CAPE COD COMMISSION

2020 REGIONAL TRANSPORTATION PLAN

Technical Appendix I: Stormwater Management

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Technical Appendix I: Stormwater Management

Stormwater runoff is caused by precipitation from rain and snowmelt events which flow over land or impervious surfaces and is unable to percolate into the ground. In natural systems, precipitation may be directly infiltrated subsurface, stored in natural depressions, or reintroduced to the atmosphere through evapotranspiration. However, development such as buildings, roads, sidewalks, and paved driveways increases impervious surface area and alters natural hydrology. The increase in impervious cover that accompanies development results in two main issues related to stormwater: 1) greater volume and peak flows of runoff and 2) transportation of contaminants into water bodies.

In natural ecosystems, runoff is infiltrated into groundwater and discharged to freshwater streams, ponds, lakes, rivers and marine estuaries. Flooding is less significant in these natural systems because greater volumes of stormwater are able to infiltrate through the soil, passing it from the surface to the groundwater. In urbanized areas, dense impervious cover reduces the amount of infiltration that can occur. The increase in stormwater runoff volume results in increased ponding, flooding, and hydroplaning potential on roadways, which makes roadways unsafe for travel.

Stormwater runoff flushes pollutants and debris from impervious areas and discharges them to local waterways. Common pollutants found in stormwater runoff include oil; grease and metals from vehicular traffic; salts and other deicing agents used to maintain safe roadway operation under winter weather conditions; pesticides and fertilizers from landscaping activities; sediments from various activities; altered water temperatures and litter. When conveyed by stormwater runoff these pollutants impair waterways, degrade natural habitat, pollute groundwater, increase flooding, cause erosion of streambeds or siltation of waterways, and decrease the amount of water recharged to aquifers. Transported by stormwater runoff, pollutants find their way into the ground and surface waters throughout Cape Cod. These waters with increased pollutant loads ultimately discharge to coastal embayments.

STORMWATER MANAGEMENT CHALLENGES ON CAPE COD

What makes Cape Cod a unique area for stormwater management is the combination of highly porous native soils left by the retreating glaciers and shallow groundwater levels, which are especially prevalent in coastal communities. Well-drained soils readily infiltrate runoff, providing excellent volume reduction of stormwater. However, the combination of highly permeable soils and a high water table results in rapid infiltration of contaminated stormwater runoff in to the groundwater. Because groundwater on Cape Cod travels towards nutrient-sensitive coastal embayments, the quality of stormwater runoff is a concern.

Where most efforts to manage stormwater focus on moving the volume of water off roadways, stormwater management on Cape Cod also requires addressing the quality of stormwater that infiltrates to the Cape's groundwater (drinking water) resources and the Cape's coastal estuaries.

Stormwater and Drinking Water Protection

Drinking water on Cape Cod is provided by a sole source aquifer and because of the hydrogeology of Cape Cod, the aquifer is sensitive to stormwater runoff. Areas of land that receive precipitation to recharge drinking water wells are called Wellhead Protection Areas (WPAs). Stormwater management is particularly important in these areas because contaminated stormwater runoff can potentially contaminate drinking water supply. Because of this threat, WPAs have specific regulations in place to protect the Cape's drinking water supply. Potential Water Supply Areas (PWSAs) have also been identified on Cape Cod to ensure consideration and possible protection of suitable land for drinking water wells. WPAs and PWSAs are mapped water resources areas in the Cape Cod Commission's Regional Policy Plan (RPP) and have specific regulatory review standards.

TMDLS and Impaired Watersheds on Cape Cod

The allowable load of a particular contaminant that changes a healthy system to a deteriorating system is defined as a critical threshold, which under the federal Clean Water Act is referred to as a Total Maximum Daily Load (TMDL). TMDLs determine the maximum allowable load of a pollutant to a water body that still enables that water body to meet state water quality standards. Establishing a TMDL includes identifying and quantifying sources of the pollutant of concern (from both point and non-point sources), taking into consideration a margin of safety, seasonal variations, and several other factors. Communities are required to restore impaired surface water bodies where a TMDL is determined. TMDLs are determined for specific pollutants such as nitrogen, phosphorous, and pathogens.

NITROGEN

In marine and coastal embayments, nitrogen generally acts as the limiting nutrient. Due to the Cape's unique geology, very little nitrogen is removed from groundwater by natural processes, so increased nitrogen loading from development has a particularly significant effect on the nitrogen-limited coastal embayments of Cape Cod. When an excess of nitrogen is introduced to an embayment, changes in the natural ecology will occur. A common result from excess nitrogen loading is eutrophication, which is the overgrowth of certain plant species (e.g. algae), often leading to the loss of species diversity and community richness, and overall habitat degradation. In some severe cases eutrophication creates anoxic environments resulting in fish kills, loss of eel grass, and aesthetically unpleasant conditions.

Nitrogen sources include septic systems and other water treatment facilities, fertilizer, stormwater, atmospheric nitrogen, sediment nitrogen, and natural background.

As of 2018, the Massachusetts Estuaries Project has studied 40 Cape Cod embayments. Of the 40 studied embayments, 36 are considered “impaired” and have a nitrogen TMDL that have been approved by the Massachusetts Department of Environmental Protection (MassDEP) and the U.S. Environmental Protection Agency (EPA). Though the majority of nitrogen reaching the coastal embayments originates from septic systems, a reasonable percentage of all controllable nitrogen sources originate from impervious surfaces (i.e. stormwater). The Waste Load Allocation (WLA) calculations in the Nitrogen TMDLs consider runoff from the entire impervious area within a 200 foot buffer zone around all waterbodies.

