelgrass habitat from the lower estuary's tidal river basin. The loss of eelgrass is the result of its sensitivity to nutrient loads. The upper wetland basin appears to be well below its nitrogen loading threshold level. Since infaunal habitat is less sensitive to the effects of nitrogen enrichment than eelgrass, protecting the more sensitive eelgrass habitat will, by default, enhance infaunal habitat within the tidal river portion of the estuary. Determining the nitrogen target to restore eelgrass habitat is the focus of the nitrogen management threshold standards presented below.



Watershed

Herring River

Herring River Subsheds

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 3,500 feet

0 1,750 3,500 Feet

Figure 6-22
Herring River System

CDM Smith

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Figure 6-23
Total Nitrogen Loading in the Herring River Watershed, Including Natural Deposition

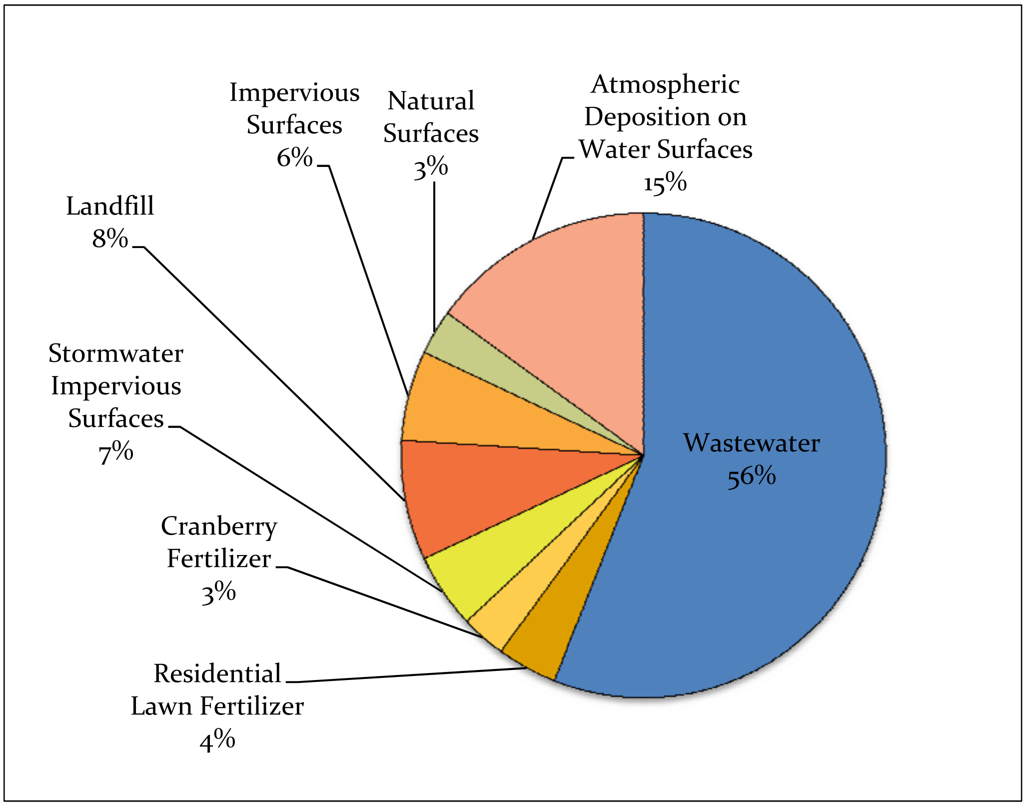
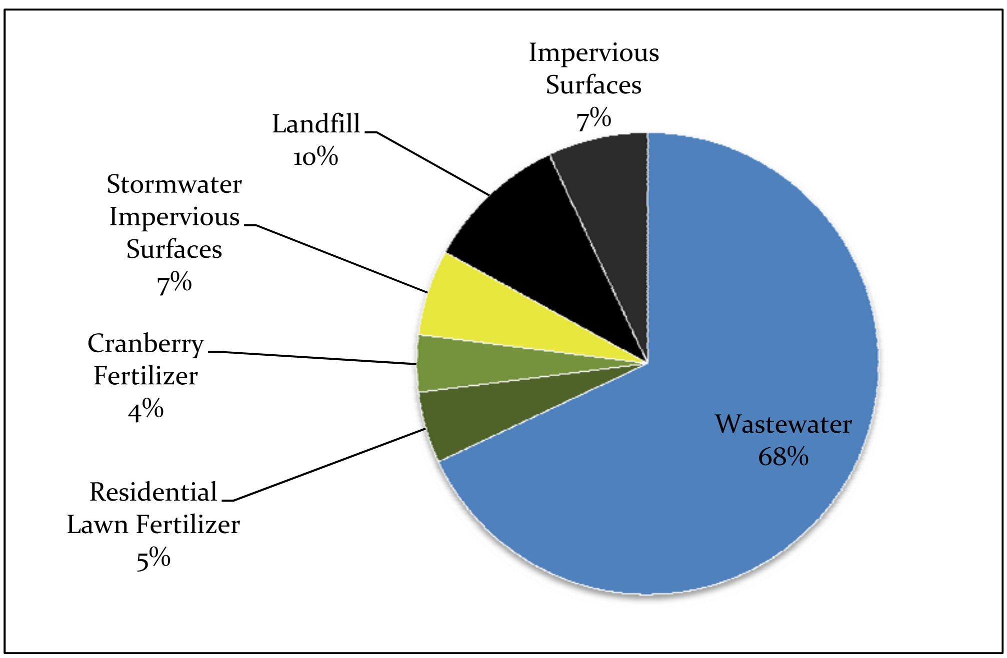


