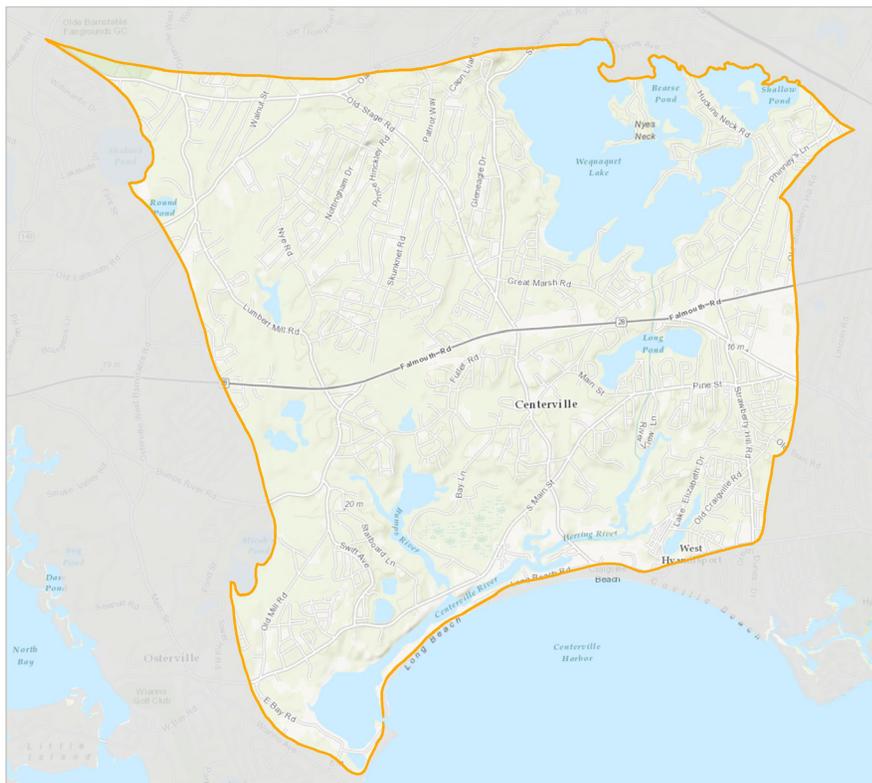
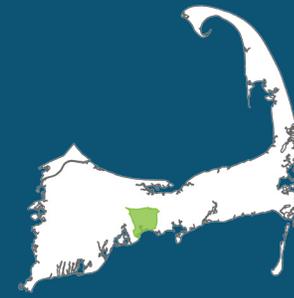


# Centerville River

BARNSTABLE

WATER THREAT LEVEL  
**MODERATE**



Centerville River Watershed

## Introduction to the Watershed Reports

In 2001, the Massachusetts Estuaries Project (MEP) was established to evaluate the health of 89 coastal embayment ecosystems across southeastern Massachusetts. A collaboration between coastal communities, the Massachusetts Department of Environmental Protection (MassDEP), the School of Marine Science and Technology (SMAST) at the University of Massachusetts-Dartmouth, the US Environmental Protection Agency (US EPA), the United States Geological Survey (USGS), the Massachusetts Executive Office of Energy and Environmental Affairs (EEA), and the Cape Cod Commission, the purpose of the MEP is to identify nitrogen thresholds and necessary nutrient reductions to support healthy ecosystems.

The Cape Cod 208 Plan Update, certified and approved by the Governor of the Commonwealth of Massachusetts and the US EPA in 2015, provides an opportunity and a path forward to implement responsible plans for the restoration of the waters that define Cape Cod.

On Cape Cod there are 53 embayment watersheds with physical characteristics that make them susceptible to nitrogen impacts. In its 2003 report, “The Massachusetts Estuaries Project – Embayment Restoration and Guidance for Implementation Strategies”, MassDEP identifies the 46 Cape Cod embayments included in the

MEP. Thirty-three embayments studied to date require nitrogen reduction to achieve healthy ecosystem function. A Total Maximum Daily Load (TMDL) has been established (or a draft load has been identified and is under review) for these watersheds. For those embayments not studied, the 208 Plan Update recommends planning for a 25% reduction in nitrogen, as a placeholder, until information becomes available.

The 208 Plan Update directs Waste Treatment Management Agencies (WMAs) to develop watershed reports within 12 months of certification of the Plan Update. The Watershed Reports outline potential “bookend” scenarios for each watershed that include two scenarios to meet water quality goals in the watershed – a traditional scenario, which relies completely on the typical collection and centralized treatment of wastewater, and a non-traditional scenario, which uses remediation, restoration, and on-site reduction techniques to remove nutrients from raw and treated wastewater, groundwater and affected waterbodies.

The intent of the Watershed Reports is to outline two distinct approaches for addressing the nutrient problem. The reports are not intended to identify preferred and detailed plans for each watershed, but to facilitate discussions regarding effective and efficient solutions, particularly in watersheds shared by more than one town. In some cases, towns have provided information on collection areas and non-traditional technologies that have been specifically considered by that town.

The 208 Update developed a regionally consistent database of the nitrogen load entering each watershed. This data set includes estimates of wastewater, stormwater and fertilizer loads - similar to methodologies used by the MEP. Using this regionally consistent database, the Watershed MVP tool (wMVP) was developed so that different strategies (i.e., bookend scenarios) to reduce excess nitrogen load

could be evaluated. The Watershed Reports use the MEP recommendations for the required nitrogen load reductions necessary to meet the threshold loads (that serve as the basis for nitrogen management), and then use the wMVP and the regionally consistent database values to develop bookend scenarios. There are variations of load between the MEP and wMVP, primarily due to differences in comparing older and newer databases.