FIGURE 1. Stormwater Runoff Nitrogen Load to Impaired Embayments

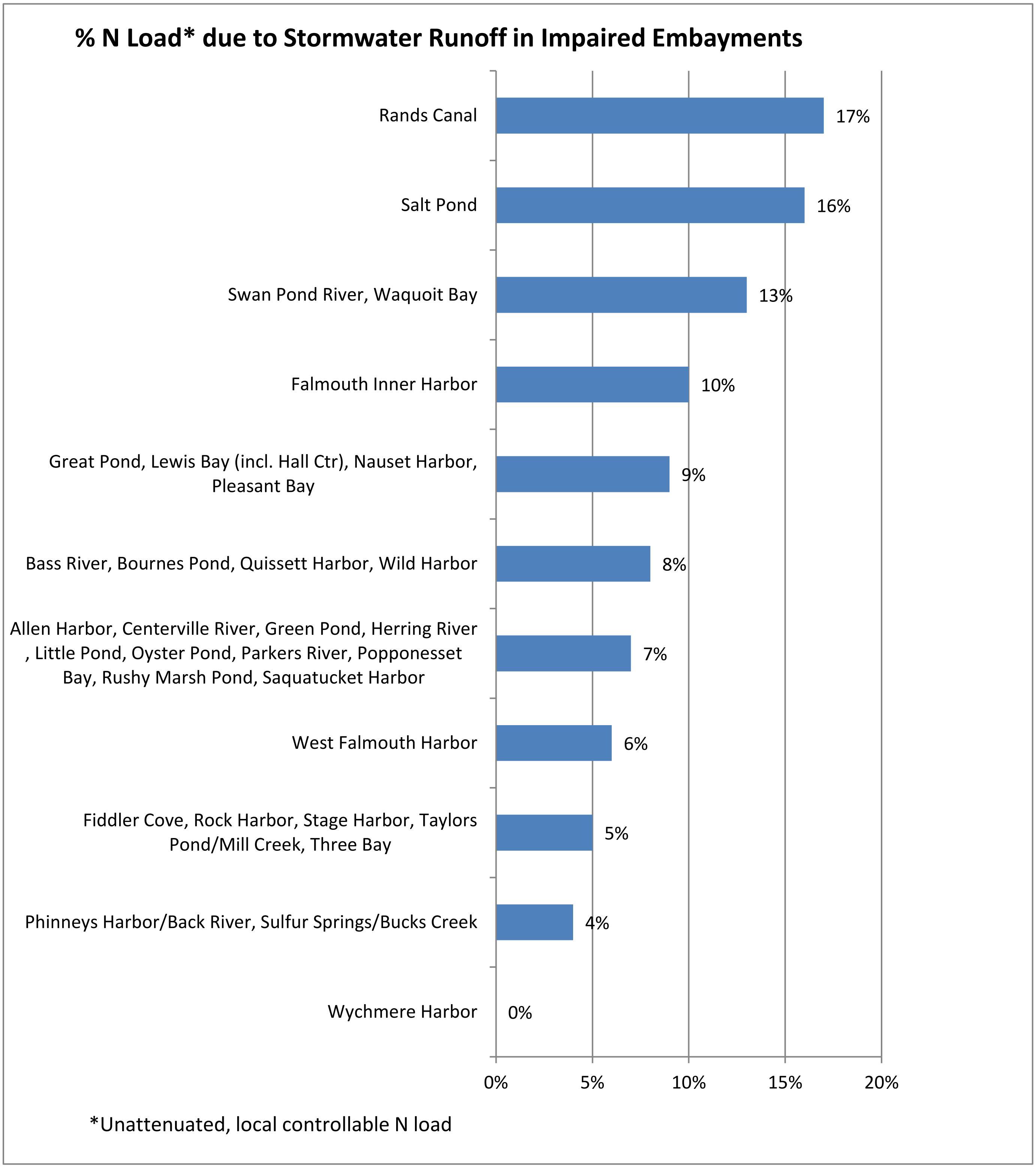
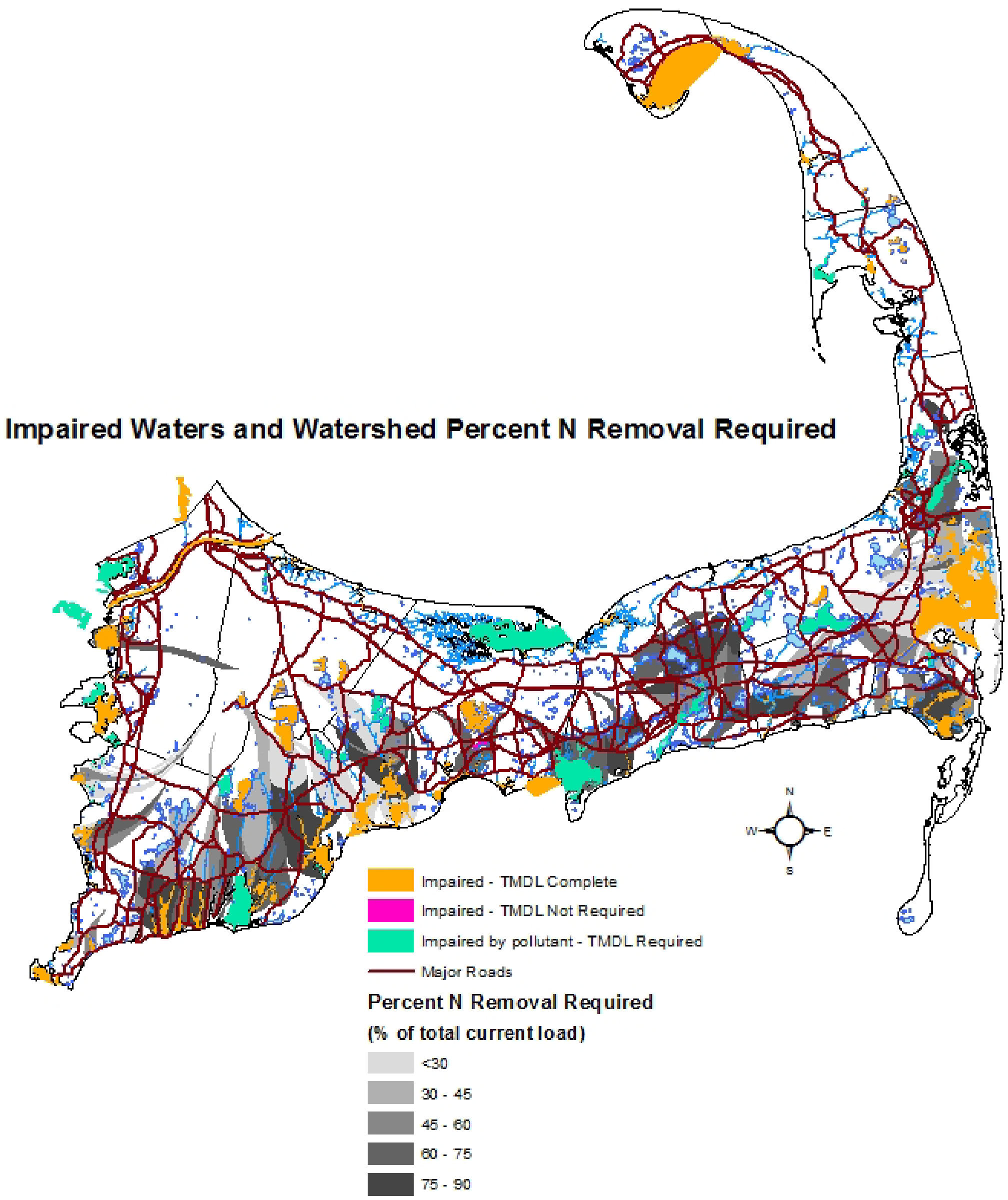


FIGURE 2. Impaired Waters and % Nitrogen Removal Required in Subembayments



BACTERIA

Pathogens can pose a risk to human health by causing gastrointestinal illness through exposure via ingestion, contact with recreational waters, and consumption of filter-feeding shellfish. Waterborne pathogens enter surface waters from a variety of sources including sewage, the feces of warm-blooded wildlife, pets, geese, gulls, and illicit discharges of boat wastes. Areas of elevated bacteria levels in Cape Cod watersheds are believed to be primarily from boat wastes, pets, wildlife, birds, stormwater, and failing septic systems. 85% of Cape Cod's watershed populations (residences and businesses) have individual septic systems for disposal of human wastes. Septic system failures or poorly performing systems play an important part to the bacterial contamination throughout the Cape.

Pathogen TMDLs were developed for all Cape Cod Watersheds using fecal coliform as an indicator bacterium for shellfish areas, enterococci for bathing in marine waters, and E. *coli* for fresh waters. Understanding sources of bacteria is essential while selecting appropriate stormwater management strategies.

Pathogen TMDLs exist for 86 pathogen-impaired water body segments on Cape Cod, defined through the following TMDL documents:

- Final Pathogen TMDL Report for the Cape Cod Watershed (49 segments) - 2009
- Addendum to Final Cape Cod Pathogen TMDL Report (17 segments) – 2012
- Final Pathogen TMDL for Buzzards Bay Watershed (14 segments) - 2009
- Final Pathogen TMDL for Three Bays Watershed, Barnstable, MA (4 segments) - 2009
- Bacteria TMDL for Muddy Creek - 2005
- Bacteria TMDL for Frost Fish Creek, Chatham, MA – 2005