Figure 6-24
Total Controllable Nitrogen Loading in the Herring River Watershed



Monitoring Stations and Thresholds

In Herring River, one sentinel station identified as HAR-7 is located at the Route 28 Bridge (the upper most limit of the historic eelgrass within the system) as shown in Figure 6-25. This location is positioned such that meeting the target criteria in this location will signify improve water quality throughout the tidal area sufficient to restore eelgrass within the tidal portion of the estuary.

The threshold nitrogen concentration for the Herring River sentinel station HAR-7 is 0.479 mg/L. The MEP concluded that an upper limit of 0.479 mg/l of nitrogen would support both eelgrass and healthy infaunal habitat in the Herring River system. The concentrations at the monitoring stations may be slightly different than the upper limit, but they are chosen so that the upper limit of 0.48 mg/l of nitrogen (tidally averaged) is achieved throughout the system. This is summarized in Table 6-10 below.

Table 6-10
Sentinel Monitoring Station with Associated Nitrogen Limit for the Herring River system

Embayment	Monitoring Station	Present total N Concentration* (mg/l)	Threshold average total N Concentration* (mg/l)	% Change
Herring River	HAR-7	0.567	0.479	-15.5%

*Present and threshold average total N values according to Table VIII-5 of the June 2012 MEP Draft Report for the Herring River Embayment System

Values in RED indicate that the value is above the standard and must be reduced.

Determination of site-specific nitrogen thresholds for an embayment requires integration of key habitat parameters (infauna and eelgrass), sediment characteristics, and nutrient related water quality information. Nitrogen threshold development builds on these data and links habitat quality to summer water column nitrogen levels. To determine the total loading several factors must be considered including septic system effluent flow into the watershed, natural attenuation throughout the watershed, wastewater treatment facilities recharge (if any exist), estuary flushing, stormwater sources, fertilizers applied throughout the watershed, and finally the threshold concentrations presented in the table above. The MEP evaluation of habitat quality supported by the Herring River system considers the natural structure of each system and its ability to support that habitat before determining the threshold septic load.

The primary source of nitrogen in the Herring River watershed is septic system effluent, which accounts for a majority of total and controllable nitrogen loading. For this reason, this source is the primary focus of nitrogen reduction to meet the threshold values. Overall, 38.592 kg/day, or roughly 14,086 kg/year, of attenuated nitrogen is estimated to originate from septic systems within the watershed. In order to meet threshold nitrogen loads, it is estimated that the current total septic load in the Herring River watershed would need to be reduced by 38 percent, as shown in Table 6-11.

Watershed

Herring River

Water Quality Monitoring Stations

Sentinel Station

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 1,000 feet

0 500 1,000 Feet

Figure 6-25
Herring River
Monitoring Stations

CDM Smith

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Table 6-11
Attenuated Septic Loading in the Herring River Watershed*

Sub – Embayment	Present Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease (% change)
Lower Herring River	7.063	7.063	0.00%
East Reservoir	0.047	0.047	0.00%
Upper Herring River	10.468	0.0	100%
West Reservoir	12.137	12.137	0.00%
Lothrop Road	8.877	4.504	49.3%
Total	**38.592**	**23.751**	**38.4%**

*Loading information according to Table VIII-2 of the June 2012 Draft Report for the Herring River Embayment System.

Values in RED indicate that the value is above the standard and must be reduced.