## Terms Defined

**Total nitrogen load:** the nitrogen load from the watershed contributed by septic, wastewater, fertilizer, stormwater, golf course, landfill, and natural sources.

**Attenuated nitrogen load:** the nitrogen load from the watershed that reaches the embayment after the effect of natural attenuation in wetlands, ponds or streams.

**Threshold:** the amount of nitrogen that a water body can receive from its watershed and still meet water quality goals; this number is based on MEP technical reports or Total Maximum Daily Load (TMDL) reports.

**Reduction target:** an approximation of the amount of nitrogen that needs to be removed from the watershed to achieve the threshold; this number is calculated by subtracting the threshold number from the attenuated total watershed load, and is for planning purposes only.

**Percent contribution:** the percent of attenuated nitrogen load that a town contributes to the watershed.

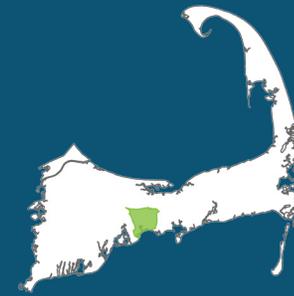
**Kilogram responsibility:** is calculated by applying the percent contribution to the reduction target and indicates the amount of nitrogen, in kg, that a community is responsible for addressing.

**Total Maximum Daily Load:** a regulatory term in the Clean Water Act, describing a value of the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. Establishing a TMDL is necessary when a water body has been listed on the 303D list of impaired waters.

# Centerville River

BARNSTABLE

WATER THREAT LEVEL  
**MODERATE**



The Centerville River estuary and embayment system is located wholly within the Town of Barnstable. It is comprised of a number of sub-basins, such as East Bay and Scudder Bay/Bumps River and supports a variety of recreational uses including boating, swimming, shell fishing and fin fishing.

## The Problem

The Massachusetts Estuaries Project (MEP) technical report (available at <http://www.mass.gov/eea/agencies/massdep/water/watersheds/the-massachusetts-estuaries-project-and-reports.html>) indicates that the Centerville River system exceeds its critical threshold for nitrogen, resulting in impaired water quality. A MEP technical report has been completed and a Total Maximum Daily Load (TMDL) for nitrogen has been developed and approved.

- **MEP TECHNICAL REPORT STATUS:** Final
- **TMDL STATUS:** Final TMDL

Watershed nitrogen load characteristics were published in the 2006 MEP report for Centerville River, reflecting current conditions at the time of writing:

- **TOTAL ATTENUATED NITROGEN LOAD:** 48,245 Kg/Y (MEP Chapter VIII)
- **SOURCES OF ATTENUATED WATERSHED NITROGEN LOAD:**
  - 87% Septic Systems
  - 6% Fertilizer
  - 7% Stormwater From Impervious Surfaces

Since the MEP report, the Commission compiled the following updated water use and nitrogen loads using the regional wMVP

database, enabling a more current estimate of nitrogen loading (see figure on page 1 for watershed boundary delineation):

- **TOTAL WASTEWATER FLOW:** 427 MGY (million gal per year)
  - Treated Wastewater Flow: 4 MGY
  - Septic Flow: 423 MGY
- **TOTAL ATTENUATED NITROGEN LOAD (wMVP):** 44,573 Kg/Y

## CONTRIBUTING TOWNS

Percent contributions listed below are the aggregate sub-embayment contributions identified in Appendix 8C of the Cape Cod Section 208 Plan Update (contributions are based on attenuated load where available). See Appendix 8C for detailed town allocations by sub-embayment.

- **BARNSTABLE:** 100%

## THE MEP RESTORATION SCENARIO:

- **WATERSHED TOTAL NITROGEN REDUCTION TARGET:** 28%
- **WATERSHED SEPTIC REDUCTION TARGET:** 34% (The scenario represents the aggregated sub-embayment percent removal targets from the MEP technical report)

## CENTERVILLE RIVER ESTUARY

- **EMBAYMENT AREA:** 218 acres
- **EMBAYMENT VOLUME:** 39.8 million cubic feet
- **2014 INTEGRATED LIST STATUS:** Category 4a
  - Bumps River: fecal coliform
  - Centerville River: fecal coliform, estuarine bioassessments and nitrogen
  - Category 4a, TMDL is completed
  - [www.mass.gov/eea/docs/dep/water/resources/07v5/14list2.pdf](http://www.mass.gov/eea/docs/dep/water/resources/07v5/14list2.pdf)

## CENTERVILLE RIVER WATERSHED

General watershed characteristics according to the current wMVP regional database (see figure on page 1 for watershed boundary) follow.

- **WATERSHED CHARACTERISTICS**
  - Acres: 6,739
  - Parcels: 7,491
  - % Developed Residential Parcels: 88%
  - Parcel Density: 0.9 acres per parcel

## Freshwater Sources

### PONDS

- **IDENTIFIED SURFACE WATERS:** 39
- **NUMBER OF NAMED FRESHWATER PONDS:** 14
- **PONDS WITH PRELIMINARY TROPIC CHARACTERIZATION:** 8
- **2014 INTEGRATED LIST STATUS:** 6 ponds listed in Category 5 requiring a TMDL.