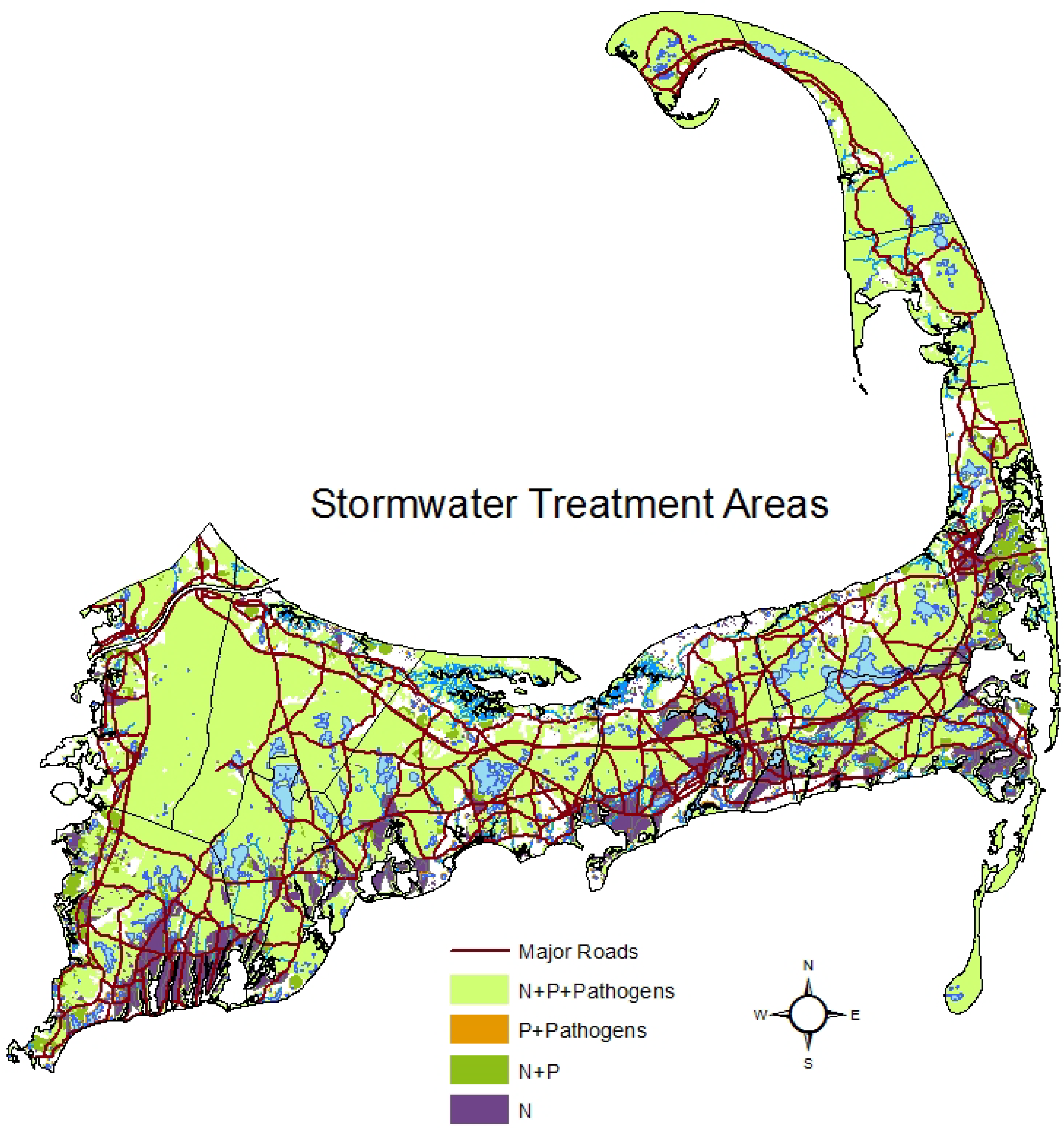
The WLA calculation for the pathogen TMDL assumes a 200-ft buffer zone around embayments as the contributing area for stormwater. According to the Cape Cod Watershed TMDL, data indicate that in general, two to three orders of magnitude (i.e., greater than 90%) reductions in stormwater fecal coliform loading will be necessary, especially in developed areas.

Stormwater Runoff and Sensitive Resource Areas

The map, below, identifies resource-sensitive areas (and buffers around those areas) that can be sensitive to pollutants in stormwater runoff. The map identifies areas where Nitrogen, Phosphorous, and/or Pathogens could be mitigated in stormwater runoff in order to protect sensitive resources areas on the Cape. Existing roadways and future roadway development should consider treatment of these pollutants in the identified areas.

Because different resource areas are sensitive to certain kinds of pollutants, the table, below, outlines the resources areas mapped and their associated pollutants of concern. Buffer distances around resource areas were chosen by considering where stormwater runoff from roads may impact sensitive natural habitats and are derived from TMDL considerations and the RPP. In general, buffers are required to protect surface water bodies from sedimentation, erosion, and pollution; they are also needed to maintain wildlife habitat. In WLA calculations used for both the Nitrogen and Pathogen TMDLs on Cape Cod, a 200 foot buffer was considered as the contributing area for stormwater runoff. The RPP designates buffer distances around Sensitive Natural Resource Areas (SNRA), where development should be located outside of these buffer zones. Buffers include a 300 foot buffer around ponds, a 350 foot buffer around certified vernal pools, and a 200 foot buffer around rivers.

FIGURE 3. Stormwater Treatment Areas



The following table shows the resource areas considered in Figure 3.

TABLE 1. Sensitive Resource Areas and Associated Pollutants of Concern

SENSITIVE RESOURCE AREA	NOTES	POLLUTANTS TO REDUCE
Watersheds requiring N removal	Indicates to what level watersheds must reduce current nitrogen loading	N
Impaired Waters	Impaired for pollutants (nutrients, metals, pesticides, solids, and pathogens) or impaired for pollution (e.g. low flow, habitat alteration, non-native species infestations). "Impaired" defined by Section 305 (b) and 303 (d) of the CWA.	P, N, Pathogens
Impaired Waters Buffer	300 foot buffer around impaired waters	P, N, Pathogens
Outstanding Resource Waters	Considered a "Critical Area" according to MA Stormwater Standards. Stormwater discharges to Outstanding Resource Waters shall be removed (and set back from the receiving water or wetland) and receive the highest and best practical method of treatment	N, P, Pathogens
WPAs & IWPAs	Considered a: "Critical Area" according to MA Stormwater Standards. Water Resource Area in the RPP which have additional considerations for maintenance of water quality "Significant Natural Resource Area" according to RPP	N, P, Pathogens
Coldwater Fisheries	200 foot buffer. Overall sensitive habitat that requires maintenance of cold temps and high dissolved oxygen.	P, N, Pathogens
National Heritage and Endangered Species Program (NHESP) Certified Vernal Pool buffers	350 foot buffer required per RPP. Considered a SNRA (per RPP). EPA recommends managing a 1000 foot radius area beyond the edge of a vernal pool basin as vernal pool upland habitat.	P, N
Ponds Buffer	300 feet	P, Pathogens
River Buffer	200 feet	P, N
MassDEP Wetland Areas	Considered a SNRA (per RPP).	N
NHESP Priority Habitats	Considered a SNRA (per RPP).	P, N, Pathogens
Freshwater Recharge Area	Considered a Water Resource Area in the RPP with additional considerations related to phosphorus loading	P, N, Pathogens
Potential Public Water Supply Area	Considered a SNRA (per RPP).	P, N, Pathogens

Climate Change Considerations in Stormwater Management

Recent storm records and predictions for storm activity in the coming years suggest that roadways in New England will trend towards more extreme events. Accordingly, Massachusetts transportation infrastructure should be designed to accommodate higher intensity storm events. The Massachusetts Climate Change Adaptation Report also cites evidence that by 2050, annual precipitation in Massachusetts may increase by 8%, with a winter increase of 16% (accompanied by a decrease in snow days and an increase in winter rain precipitation). These climate predictions suggest that future planning for stormwater management should consider increased volumes of water (and stormwater runoff) on Massachusetts roadways.

DESIGN CRITERIA FOR MANAGING STORMWATER VOLUME

First Flush

The Water Quality Volume (WQV) represents the runoff generated by a design depth of rainfall from a given drainage area. This provides a minimum quantity (ft^3) of water to capture and treat for the constituents of concern. To capture the full volume of each rain event would be costly and require large dedicated portions of land. In its essence, the goal of stormwater management is twofold and includes treating contaminated runoff and minimizing flooding issues for the majority of storm events. The WQV calculation ensures that water quality treatment is provided for the most contaminated runoff, or the "first flush," of each event. The first flush typically includes the most polluted runoff of an event as it re-suspends contaminants that have been gathering on impervious surfaces during dry periods. Therefore, guaranteeing the capture and treatment of this initial runoff stream is the most important consideration from a water quality standpoint.

As defined by the Massachusetts Stormwater Design Handbook, the required WQV for the below land use types equals 1.0" of runoff times the total impervious area.

- from a land use with a higher potential pollutant load;
- within an area with a rapid infiltration rate (greater than 2.4 inches per hour);
- within a Zone II or Interim Wellhead Protection Areas (IWPAs)
- near or to the following critical areas:
  - Outstanding Resource Waters
  - Special Resource Waters,
  - bathing beaches,
  - shellfish growing areas
  - cold-water fisheries.

The remaining land use types not listed here require a design depth of 0.5”, but 1” is currently a recommended practice and will likely be the standard in the near future.