The threshold septic loading for the Herring River system is the sum of five threshold loads developed in the MEP report for the Lower Herring River, The East Reservoir, Upper Herring River, West Reservoir and the Lothrop Road sub-embayments. Together these five thresholds combine to give a total threshold septic load for the watershed. To meet the requirements of check and sentinel stations, the system will require at least 38.4% of the attenuated present septic load to be reduced

The buildout assessment performed by the MEP is a straightforward buildout assessment that considers a buildout scenario for both residential and commercial parcels throughout the studied watershed. The buildout assessment is an attempt at estimating buildout in a watershed based on current zoning and any projected changes using local input. The estimates developed for the model allows modelers to run a "what if" scenario that considers nitrogen loading associated with future development.

In the buildout projection, septic system loading also accounts for most of the controllable nitrogen in the Harbor. Thus, septic nitrogen is the primary source which is recommended to be targeted for total reduction within the contributing watershed. Overall, 56.59 kg/day, or roughly 20,655 kg/yr, total attenuated nitrogen was estimated to originate from septic systems within the watershed. This is about a 46.6% *increase* over present loads. In order to meet threshold total nitrogen loads, it is estimated that the current total septic load in the Herring River system watershed would need to be reduced by 58.0 %, as summarized in Table 6-11A below to meet the MEP established threshold.

Table 6-11A
Buildout Attenuated Septic Loading in the Herring River System

Sub – Embayment	Buildout Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load Decrease (% change)
Lower Herring River	7.781	7.063	9.23%
East Reservoir	0.0048	0.0047	2.08%
Upper Herring River	13.945	0.0	100%
West Reservoir	23.592	12.137	48.55%
Lothrop Road	11.229	4.504	59.89%
Total	**56.59**	**23.751**	**58.03%**

*Loading information according to Table VIII-2 and the MEP Loading Spreadsheets (AKA Rainbow Tables) of the June 2012 Draft Report for the Herring River Embayment System

Values in RED indicate that the value is above the standard and must be reduced.

Each communities contribution to the Herring River system is summarized below in Table 6-12. This table presents the *unattenuated* buildout nitrogen contribution from each community and the percentage of the total unattenuated load to the system.

Table 6-12
Unattenuated Buildout Septic Loading in the Herring River System by Community

Town	Unattenuated Present Septic Load (kg/day)	Unattenuated Buildout Septic Load (kg/day)	Buildout % of Total Nitrogen Load
Harwich	58.5	77.5	82.8%
Dennis	1.8	2.4	2.5%
Brewster	9.1	13.7	14.7%

*Loading information according to the MEP Loading Spreadsheets (AKA Rainbow Tables) of the June 2012 Draft Report for the Herring River Embayment System

6.4 Summary

This section summarizes the findings of the MEP investigation of the five embayments within the Town of Harwich. Conclusions from these investigations were used to develop this CWMP, including septic nitrogen loading, and reduction percentages of septic nitrogen loading required to meet established thresholds in the MEP reports. These thresholds will, upon review by the Massachusetts Department of Environmental Protection, be eventually subject to a nitrogen TMDL.

Allen Harbor

Controllable sources of nitrogen in Allen Harbor include septic discharge and residential and commercial fertilizer applications which account for approximately 86% of total nitrogen loading in the watershed. Using the MEP buildout assumptions, 6.71 kg/day, or roughly 2,449 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. Total septic loading in Allen Harbor must be reduced by 78% in order to restore ecological conditions in the Harbor and meet the MEP established threshold.

Wychmere Harbor

Controllable sources of nitrogen in Wychmere Harbor include septic discharge and residential and commercial fertilizer applications which account for approximately 83% of total nitrogen loading in the watershed. Using the MEP buildout assumptions 3.30 kg/day, or roughly 1,206 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. Total septic loading in Wychmere Harbor must be reduced by 100% in order to restore ecological conditions in the Harbor and meet the MEP established threshold.

Saquatucket Harbor

Controllable sources of nitrogen in Saquatucket Harbor include septic discharge and residential and commercial fertilizer applications which account for approximately 79% of total nitrogen loading in the watershed. Using the MEP buildout assumptions, 12.51 kg/day, or roughly 4,566 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. Total septic loading in the Saquatucket Harbor must be reduced by 58% in order to restore ecological conditions in the Harbor and meet the MEP established threshold.