Three ponds within the adjacent Three Bays watershed (Shubael Pond, Micahs Pond and Joshuas Pond) also

contribute to Centerville River. The recent comprehensive wastewater management plan (CWMP) included the preparation of a Pond Action Report.

Yarmouth has participated in the Pond and Lake Stewardship (PALS) program that has helped establish baseline water quality.

### STREAMS

- **SIGNIFICANT FRESHWATER STREAM OUTLETS:** 4
  - Skunknett River:
    - Average Flow: 13,925 cubic meters per day (m3/d)
    - Average Nitrate Concentrations: 1.113 milligrams per liter (mg/L)
  - Bumps River:
    - Average Flow: 5,679 m3/d
    - Average Nitrate Concentrations: 2.207 mg/L
  - Long Pond Stream:
    - Average Flow: 6,518 m3/d
    - Average Nitrate Concentrations: 0.199 mg/L
  - Lake Elizabeth:
    - Average Flow: 1,547 m3/d
    - Average Nitrate Concentrations: 0.937 mg/L

Stream data from MEP technical report. Nitrate concentrations higher than 0.05 mg/L background concentrations, evident in public supply wells located in pristine areas, provide evidence of the impact of non-point source pollution on the aquifer and receiving coastal water bodies.

## DRINKING WATER SOURCES

- **WATER DISTRICTS:** 2
  - Hyannis Water District
  - Centerville-Osterville-Marstons Mills (COMM) Water District
- **GRAVEL PACKED WELLS:** 6
  - 1 has nitrate concentrations between 1 and 2.5 mg/L
  - 5 have nitrate concentrations between 2.5 and 5 mg/L
- **SMALL VOLUME WELLS:** 0

Drinking water data from Cape Cod Commission and MassDEP data sources – nitrate values obtained from drinking water wells are from 2009-2012. The state and federal drinking water limit for nitrate is 10 mg/L. The Cape Cod Commission nitrate loading standard is 5 mg/l.

## Degree of Impairment and Areas of Need

For the purposes of the 208 Plan Update, areas of need are primarily defined by the amount of nitrogen reduction required as defined by the TMDL and/or MEP technical report. For the Centerville River, this amount is 34% of the septic load or 28% of the total attenuated nitrogen load. The MEP technical report also provides a specific targeted amount of nitrogen reduction required by subwatershed, (see the figures: Subwatersheds with Total and Septic Attenuated Nitrogen Removal Targets).

The nitrogen load from the watershed exceeds the threshold for the Centerville River, resulting in impaired water quality. Lower portions of Centerville River have generally good water quality supported by tidal flushing and significant attenuation to contributing areas, while the upper reach of Centerville

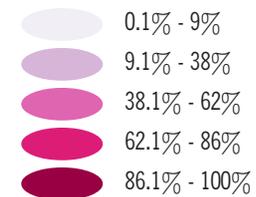
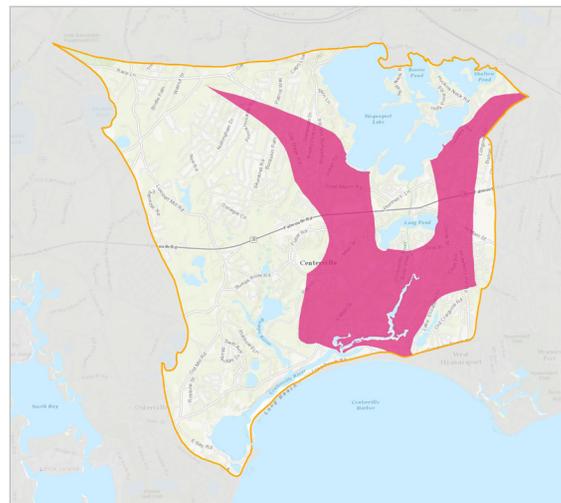
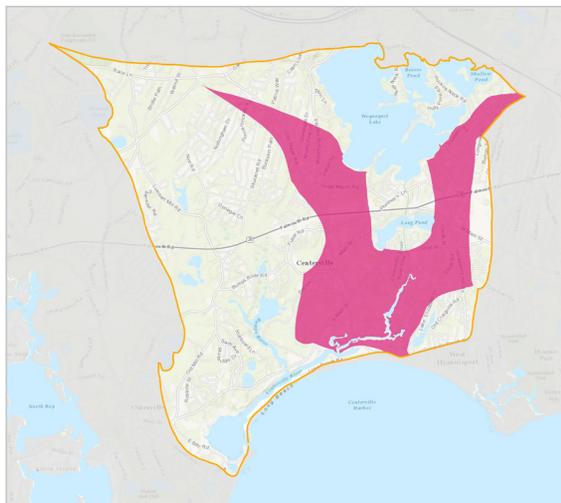
River, Centerville River East, has decreased water quality. The ecological health of a water body is determined from water quality, extent of eelgrass, assortment of benthic fauna, and dissolved oxygen and ranges from severe degradation, significantly impaired, moderately impaired, or healthy habitat conditions.