For the purposes of this report the WQV is calculated following Equation 1 and is defined below.

Equation 1: WQV Calculation

WQV = P * Rv * I * A

Where:

P = precipitation (in.)

Rv = unitless volumetric runoff coefficient

I = percent impervious cover draining to structure

A = contributing drainage area to BMP (acre)

Greater Design Flood Frequency

As discussed in the 2011 Massachusetts Climate Change Adaptation Report, addressing the resiliency and adaptability of infrastructure in the face of global climate change is of paramount concern. A 2010 study from the University of New Hampshire discussing trends in precipitation in the Northeastern United States indicates “that the occurrences of extreme precipitation events, and the intensity of rainfall, are increasing.” The study shows that annual precipitation has increased since the late 1940’s with the largest increases occurring in recent years. Researchers with the University of Massachusetts Boston Environmental, Earth and Ocean Science Department analyzed trends in precipitation from 1954 to 2008. Findings in the study strongly suggest the need for updating design storm estimates in Maine, New Hampshire and Massachusetts.

The table below is an excerpt from Chapter 8 of the Mass Highway Design Manual, 2006 Edition and shows the recommended design flood frequencies for drainage systems by highway functional class. With trends showing an increase in event intensity and frequency, consideration should be taken to use greater design flood frequency values in areas of increased hydroplaning risk. It is becoming increasing common, and generally recommended, to the 2015 NOAA Atlas 14 or the regularly updated Northeast Regional Climate Center estimates.

FIGURE 4. Recommended Design Flood Frequency (excerpt from MassHighway Design Manual)

Highway Functional Class	Urban/Rural	Type of Installation: Cross Culverts	Storm Drain System[2]	Open Channels[3]
Interstate/Freeway/Expressway	Both	50-yr	10-yr[4]	50-yr
Arterial	Urban	50-yr	10-yr[4]	50-yr
	Rural	50-yr	10-yr[4]	50-yr
Collectors/Local	Urban	25-yr[5]	5-yr	25-yr[5]
	Rural	10 or 25-yr	2 or 5-yr	10 or 25-yr

1. The values in the table are typical ranges. The selected value for a project is based on an assessment of the likely damage of a given flow and the costs of the drainage facility.
2. This includes pavement drainage design.
3. This includes any culverts which pass under intersecting roads, driveways, or median crossings.
4. Use a 50-yr frequency at underpasses or depressed sections where ponded water can only be removed through the storm drain system.
5. The selected frequency depends on the anticipated watershed development and potential property damage.

Source: HEC #1, March, 1969. Design of Highway Pavements, pp. 12-5 to 12-6. Note: HEC #12 — Revised, March, 1984.

Note: 100-year requirements must be checked if the proposed highway is in an established regulatory floodway or floodplain, or resource area is defined by the April, 1983 revisions to Ch. 131 MGL, Section 40. See Section 10.1.2.

Pavement Cross Slope and Expanded Shoulder

Providing adequate cross slope on a roadway surface and expanding the road shoulder are effective ways to manage runoff. Assuming shoulders are properly sloped to drain away from pavement, both help convey design runoff from driving lanes. Because adjusting roadway cross slopes is expensive and results in significant disruption to vehicular travel, such an approach would be considered only if a segment of roadway was already slated for reconstruction and resources like historic character and critical vegetation would not be damaged with inclusion of an expanded shoulder.

Minimize Drainage Path Lengths

Long downhill grades where water is channelized through raised shoulders or berms increasestormwater velocity and quantity until release points are reached, such as a curb cut or a curve transition where concentrated flow turns to sheet flow across the roadway. As drainage path lengths increase, the effects of channelization are compounded. By minimizing drainage path lengths through frequent curb cuts; runoff velocity, volume, and associated ponding are minimized. Catch basins, while a useful management tool for overall runoff reduction, should not be relied upon to minimize drainage path lengths. Due to improper placement, clogging and infrequent maintenance, catch basins are often unable to capture design volumes on busy roadways.

Curbing and Berming

Curbing is primarily used at the outside edge of pavement to contain surface runoff within the roadway and away from adjacent properties. Secondary and tertiary benefits of curbing include the prevention of slope erosion, roadside delineation, and pedestrian sidewalk protection.

In many instances, preventing runoff from exiting the road surface is an important goal when large quantities of runoff have the potential to affect adjacent property owners and protected natural resources. However, curbing and berming may be unnecessary in areas where there are sufficient median and adjacent rights of way to capture roadway runoff. Where there is sufficient land area to capture roadway runoff excess curbing and berming may be an unnecessary preventative measure and counterproductive when attempting to minimize the potential for hydroplaning. Intermittent or complete removal of curbing and berms in applicable areas will reduce runoff build up and minimize drainage path lengths.

When combined with a properly designed cross slope, the complete removal of curbing and berms will promote country drainage and have minimal risk for slope erosion. Where curbing and berming must remain, drainage pathways should still be minimized by frequent curb cuts. Curb cuts capturing runoff from large drainage areas and long drainage path lengths must account for the increased energy and velocity of runoff to prevent erosion. This may be accomplished through a variety of energy dissipaters such as vegetated filter strips, riprap aprons and riprap outlet basins. Curb cuts capturing runoff within nitrogen sensitive watersheds could utilize specific stormwater controls that address nutrient reduction. The targeted controls should be placed down gradient of energy dissipaters to accept a more controlled flow.

DESIGN CRITERIA FOR WATER QUALITY

Pollutants in stormwater fall into two groups: suspended solids and dissolved pollutants. Particle sizes greater than 0.45 micron are considered suspended solids. Pretreatment devices, such as a sediment forebay or oil grit separator, are ordinarily designed to remove suspended solids that have larger particle sizes. Dissolved solids, however, are removed by treatment practices that rely on settling (e.g. extended dry detention basins and wet basins) or filtration (e.g. sand filters and filtering bioretention areas).

If stormwater runoff will affect surface water that is subject to a TMDL, proponents must design, construct, operate and maintain a stormwater management system that is consistent with the TMDL. Currently, there are TMDLs for both nitrogen and bacteria on Cape Cod.

Treating Nitrogen

There are a growing number of stormwater management technologies which effectively remove nitrogen from stormwater. Stormwater BMPs equipped with vegetation can remove nitrogen through nutrient uptake, while other BMPs create an anoxic, or oxygen free, environment for denitrifying bacteria to convert nitrogen in stormwater to inert nitrogen gas. BMPs that can effectively remove nitrogen include bioretention systems, tree box filters, sub-surface constructed wetlands and retention ponds. Nitrogen removal efficiencies of chosen BMPs can be found in Table 4.

Treating Bacteria

In shellfish growing areas and public swimming beaches, bacterial contamination is of concern. Therefore, designers should evaluate BMPs for their ability to capture bacteria or limit their growth. BMP technologies that retain water under conditions that promote bacteria growth (such as enclosed spaces that can become "septic" during extended no flow periods) should be avoided in these areas. For example, identification and remediation of dry weather bacteria sources is usually more straightforward and successful than tracking and eliminating wet weather sources. Only segments that remain impaired during wet weather should be evaluated for stormwater BMP implementation opportunities. Bacterial removal efficiencies for some chosen BMPs can be found in Table 4.

Environmentally-sensitive Roadway Design

Low impact development (LID) techniques are innovative stormwater management systems that are modeled after natural hydrologic features. Environmentally sensitive roadway design involves incorporating LID techniques to prevent the generation of stormwater and non-point source pollution by reducing impervious surfaces, disconnecting flow paths, treating stormwater at its source, maximizing open space, minimizing disturbance, protecting natural features and processes, and/or enhancing wildlife habitat.

BEST MANAGEMENT PRACTICES FOR ROADWAYS

Best management practices (BMPs) are control measures to limit untreated, polluted stormwater runoff from reaching waterbodies. BMPs can be categorized in to two categories: structural and non-structural BMPs. Structural BMPs are physical interventions in the landscape, while non-structural BMPs are administrative measures/requirements, such as trainings and operating procedures.