Pleasant Bay

The Pleasant Bay system was modeled with the understanding that the current inlet to the Muddy Creek would be expanded to increase flushing by utilizing a larger, 24-foot opening. The modeling that was performed for the Pleasant Bay system showed that replacing the existing inlet to Muddy Creek with a 24-foot opening has little effect on the nitrogen levels throughout the Pleasant Bay System, but the wider opening results in a 20% drop in the difference between the existing conditions modeled nitrogen concentration and the threshold concentration at the Lower Muddy Creek check station. Additional nitrogen reductions are still required in the Muddy Creek watershed to meet the threshold concentration in Lower Muddy Creek, but the magnitude is reduced through the installation of the wider opening.

Controllable sources of nitrogen in the Pleasant Bay include septic discharge and residential and commercial fertilizer applications which account for approximately 75% of total nitrogen loading in the watershed. For the subwatersheds within the Harwich town boundaries, 43.90 kg/day, or roughly 16,023 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed using buildout assumptions. Septic loading in the Pleasant Bay subwatersheds in Harwich must be reduced by 65% in order to meet the MEP established threshold.

Since the Pleasant Bay system is so complex and is shared by several towns, each individual community will need to develop a mutually beneficial plan aimed at reducing excess nutrients in the sub watershed that falls within its boundaries. From a management perspective, each community will want to understand its individual contribution to these subwatersheds and develop a plan that will address their contribution to meet the established thresholds. Communities should be encouraged to develop regional solutions so that nitrogen reduction may be done in the most economical manner.

Herring River

Controllable sources of nitrogen in the Herring River watershed system include septic discharge and residential and commercial fertilizer applications which account for approximately 63% of total nitrogen loading in the watershed. Using the MEP buildout assumptions, 56.59 kg/day, or roughly 20,655 kg/yr, total nitrogen was estimated to originate from septic systems within the watershed. Since infaunal habitat is less sensitive to the effects of nitrogen enrichment than eelgrass, a reduction in the level of nitrogen to restore eelgrass is the main focus of the threshold in this system. Total septic loading in Herring River watershed must be reduced by 58.0% in order to restore ecological conditions in the estuary and meet the MEP established threshold.

Overall Septic Load Reductions Required to Meet TMDL

Table 6-13 provides a summary of the results for the MEP watersheds in Harwich and the percent wastewater nitrogen reduction that will be targeted in the development of wastewater management scenarios in later sections of this report. Table 6-13A provides a summary of the percent wastewater nitrogen reduction using the buildout assumptions developed by the MEP. These values are also based on meeting existing (highest and best use) water quality standards.

Table 6-13
Decrease in Present Attenuated Septic Loading Required to Meet Established TMDL Thresholds

MEP Watershed	Present Septic Load (kg/day)	Threshold Septic Load (kg/day)	Septic Load Decrease to Meet Threshold (% change)	Shared Communities
Allen Harbor	5.64	1.483	74%	None
Wychmere Harbor	3.208	0.00	100%	None
Saquatucket Harbor*	13.246	5.280	60%	None
Pleasant Bay (Round Cove)	5.18	1.87	64%	Brewster, Chatham, Orleans
Pleasant Bay (Muddy Creek)*	13.32	6.89	48%	
Pleasant Bay	16.69	6.51	61%	
Herring River	38.592	23.751	38%	Dennis, Brewster

*Saquatucket Harbor and Muddy Creek Loads include Enhanced Attenuation

Values in RED indicate that the value is above the standard and must be reduced.

Table 6-13A
Decrease in Buildout Attenuated Septic Loading Required to Meet Established TMDL Thresholds