### ECOLOGICAL CHARACTERISTICS AND WATER QUALITY

The MEP report provides the following characterization of the estuary’s health:

- **OVERALL ECOLOGIC CONDITION:** Healthy to Significantly Impaired
- **UPPER CENTERVILLE RIVER:** Healthy
- **MID CENTERVILLE RIVER:** Healthy to Moderately Impaired

- **LOWER CENTERVILLE RIVER:** Healthy to Significantly Impaired
- **EAST BAY:** Moderately to Significantly Impaired
- **BUMPS RIVER:** Healthy
- **SCUDDER BAY:** Moderately Impaired
- **SENTINEL STATION:**
  - Total Nitrogen Concentration Threshold: 0.37 mg/L
  - Total Nitrogen Concentration Existing: 0.41 mg/L (As reported at the MEP sentinel water-quality monitoring station.)



**Subwatersheds with Total Attenuated Watershed Removal Targets**

(Left) Benthic and atmospheric loads directly on embayments are not included.

**Subwatersheds with Septic Attenuated Nitrogen Removal Targets**

(Right)

## Traditional & Non-Traditional Scenarios

### SCENARIO DEVELOPMENT

Through the 208 Stakeholder process, the Commission developed “bookend” scenarios – one looking at a possible solution using traditional collection and treatment, the other examining a possible suite of non-traditional technologies – to address the nitrogen management needs in each watershed. These bookend scenarios provide guidance for communities as they continue to discuss alternatives, priorities, and opportunities for identifying well-considered solutions that will address communities’ needs and interests.

### REGIONAL DATA

In preparation for this effort, the Commission collected regionally consistent data for the purposes of watershed scenario development. Both parcel data and water use data was identified and collected for the entire region. While the scientific basis for planning is the thresholds identified in the MEP technical reports, each report uses data from different years, and in some cases the MEP data used are 10 or more years old. In addition, there are watersheds on Cape Cod without the benefit of an MEP report; therefore, similar data was not available for planning purposes.

The updated regional data set was used to estimate wastewater, stormwater and fertilizer loads, using the same methodologies as the MEP. This approach allows for a reevaluation of existing development, which may have changed

in the last 10 years. Parcel data included in the regional database is from 2010-2012 and water use data is from 2008-2011, depending on the water supplier and based on best available data. This approach allows for regionally consistent watershed scenario development.

### WATERSHED SCENARIOS

The watershed scenarios that follow outline possibilities for the watershed. A series of non-traditional technologies that might be applicable are included, as well as the amount of residential load that would need to be collected if a traditional collection system and treatment facility was implemented. The pie charts show the load to be collected for treated effluent disposal both inside and outside the watershed.

Site specific analyses of collection areas may result in the need to collect wastewater from more or fewer parcels to meet the nitrogen reduction target. The scenarios presented are conceptual and are meant to inform discussions regarding effective and efficient solutions; they are not specific recommendations and should be viewed as resource information for additional and more detailed wastewater management planning.

In Centerville River, the Town of Barnstable has done additional and more detailed planning. Included in the last section of this report is a description of their efforts, along with details of plans developed to date.

#### TOTAL ATTENUATED WATERSHED NITROGEN LOAD VALUES (FROM WMVP)

Centerville River Nitrogen Sources	Total Attenuated Watershed Nitrogen Load (kg-N/yr)
Wastewater <sup>1</sup>	36,000
Fertilizer <sup>2</sup>	3,166
Stormwater	4,475
Other <sup>3</sup>	932
<b>TOTAL WATERSHED LOAD</b>	<b>44,573</b>
Total Watershed Threshold	34,833
<b>TOTAL ATTENUATED LOAD TO BE REMOVED</b>	<b>9,740</b>

1. Includes nitrogen loads from septic systems and wastewater treatment facilities.
2. Includes nitrogen loads from lawns, cranberry bogs, and golf courses.
3. Includes nitrogen loads from landfills and atmospheric deposition to vacant land.

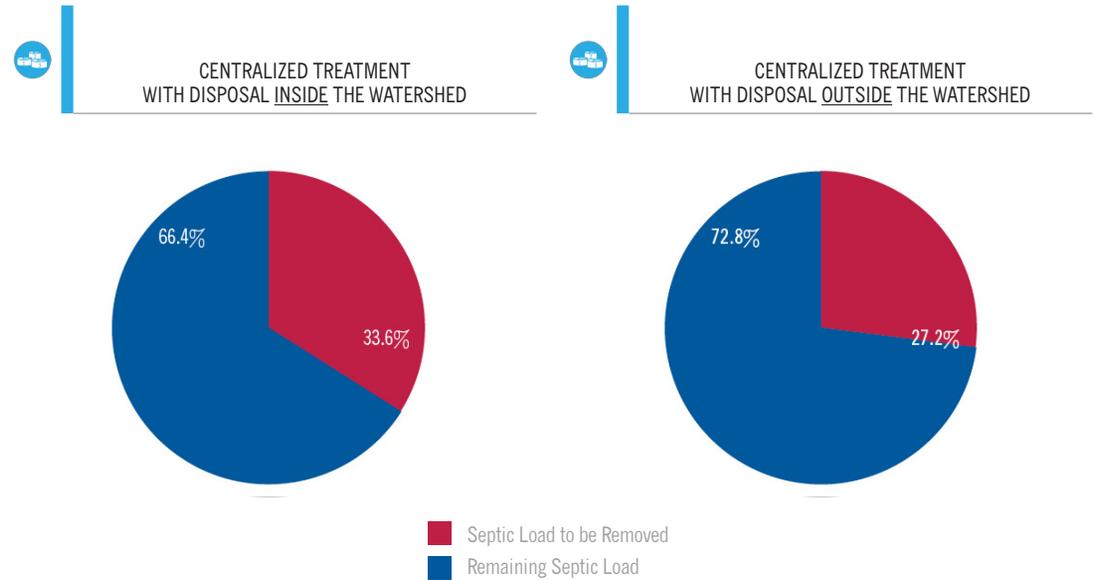
## Traditional & Non-Traditional Scenarios