Structural BMPs

Structural BMPs are physical interventions for stormwater management that can be used alone or together to convey, treat, and/or infiltrate stormwater runoff. Structural BMPs can be classified in one or several of the following categories:

- Pretreatment
- Treatment
- Conveyance
- Infiltration
- Other

PRETREATMENT

Pretreatment BMPs are typically the first BMPs in a treatment train and typically remove coarse sediments that can clog other BMPs. The settling process generates sediment that must be routinely removed. Maintenance is especially critical for pretreatment BMPs, because they receive stormwater containing the greatest concentrations of suspended solids during the first flush. Pretreatment BMPs can be configured as on-line or off-line devices. On-line systems are designed to treat the entire WQV. Off-line practices are typically designed to receive a specified discharge rate or volume. A flow diversion structure or flow splitter is used to divert the design flow to the off-line practice.

- Deep Sump Catch Basins
- Oil Grit Separators
- Proprietary Separators
- Sediment Forebays
- Vegetated Filter Strips

TREATMENT

Stormwater Treatment Basins provide peak rate attenuation by detaining stormwater and settling out suspended solids. The basins that are most effective at removing pollutants have either a permanent pool of water or a combination of a permanent pool and extended detention, and some elements of a shallow marsh. Stormwater basins include:

- Extended Dry Basins (Detention Ponds)
- Wet Basins (Retention Ponds)

Constructed stormwater wetlands are designed to maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling. Gravel wetlands, however, remove pollutants by filtering stormwater through a gravel substrate.

- Constructed Stormwater Wetland
- Gravel Wetland

Other filtration BMPs include:

- Filtering Bioretention Areas and Rain Gardens
- Proprietary Media Filter
- Sand Filters/Organic Filters
- Treebox Filter

CONVEYANCE

These BMPs collect and transport stormwater, usually to other BMPs for treatment and/or infiltration. Conveyance BMPs may also treat runoff through infiltration, filtration, or temporary storage. For example, a vegetated swale functions both as a runoff conveyance channel and the vegetation prevents erosion, filters sediment, and provides some nutrient uptake benefits.

- Drainage Channels
- Grass Channels
- Water Quality Swales
  - Dry
  - Wet

INFILTRATION

Infiltration techniques reduce the amount of surface flow and direct the water back into the ground.

- Exfiltrating Bioretention Areas and Rain Gardens
- Dry Wells
- Infiltration Basins
- Infiltration Trenches
- Leaching Catch Basins
- Subsurface Structures

OTHER

- Dry Detention Basins
- Green Roofs
- Porous Pavement
- Rain Barrels and Cisterns

BMP accessories are devices that enable BMPs to operate as designed. BMP accessories include the following:

- Check Dams
- Level Spreaders
- Outlet Structures
- Catch Basin Inserts

TREATMENT TRAINS

A BMP "treatment train" incorporates several stormwater treatment mechanisms in sequence to enhance the treatment of runoff. A series, rather than using a single method of treatment, improves the levels and reliability of pollutant removal. The effective life of a BMP can be extended by combining it with pretreatment BMPs, such as a vegetated filter strip or sediment forebay, to remove sediment prior to treatment in the downstream "units." Sequencing BMPs can also reduce the potential for re-suspension of settled sediments by reducing flow energy levels or providing longer flow paths for runoff.

Examples of treatment trains:

- A sediment forebay discharging to a wet basin flowing into a constructed stormwater wetland
- A water quality swale flowing into a wet basin or a constructed stormwater wetland
- An oil grit separator connected to a sand or organic filter
- A sediment forebay discharging to an extended dry detention basin connected to a sand filter
- A water quality swale discharging to a vegetated filter strip connected to an infiltration trench

Non-Structural BMPs

Non-structural BMPs are policies, educational efforts, and housekeeping efforts that can help mitigate stormwater runoff. Because nonstructural practices can reduce stormwater pollutant loads and quantities, the size and expense of structural BMPs can be reduced, thereby affording substantial cost savings. Below are two BMPs that can be used to reduce the amount of contaminants in roadway stormwater runoff.

STREET SWEEPING

Street sweeping programs have the capacity to be effective in removing pollutants, primarily total suspended solids (TSS), from stormwater.

Three factors that can have an influence on the effectiveness of a street sweeping program are:

(1) Access - Studies have shown that up to 95% of the solids on a paved surface accumulate within 40 inches of the curb, regardless of land use. Those responsible for stormwater maintenance have the ability to impose parking regulations to facilitate proper sweeping so that sweepers can get as close to curbs as possible.

(2) Type of sweeper - There are three types of sweepers: Mechanical, Regenerative Air, and Vacuum Filter. Each has a different ability to remove TSS.

- Mechanical: use brooms or rotary brushes to scour the pavement. They are not effective at removing TSS (0% to 20% TSS removal).
- Regenerative Air: blow air onto the road or parking lot surface, causing fine particles to rise where they are vacuumed. Regenerative air sweepers may blow particulates off the vacuumed portion of the roadway or parking lot, where they contaminate stormwater when it rains.
- Vacuum filter: Two types, wet and dry. The dry type uses a broom in combination with the vacuum. The wet type uses water for dust suppression. Research indicates vacuum sweepers are highly effective in removing TSS.

Regardless of the type chosen, the efficiency of street sweeping is increased when sweepers are operated in tandem.

(3) Frequency of sweeping - TSS removal efficiency is determined based on annual loading rates. If a road were swept only once a year with a sweeper that is 100% efficient, it would remove only a small fraction of the annual TSS load. Many studies and reports suggest that optimum pollutant removal occurs when surfaces are swept every two weeks.

TABLE 2.   TSS Removal Credits for Street Sweeping

TSS REMOVAL RATE	HIGH EFFICIENCY VACUUM SWEEPER – FREQUENCY OF SWEEPING	REGENERATIVE AIR SWEEPER – FREQUENCY OF SWEEPING	MECHANICAL SWEEPER (ROTARY BROOM)
10%	Monthly Average, with sweeping scheduled primarily in spring and fall.	Every 2 Weeks Average, with sweeping scheduled primarily in spring and fall.	Weekly Average, with sweeping scheduled primarily in spring and fall.
5%	Quarterly Average, with sweeping scheduled primarily in spring and fall.	Quarterly Average, with sweeping scheduled primarily in spring and fall.	Monthly Average, with sweeping scheduled primarily in spring and fall.
0%	Less than above	Less than above	Less than above

It has been found that street sweeping programs may NOT be effective due to the following:

- The period immediately following winter snowmelt, when road sand and other accumulated sediment and debris is washed off, is frequently missed by street sweeping programs.
- Larger particles of street dirt may prevent smaller particles from being collected.
- The entire width of roadway may not be swept.

- Sweepers may be driven too quickly to achieve maximum efficiency.
- Land surfaces along the paved surfaces may not be entirely stabilized.

Successful street sweeping programs should consider factors such as whether road and parking lot shoulders are stabilized, the speed at which the sweepers will need to be driven (safety factor such as along a highway), whether access is available to the curb (whether vehicles parked along the curb line will preclude sweeping of the curb line), the type of sweepers, and whether the sweepers will be operated in tandem. Municipalities or private developers that are planning to purchase a new street sweeper should consider vacuum sweepers, because they are the most consistently effective.

ROAD SALTING

The application and storage of deicing materials, most commonly salts such as sodium chloride, can lead to water quality problems for surrounding areas. Salts, gravel, sand, and other materials are applied to highways and roads to reduce the amount of ice or to provide added traction during winter storm events. Salts lower the melting point of ice, allowing roadways to stay free of ice buildup during cold winters. Sand and gravel increase traction on the road, making travel safer.

As snow melts, road salt, sand, litter, and other pollutants are transported into surface water or through the soil where they may eventually reach the groundwater. Road salt and other pollutants can contaminate water supplies and may be toxic to aquatic life. Sand washed into waterbodies can create sand bars or fill in wetlands and ponds, impacting aquatic life, causing flooding, and affecting our use of these resources.

To prevent increased pollutant concentrations in stormwater discharges, the amount of road salt applied should be reduced. Calibration devices for spreaders in trucks aid maintenance workers in the proper application of road salts, so the amount of salt applied could be varied to reflect site-specific characteristics such as road width and design, traffic concentration, and proximity to surface waters. Alternative materials, such as sand or gravel, calcium chloride, and calcium magnesium acetate may be used in especially sensitive areas.