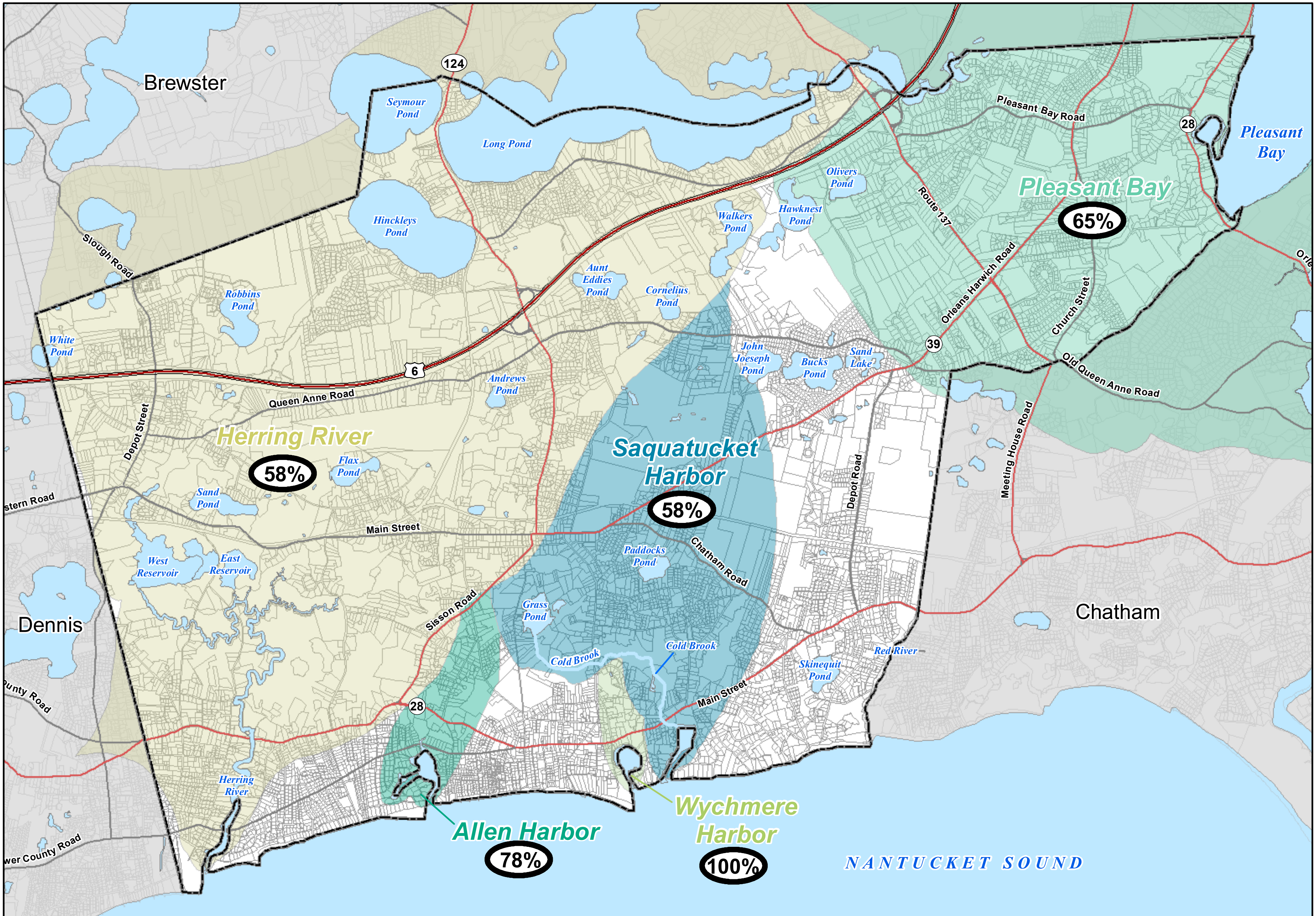
MEP Watershed	Buildout Septic Load (kg/day)	Threshold Septic Load (kg/day)	Septic Load Decrease to Meet Threshold (% change)	Shared Communities
Allen Harbor	6.71	1.483	78%	None
Wychmere Harbor	3.30	0.00	100%	None
Saquatucket Harbor*	12.51	5.28	58%	None
Pleasant Bay (Round Cove)	5.78	1.87	68%	Brewster, Chatham, Orleans
Pleasant Bay (Muddy Creek)*	16.28	6.89	58%	
Pleasant Bay	21.84	6.51	70%	
Herring River	56.59	23.751	58%	Dennis, Brewster

*Saquatucket Harbor and Muddy Creek Loads Include Enhanced Attenuation

Values in RED indicate that the value is above the standard and must be reduced.

See Figure 6-26 for the total buildout percent reduction required for each MEP watershed in Harwich.

Since the Pleasant Bay and the Herring River embayment systems are shared by several towns, each individual community will need to develop a mutually beneficial plan aimed at reducing excess nutrients in the subwatersheds that fall within its boundaries. From a management perspective, each community will want to understand its individual contribution to each subwatershed and develop a plan that will address their contribution and ultimately meet the established TMDL. Regional solutions should be encouraged.



Legend

Watersheds

- Allens Harbor
- Herring River
- Pleasant Bay
- Saquatucket Harbor
- Wychmere Harbor
- 78% Septic Load Decrease to Meet Threshold

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 4,000 feet

0 1,000 2,000 4,000 Feet

Figure 6-26

Watershed Septic Load Reductions

CDM Smith

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