### Non-Traditional

UNIT OF APPLIED TECHNOLOGY	ATTENUATED NITROGEN REMOVED IN KG/Y
 25 % Nitrogen Reduction - Fertilizer Management	792
 25 % Nitrogen Reduction - Stormwater Mitigation	1,119
 6 Acres - Constructed Wetlands (Collection System)	3,000
 5,600 Linear Feet - Permeable Reactive Barrier (PRB) (Capture load calculated by wMVP: 6,863.4 kg/Y)	4,976
 150 Acres - Fertigation - Turf	600
 9 Acres - Aquaculture/Oyster Beds	2,200
 1,285 People Per Year - UD School or Public Facility	600
<b>TOTAL</b>	<b>13,287</b>

A summary of the approach and methodology that was applied using non-traditional technologies follows at the end of this report.

### Traditional



Assumes load to be collected and treated is disposed in the watershed, requiring additional collection to offset the load.

Assumes that the load to be collected and treated is removed from the watershed so no offset is required.

## Town of Barnstable Local Progress

The Cape Cod Commission and the Town of Barnstable met and discussed the use of WatershedMVP to evaluate targeted watershed approaches for each of the watersheds in which they have jurisdiction. In 2015, the town reformulated its Citizen's Advisory Committee (CAC) for wastewater planning to better address local needs. In addition to local participation, the newly formed committee (the Water Resources Advisory Committee or WRAC) includes state and regional representatives. Town staff provided modifications to Commission-developed watershed scenarios and presented those scenarios to their WRAC for review and discussion. Those scenarios are included in this report.

Barnstable is also working closely with Mashpee and Sandwich on a watershed permit for the Popponesset Bay watershed.

The Town of Barnstable operates the Hyannis Water Pollution Control Facility (WPCF), located off Bearses Way in Hyannis, which is the primary wastewater treatment facility serving approximately 2,900 properties in Hyannis and Barnstable village. The treatment facility has been upgraded and permitted to treat additional flows up to a total of 4.2 million gallons per day (MGD), upon meeting requirements of an adaptive management plan approved by the Commission in 2007. Property along Route 132 was acquired by the town in 2002 to potentially accommodate future disposal needs. The site is approved under a 2006 Massachusetts Environmental Policy Act (MEPA) certificate to discharge up to 0.5 MGD. The site is not presently in use. However, a force main and sewer has been extended to the site from the WPCF.

The WPCF treats an average daily flow of 1.46 MGD and a maximum monthly average flow of 1.94 MGD. Treatment performance has averaged 5 milligrams per liter (mg/L) total nitrogen in the treated effluent and the facility has a discharge limit of 5 mg/L under the 2007 Development of Regional Impact (DRI) decision and a limit of 10 mg/L under a Groundwater Discharge Permit (GWDP). The facility is also equipped with sludge thickening, storage and dewatering facilities sized for the current process conditions.

The Town of Barnstable also operates two smaller facilities – the Marstons Mills Wastewater Treatment Facility (WWTF) and the Red Lily Pond Cluster System. The Marstons Mills WWTF is limited to a discharge flow of 42,900 gallons per day (GPD) and is intended to service the Barnstable United Elementary School and the Village at Marstons Mills affordable housing development. The Red Lily Pond Cluster System currently serves 17 homes. According to the comprehensive wastewater management plan (CWMP) approved in 2007, no performance sampling of the system occurs and the system is assumed to produce comparable effluent to any conventional single family septic system.

In addition to municipally-owned facilities, there are two privately-owned treatment facilities treating wastewater from the Cotuit Landing shopping plaza and the Cape Regency nursing and rehabilitation facility. These facilities provide high levels of wastewater treatment. The treatment facility at Cotuit Landing was designed with additional treatment capacity beyond the expected needs of the shopping plaza for potential treatment of flows from neighboring properties.

Barnstable is working on a town-wide nutrient management plan that will provide the basis of its CWMP. The plan will address nitrogen and other needs in watersheds draining to Three Bays, Centerville River, and Lewis Bay. A nitrogen total maximum daily load (TMDL) for Barnstable Harbor has not been approved by US EPA. The MEPA certificate scope for the Final Environmental Impact Report (FEIR) includes engagement in a targeted watershed approach, consistent with the 208 Plan Update.

In the fall of 2014, Barnstable adopted local nitrogen-oriented fertilizer management regulations consistent with the Cape-wide Fertilizer Management District of Critical Planning Concern (DCPC).

In 2015, the Town submitted a Statement of Interest to the US EPA for a hydrogeologic site characterization as an initial step toward piloting a permeable reactive barrier in the town. One of three sites proposed by the Town was selected for characterization. The work was completed in 2016. The draft report is presently being reviewed by the Town.

In June 2016, Barnstable received \$28,850 from the Commission to fund upgrades to three stormwater treatment BMPs. Funding was part of \$142,149 in local grants made available to communities by the Commission in support of 208 Plan implementation.