BMPs for Cape Roadways

The following BMPs are discussed in more detail, as they are suitable for construction on the Cape considering the Cape's permeable soils and more rural, semi-urban landscape.

- Porous pavement (other)
- Leaching Catch Basins (infiltration)/ Infiltration Basins (infiltration)
- Sub-surface Sediment Chambers (pretreatment + infiltration)

- Retention Pond (treatment)
- Bioretention (treatment)
- Advanced Bioretention (treatment)
- Water Quality Swales (conveyance, treatment, infiltration)
- Constructed Stormwater Wetlands (treatment)

POROUS PAVEMENT

FIGURE 5. Porous Pavement adjacent to traditional impervious asphalt pavement (foreground)

(Source: Virginia Asphalt Association)

Porous pavement, also known as pervious, permeable, or open-graded asphalt, is a standard hot-mix asphalt with reduced sand or fines allowing stormwater to infiltrate through a permeable surface. The reduced fines provide air pockets in the pavement creating interconnected void space allowing stormwater to flow through the pavement and into a sand and crushed stone aggregate bedding layer base supporting the pavement. The sub-base provides storage and runoff treatment without requiring additional land area to do so. Porous pavement over an aggregate storage bed will reduce stormwater runoff volume, and pollutants. When properly constructed, porous pavement is a viable alternative to traditional pavement especially in areas where green space and/or additional land area to capture and treat stormwater is limited. Porous pavement may also be incorporated into sidewalks and bike lanes to further reduce site runoff.

Porous pavement has been shown to remove high levels of TSS and petroleum hydrocarbons. When designed correctly, porous pavements may also reduce bacteria contamination.

LEACHING CATCH BASINS/INFILTRATION BASINS

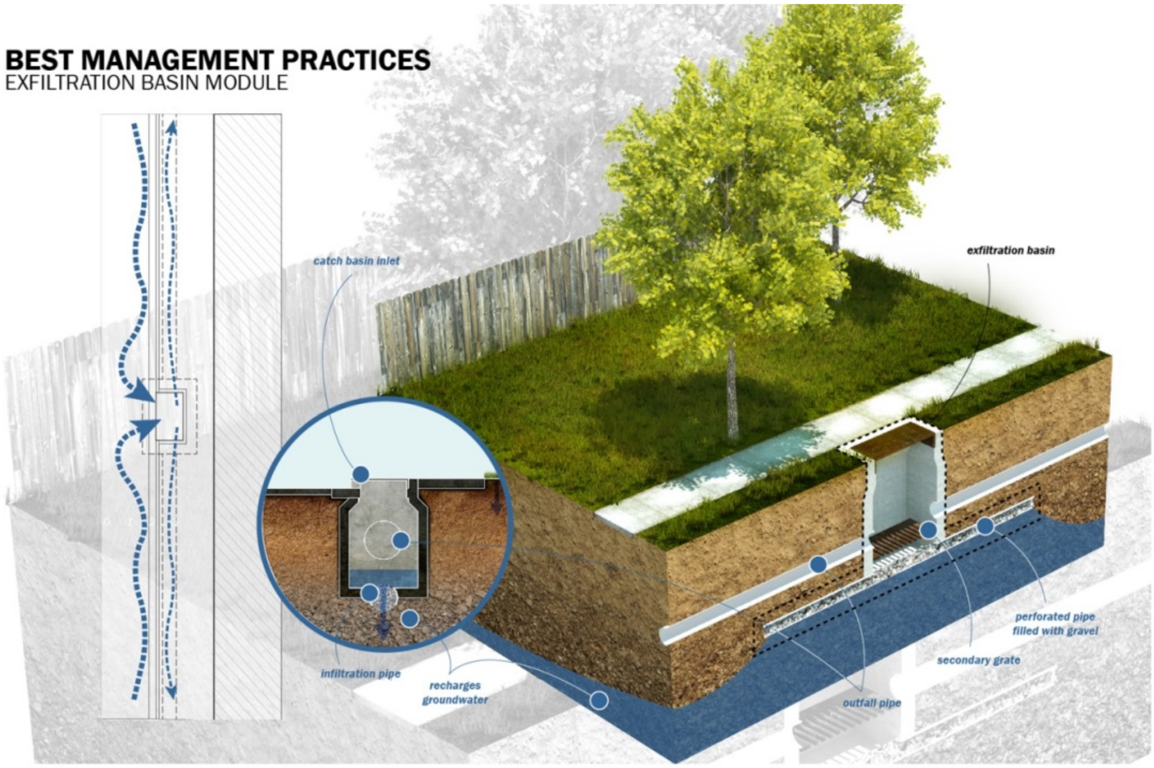


FIGURE 6.	Leaching Catch Basin

(Source: Waggonner and Ball Architects)

A leaching catch basin is similar to a traditional catch basin with the added ability to permit the infiltration of captured runoff. Leaching basins are often installed in series with a deep sump catch basin that provides pretreatment. Because of this pretreatment, the catch basin/leaching basin combination is preferable to the leaching catch basin as a higher removal of TSS may be achieved while also extending the life and minimizing maintenance on the leaching catch basin. Leaching catch basins and leaching basins should only be used in areas with highly permeable soils, making these basins a popular stormwater control throughout the Cape.

Leaching catch basins, in series with pre-treatment catch basins, achieve excellent TSS removal in addition to constituents that sorb to fine particulates including petroleum hydrocarbons and metals.

SUB-SURFACE SEDIMENT CHAMBERS/UNDERGROUND SAND FILTERS

FIGURE 7. Sub-surface Treatment Chambers

(Source: Lindsay Cook, Cape Cod Conservation District Intern)

Sub-surface sediment chambers function similarly to surface sedimentation systems. Sediment trapping systems remove pollutants (mainly particulates) from stormwater runoff through a pretreatment sedimentation area followed by an outflow mechanism returning treated flow to a stormwater conveyance system.

In a treatment train, the outflow from the sedimentation area can be followed by an infiltration bed containing filter media (typically sand, soil, gravel or a combination of media). This infiltration bed removes fines and the pollutants sorbed, or attached, to these particulates. Various contaminants including, but not limited to metals, petroleum hydrocarbons and bacteria may sorb to fines allowing infiltration systems to achieve removal efficiencies in these categories though the physical process of filtration.

RETENTION PONDS

FIGURE 8. Retention Pond

(Source: U.S. EPA)

Retention ponds, or “wet ponds,” are a widely used conventional stormwater management tool. They are designed to retain a permanent pool of runoff allowing for continuous water quality treatment. Unlike detention basins, or dry basins, which detain runoff only for a limited period of time, retention ponds may be retrofitted from a flood control measure to a water quality treatment system through the installation of additional outlets. As retention ponds contain an active aquatic ecosystem frequent maintenance is required to prevent the buildup and export of contaminants.

Limitations include standing water increasing the risk of drowning and creating mosquito habitat. As mentioned above, retention ponds also may contain excess nutrients that, without proper maintenance, may lead to harmful algal blooms.

Retention ponds remove TSS, petroleum hydrocarbons, nitrogen (with proper maintenance), metals and in some cases bacteria.

BIORETENTION

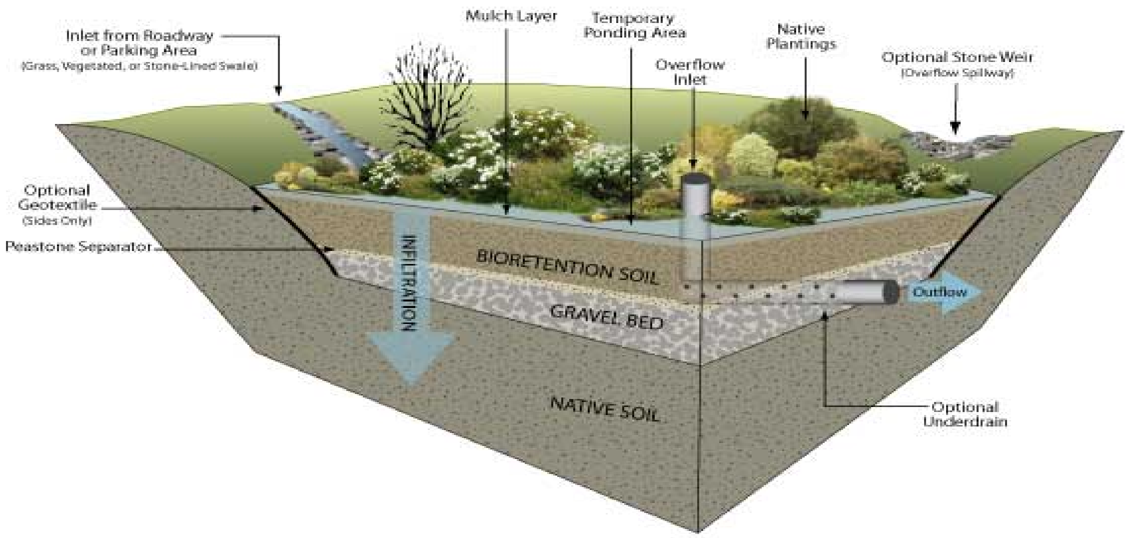


FIGURE 9. Bioretention

(Source: Douglas County Environmental Services)

Bioretention is a method of treating stormwater by ponding water in shallow depressions underlain by a sandy engineered soil media through which most of the runoff passes.