## Town of Barnstable Watershed Scenario Details

Centerville River	CREDITS		REDUCTION TECHNOLOGIES			REMEDICATION AND RESTORATION TECHNOLOGIES			REMOVAL	
	NAME OF TECHNOLOGY	% Nitrogen Reduction	Load Reduction (kg-N/yr)	# Properties / Units	Flow Collected (gpd)	Load Reduction (kg-N/yr)	# Units Proposed	Unit Metric	Load Reduction (kg-N/yr)	Total Scenario Load Reduction (kg-N/yr)
Traditional Scenario										15,256
Centralized Sewer				3,183	491,518	15,256				
Non-Traditional Scenario										15,059
Fertilizer Management	25%	764								
Stormwater Mitigation	25%	1,119								
Constructed Wetlands (No Collection System)							6 Acres		3,000	
Permeable Reactive Barrier (PRB)							9,952 Linear Feet		4,976	
Fertigation - Turf							143 Acres		600	
Aquaculture/Oyster Beds							9 Acres		2,200	
Floating Constructed Wetlands							9,000 Square Feet		1,800	
Ecotoilets (UD & Compost)				140 Units		600				

# Scenario Maps

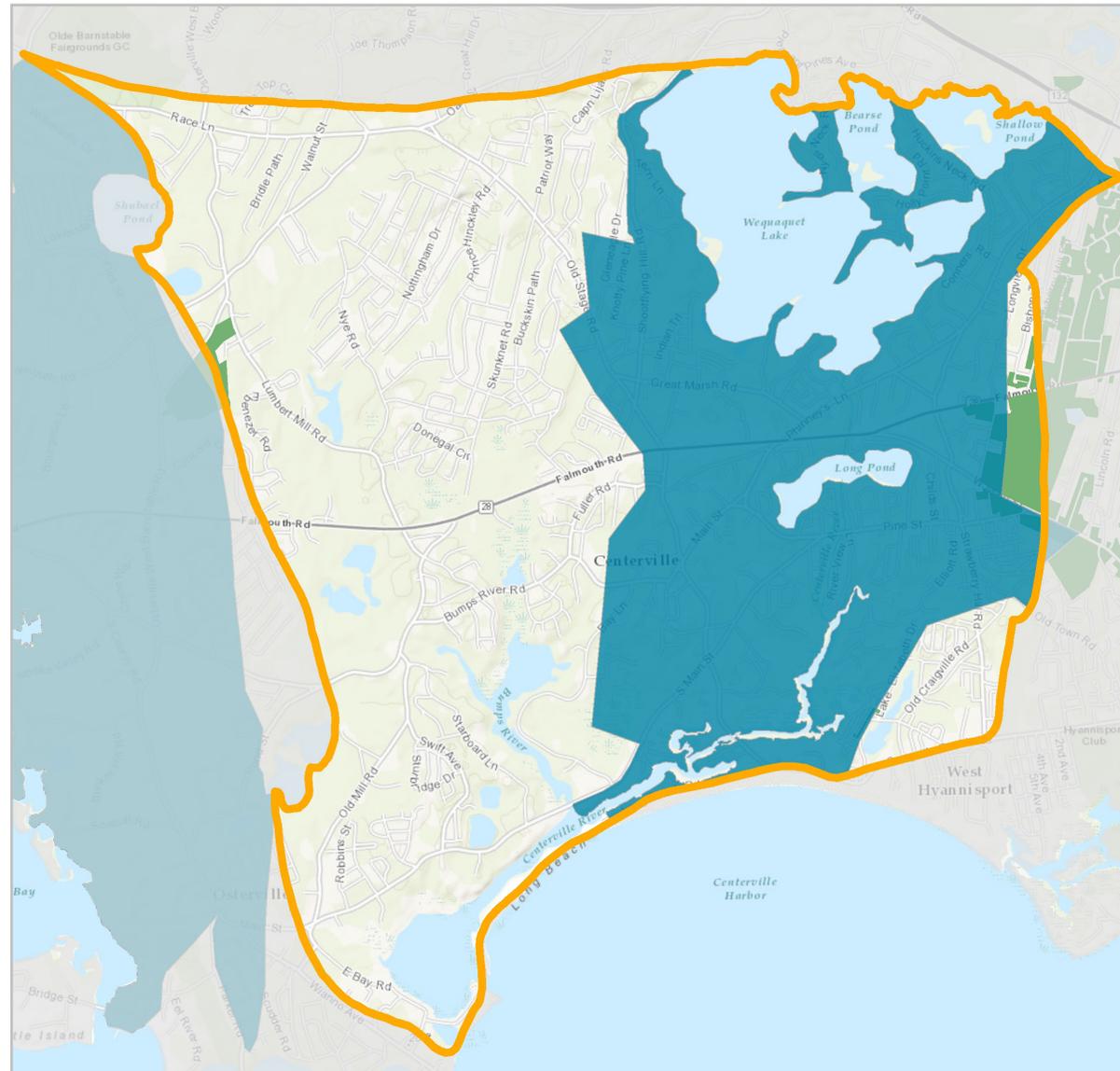
## Centerville River Watershed Traditional Scenario

**BARNSTABLE**

Representative locations of conceptually proposed infrastructure

### Legend

-  Town Lines
-  Sewered Areas
-  Embayment Watersheds
-  Proposed Sewershed



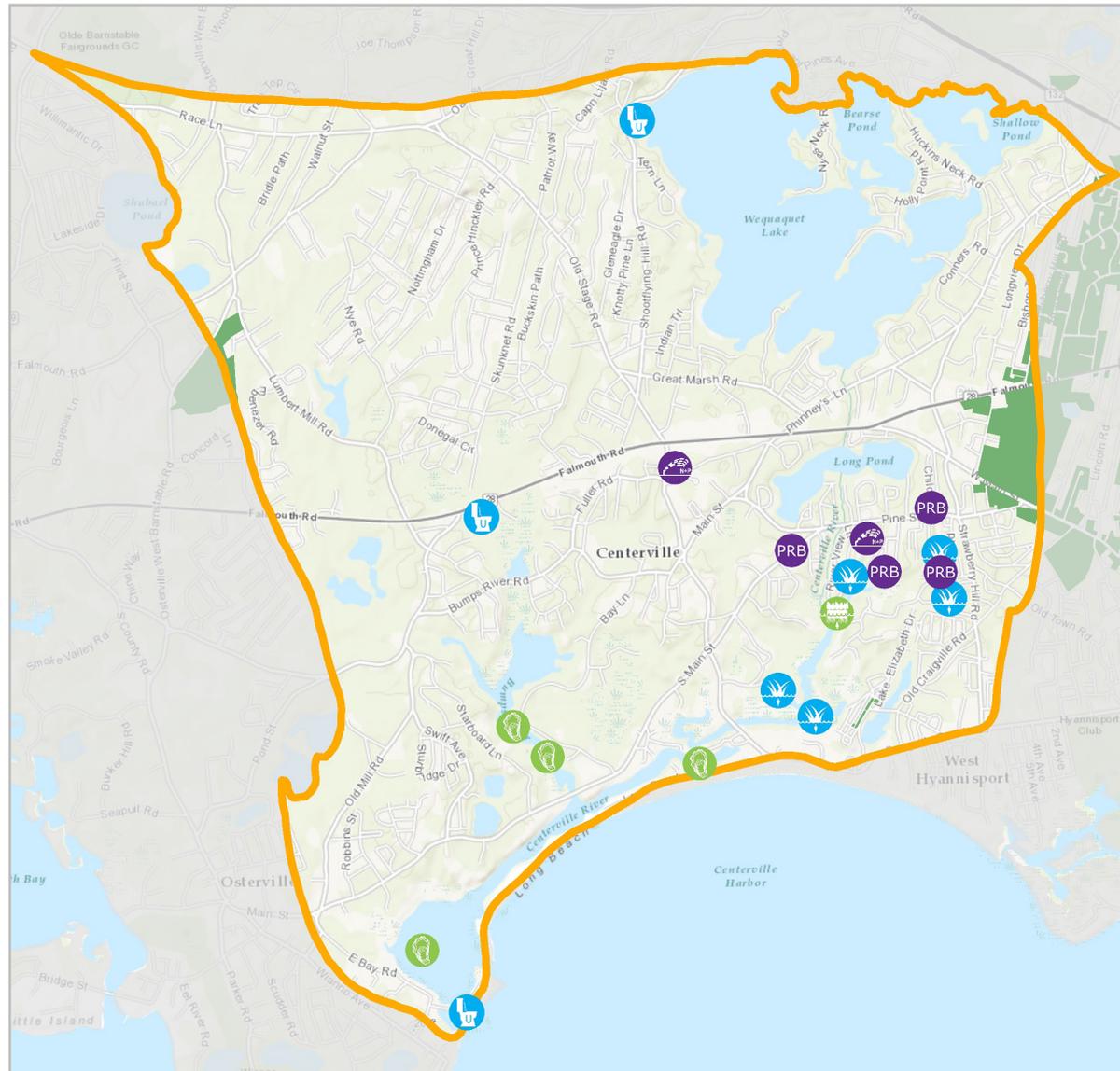
# Scenario Maps

## Centerville River Watershed Non-Traditional Scenario BARNSTABLE

Representative locations of conceptually proposed infrastructure

### Legend

-  Eco-Toilets
-  Fertigation
-  Floating Constructed Wetlands
-  Constructed Wetland
-  Permeable Reactive Barrier
-  Aquaculture
-  Town Lines
-  Embayment Watersheds
-  Sewered Areas



## Methodology for Selecting Non-Traditional Technology Scenarios

This section summarizes the approach and methodology that was applied during the 208 Update to develop plans for reducing nitrogen loading to estuaries using non-traditional (NT) technologies. It includes descriptions of regional credits for stormwater and fertilizer reductions, regional screening for potential sites for several technologies, and site-specific analyses for others. Nitrogen attenuation rates for each technology were derived from the Technologies Matrix. The nitrogen thresholds for each embayment were determined from the Massachusetts Estuaries Project (MEP).

This section summarizes the approach and methodology that was applied during the 208 Update to develop plans for reducing nitrogen loading to estuaries using non-traditional (NT) technologies. It includes descriptions of regional credits for stormwater and fertilizer reductions, regional screening for potential sites for several technologies, and site-specific analyses for others. Nitrogen attenuation rates for each technology are noted below, based on the Technologies Matrix or newer data. The nitrogen thresholds for each embayment were determined from the Massachusetts Estuaries Project (MEP).

Regional credits were developed for potential stormwater retrofits and fertilizer reductions. They were calculated as a percent reduction of existing nitrogen loads as identified in the MEP reports and updated GIS data developed by the Cape Cod Commission.