Bioretention systems can easily be incorporated into the landscape to address and maintain many of the natural hydrologic functions. Pollutants within these systems are removed through both chemical and physical means within the bioretention soil mix. Bioretention systems also encourage biological treatment of nutrients, such as nitrogen, through nutrient uptake by vegetation within the system. Bioretention tends to work best in sandy soils, such as are present in many areas of Cape Cod.

Properly designed bioretention systems achieve excellent removal efficiencies for a wide range of pollutants including TSS, petroleum hydrocarbons, nitrogen, metals, phosphorus and bacteria. Typical removal efficiencies are shown in Table 4.

ADVANCED BIORETENTION

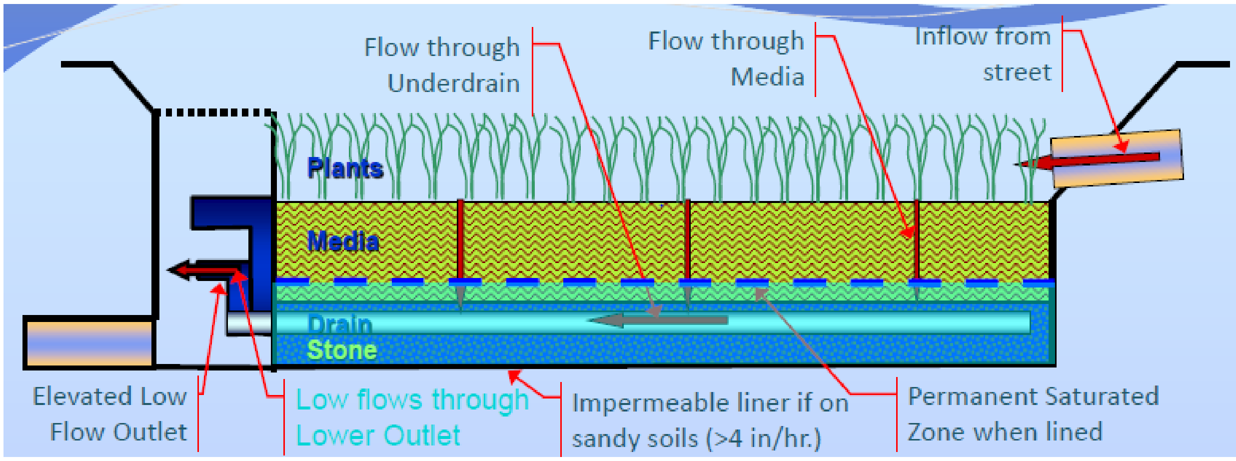


FIGURE 10. Advanced Bioretention

(Source: Washington Stormwater Center)

Advanced bioretention systems provide additional treatment through increased travel and residence time of stormwater. As runoff infiltrates vertically through the soil media, an impermeable liner intercepts and redirects the flow horizontally. This horizontal flow increases contact between runoff, bioretention soil media and root vegetation thereby attaining a reduction in nutrients and various other contaminants greater than traditional bioretention systems. Advanced systems are often lined at the bottom of excavation preventing infiltration and rerouting water once again on a horizontal flow path prior to discharge.

Other modifications to bioretention systems aimed at improving performance include adding supplements to the soil media. Additives such as activated charcoal, sawdust and shredded paper have been shown to improve removal of certain constituents from stormwater runoff. Another approach employs modifications to the configuration of the bioretention system to retain a portion of the accumulated stormwater. This internal water storage design has been shown to reduce soluble nitrogen levels by inducing an anaerobic condition within the bioretention facility itself. Research advances in bioretention system design are continuing to emerge, with promising new methods of increasing pollutant removal.

WATER QUALITY SWALES

FIGURE 11. Water Quality Swales

(Source: Washington Stormwater Center)

Water quality swales are channels providing conveyance, water quality treatment, and flow attenuation of stormwater runoff. Water Quality Swales provide pollutant removal through vegetative filtering, sedimentation, biological uptake, and infiltration into the underlying soil media. Both wet and dry water quality swales can be implemented with the appropriate type being dependent upon site soils, topography, and drainage characteristics. Water quality swale stormwater practices work best with well-drained soils that encourage infiltration as part of the water quality treatment approach. Recommended cross section of water quality swales includes a ¾ - 1" stone sub base covered with Type A native soils and vegetation.

A variety of shrubs, grasses, and ground covers are acceptable vegetation in both sun and shade conditions for the above mentioned stormwater technologies. Vegetation should designed to maximize pollutant removal and contribute to native ecological systems and selected based on its tolerance to flooding and its ability to survive with little or no fertilizers and pesticides. This vegetation should preferably be native, but at very least not be invasive.

Roadside water quality swales paired with country drainage provide increased water quality benefits, mimic the natural landscape, are highly compatible with LID design, have minimal impact on wildlife and reduce driving hazards by keeping stormwater flows off of the roadway surface.

Water quality swales achieve adequate removal efficiencies for TSS, petroleum hydrocarbons, and metals. Typical removal efficiencies are shown in Table 4.

CONSTRUCTED STORMWATER WETLANDS

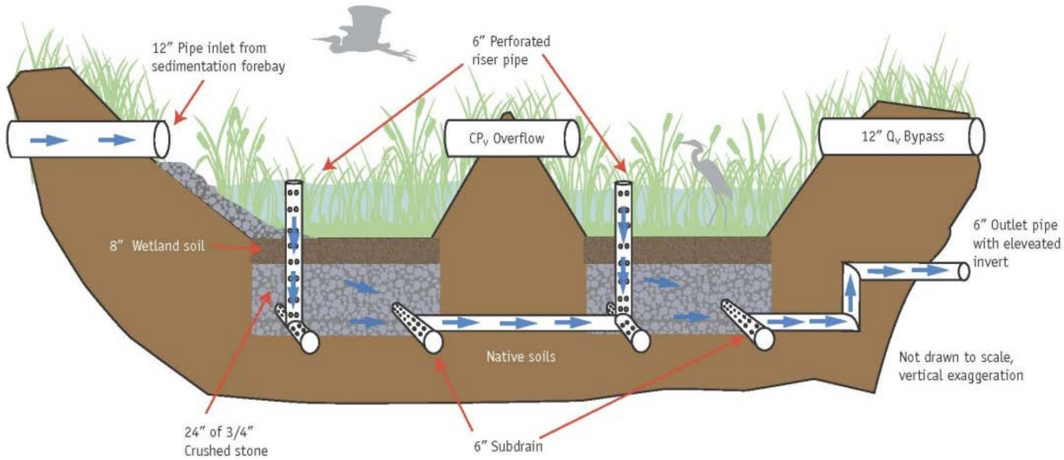


FIGURE 12. Constructed Stormwater Wetlands

(Source: University of Idaho)

Constructed wetlands are intended to simulate the functions of natural wetlands by utilizing vegetation, soils, and microbial activity. Constructed wetlands are typically separated into surface flow wetlands and subsurface flow wetlands. These wetland systems have the ability to treat wastewater from a range of pollutant sources, utilize few to no chemicals, have a lower carbon footprint and may be less expensive in both capital costs and operation and maintenance than conventional treatment options.