- **STORMWATER MANAGEMENT:** Most Cape communities have already begun the process of identifying significant untreated stormwater discharges and developing appropriate mitigation projects. With the prospect of the MS4 regulatory requirements it was assumed that additional mitigation efforts would be implemented. Based upon the evidence developed by the University of New Hampshire Stormwater Center that several vegetated stormwater management practices (including bioretention and constructed wetlands) are able to achieve nitrogen reductions of 50% or more and the assumption that only a portion (estimated at 50%) of identified sites would be retrofitted a 25% nitrogen reduction credit was assumed for each watershed. Specific locations and number of locations were not identified; this was deferred to individual towns to consider as part of the suite of nitrogen management strategies.
- **FERTILIZER REDUCTIONS:** Based upon the success of most Cape Cod towns to implement either regulatory or non-regulatory fertilizer management programs and the efforts of the Cape Cod Extension Service in

educating homeowners a 25% reduction in fertilizer applications was assumed for each watershed.

Regional GIS screening methods were developed to identify locations for some non-traditional technologies. A GIS viewer was developed as an on-line tool for staff and consultants to utilize during the watershed planning process.

- **CONSTRUCTED WETLANDS/ PHYTOREMEDIATION:** A GIS-based screening method was developed by the Cape Cod Commission to identify and rank parcels of land that have potential for the location of constructed wetlands and phytoremediation. The ranking utilized parcel size and ownership, depth to groundwater, suitable soils, distance from wetlands, and undeveloped parcels. A nitrogen removal rate of 500 kg/Y/acre and 532 kg/Y/acre was used for Constructed Wetlands and Phytoremediation, respectively.
- **PERMEABLE REACTIVE BARRIERS (PRBS):** A GIS-based screening method was developed to identify existing roads that are proximate to receiving waters, downgradient of high density development, run perpendicular to groundwater flow (to have the highest potential to intercept nutrients in groundwater), and where the depth to groundwater is relatively shallow to maximize the area of saturated thickness treated in the aquifer.

## Methodology for Selecting Non-Traditional Technology Scenarios

■ **FERTIGATION WELLS:** Golf courses were mapped to identify areas where fertigation wells could be utilized to recapture nitrogen-enriched groundwater and re-apply it to the managed turf areas to serve both irrigation and fertilization needs. Most golf courses were assumed to be eighteen holes with a fertilized area of 75 acres. Fertigation water was assumed to have an average concentration of 5 mg/liter. An uptake/attenuation rate of 80% was applied resulting in an assumed nitrogen reduction of 300 kg/year for each golf course with effectively located fertigation wells. In some cases other irrigated areas (such as athletic fields and cemeteries) were identified as potential fertigation locations. A nitrogen removal rate of 4 kg/Y/acre was used.

The MVP tool and other site-specific tools were utilized to quantify nitrogen load reductions for several potential NT interventions.

■ **PERMEABLE REACTIVE BARRIERS:** for each PRB that was identified during the prior GIS-screening process an approximate capture area was identified using available water table maps and the wMVP tool. Upgradient contributing areas were digitized within wMVP and the nitrogen load was calculated. A nitrogen reduction of 72.5% was applied (calculated as an average of the reported attenuation range from the Technologies Matrix).

■ **CONSTRUCTED WETLANDS (WITH COLLECTION):** Constructed wetlands were considered as a tertiary, polishing treatment for existing wastewater treatment plants. This included small-scale wastewater treatment systems. A nitrogen removal rate of 500 kg/Y/acre was used.

■ **AQUACULTURE/OYSTER REEFS:** Potential areas for aquaculture and/or oyster reef restoration were considered based upon discussions with town representatives and review of maps to identify potential areas for these operations without significant conflicts to navigation. In some cases actual recent aquaculture expansions were included where they were developed after the MEP reports were prepared. An assumption of 1 million oysters per acre was used with a nitrogen removal rate of 250 kg/Y/acres.

■ **FLOATING CONSTRUCTED WETLANDS:** Potential areas for floating wetlands were considered in areas where no conflicts with navigation or swimming areas were identified. A nitrogen removal rate of 0.4 kg/Y/sq foot was used.

■ **INLET WIDENING AND COASTAL HABITAT RESTORATION:** Only considered in areas where these projects were identified by towns or state agencies and where detailed hydrologic investigations and modeling had been performed due to wide variations in nitrate load reduction, flushing impacts, impacts on flooding, and costs (dredging only, replacing infrastructure,

removing and replacing roadways or bridges, etc.). Nitrogen removal rates were based on MEP or other studies.

■ **INNOVATIVE & ALTERNATIVE SEPTIC SYSTEMS AND ECOTOILETS:** In most cases specific locations for these technologies were not identified. Rather general estimates for the percent adoption were provided based upon discussions with the stakeholder groups and their views on potential adoption rates. In some watersheds a 5% adoption rate was included based upon this stakeholder input. In a limited number of instances specific locations for these technologies were included based upon town input and suggestions. A nitrogen removal rate of 1.658 kg/Y for each system was used for I&A Septic Systems, and 2.984 kg/Y for enhanced I&A systems. A removal rate of 2.542 kg/Y was used for each home installation of an Ecotoilet, and 0.467 kg/Y for installation of urine diversion toilets in public settings.

Finally, the locations of specific technologies were discussed during the 208 stakeholder engagement process. Stakeholders across the Cape 'groundtruthed' potential NT locations and NT scenarios were adjusted accordingly.