The subsurface gravel wetland is designed as a series of flow-through treatment cells, preceded by a sedimentation basin. It is designed to attenuate peak flows and provide subsurface anaerobic treatment. The subdrains distribute the incoming flow, which then passes through the gravel substrate, and then to the opposite subdrains, into the adjacent cell, and then exits the treatment system. In the event of a high intensity event, the WQV is stored above the wetlands, and drains into the perforated riser on one end of the wetland, and into the substrate. Biological treatment occurs through plant uptake and soil microorganism activities. This is followed by physical-chemical treatment within the soil including filtering and absorption with organic matter and mineral complexes. Sub-surface gravel wetlands consistently achieve the highest removal efficiencies of any stormwater management system for a wide range of pollutants including TSS, petroleum hydrocarbons, nitrogen, metals, phosphorus and bacteria. Typical removal efficiencies are shown in Table 4.

MAINTENANCE OF PREFERRED BMPS

It is important to note that these systems may require different maintenance and ongoing care regimes than what has been traditionally provided for stormwater management and landscape systems in the past. However, many of these systems do not require more time or cost intensive care than typical regimes; the care is instead is just a different type of maintenance practice and these learning hurdles need to be overcome. For example, weekly mowing of traditional grass strips between roadways and sidewalks is both cost and time and fossil fuel resource intensive. In lieu of mown grass strips, Water Quality Swales could instead be constructed to provide contaminant removal benefits in addition to desired green aesthetics. Water Quality Swales may require less overall mowing than traditional grass strips, however, trash may need to be removed in monthly intervals. Overall, the amount of maintenance may be the same or less, but the ongoing care practices are different than what road maintenance crews may be used to. Introduction of preferred BMPs should be accompanied by an educational program that emphasizes how maintenance practices are not more intensive, just different, and educates maintenance personnel to ensure long-term maintenance adjustment to provide functional systems.

Below, a typical maintenance summary is provided for the vegetated systems described in the previous section.

Year 1 & 2- Establishment

Just like any landscape installation, correct moisture levels following construction are essential to plant survival. The first ninety (90) days after planting is the critical time for watering. Young plants require heavy watering to establish. This is the same maintenance as required for traditional roadway edges such as mown grass strips.

The plants in a vegetated stormwater system need to be monitored to make sure they become established. It is suggested that this be specified as part of the original construction contract. A two year maintenance period is suggested to be added onto the construction contract to ensure plant survival. Monitoring points should be set up to photograph and document progress of re-vegetation at 3 month intervals. The maintenance contractor would monitor and water the plants, be responsible for replacing any plants that have died and would control weeds when needed.

Throughout the establishment phase it may be necessary to review individual species tolerance. Some planted species may need to be replaced with species that are performing well. A small allowance should be left in the project budget to perform adjust the species as needed during the 2 year establishment phase if needed.

During the 2 year establishment phase, it is suggested that the following maintenance procedures be put in place as part of the original construction contract:

First 90 days, Bi-Weekly:

1. Weed

2. Water as needed

3. Check for and fix erosion

4. Inspection for good general appearance of area/gardens, remove trash as needed

Rest of 2 year Establishment Period, Monthly:

1. Regularly inspect for signs of erosion, obstructions, and unhealthy vegetation.

2. Remove weeds and invasive plants.

3. Remove any trash that has washed into the vegetation areas or the inlet channels or pipes.

4. Check the facility a few days after a rain storm to observe drainage and infiltration as required.

Rest of 2 year Establishment Period Seasonally (Spring and Fall):

1. Replace mulch and finish surfaces where needed

2. Plant/replant as needed. Adjust replacement species if required.

3. Scratch surface to prevent “crust”

4. Check pH; adjust as indicated

Once the vegetated systems are established during the maintenance contract, the ongoing maintenance required can actually be less than a typical mown area. The key is that it is a different kind of maintenance that need to be performed by trained personnel.

<u>Ongoing Maintenance After Establishment Phase</u>

The below seasonal maintenance schedule reflects the maintenance needed after the two year establishment period. Bi-weekly mowing would NOT be required unless grass species are specified as part of a mown Water Quality Swale. Water Quality Swales may require bi-weekly mowing (just like regular grass) in addition to the schedule noted below. Other than the necessary sediment and debris removal 4x per year, the maintenance required would be the same as a mown lawn strip.

TABLE 3. Recommended Time Frames for Typical Maintenance of Vegetated Stormwater BMPs

	JAN	*FEB*	*MAR*	*APR*	*MAY*	*JUN*	*JUL*	*AUG*	*SEP*	*OCT*	*NOV*	*DEC*
Post Establishment:												
Remove sediment, leaves, debris and weeds		X			X			X			X	
Pruning/Cutback		X									X	

TABLE 4. Comparison of Selected BMPs

BMP	SOURCE	COST/METRIC	% POLLUTANT REMOVAL						MAINTENANCE NOTES
			TSS	N	P	METALS	ORGANIC C	OTHER % REMOVAL	
Sub surface sediment chambers/Underground sand filters	EPA (1999)	$6,600 to $18,500 / acre drainage area	70 %	46% (TKN)	33% (Total P)	45%	48%	76% Fecal Coliform	Routine inspections (after major storms) that include trash and debris removal. Lifespan 3-5 yrs. before corrective maintenance red: removal and replacement of top layers of sand, gravel, or filter fabric.
	NPREPD (2007)		86 %	32% (Total N)	59% (Total P)	37% Cu; 87% Zn		37% Bacteria	
Retention pond (Wet Detention Ponds)	EPA (1999)	$0.50 - $1.00/cubic ft.	50-90 %	40-80% (soluble nutrients)	30-90% (Total P)	40-80%	20-40%	40-90% Pathogens (source: MA Stormwater Handbook)	Routine inspections (after major storms) that include trash and debris removal. Maintenance includes repairs to embankment, sediment removal, and control of algae, insects, and odors.
	NPREPD (2007)		80 %	31% (Total N)	52% (Total P)	57%(Cu); 64% (Zn)		70% Bacteria	
Bioretention	EPA (1999)	$1.25/sq. ft. (installation cost)	90 %	68-80% (TKN)	70-83% (Total P)	93-98%	90%	90% Bacteria	Biannual inspection of trees and shrubs, pruning and weeding, alkaline application.
	NPREPD (2007)		59 %	46% (Total N)	5% (Total P)	81%Cu ;79%Zn			
Water Quality	EPA	$8.50 -$50.00/	81	38% (Nitrate)	9% (Total P)	42 -	67%	62%	Periodic mowing, weed control,

Swales	(1999)	linear ft. (capital cost)	%			71%		Hydrocarbons	watering, reseeding of bare areas, mulch and fertilizer application, clearing of debris and sediment. Inspect four times per year. Indefinite lifespan, if properly maintained.
	NPREPD (2007)		81%	39% (Nitrate&Nitrite)	24% (Total P)	65% Cu; 71%Zn			
Porous Pavement	EPA (1999)	$0.50 to $1.00 / sq. ft. (installation cost)	94%	43% (Nutrients)		76-93%	N/A	N/A	Vacuum sweeping and high-pressure hosing at least four times a year. Annual inspections. Longer lifespan than regular pavement: 30 yr. lifespan in Northern climates due to reduced freeze/thaw stress.
	NPREPD (2007)		89%	42% (Total N)	65% (Total P)	86% Cu; 66%Zn			
Constructed Stormwater Wetlands	EPA (1999)	$26,000 - $55,000 per acre (construction cost)	67%	28% (Total N)	49% (Total P)	36 - 62%	34%	77% Bacteria; 87% Hydrocarbons	Replanting, sediment removal, plant harvesting. Biannual inspections for first few years, annual inspections thereafter. >20 yr. lifespan
	NPREPD (2007)		72%	24% (Total N)	48% (Total P)	47% Cu; 42%Zn		78% Bacteria	

REGULATIONS AND PERMIT CONDITIONS

Massachusetts Stormwater Management Standards

Many transportation projects in Massachusetts require adherence to MassDEP's Massachusetts Stormwater Management Standards. Specifically, the standards apply to transportation projects that require either a Massachusetts wetlands permit and/or require a Water Quality Certification. Through the State's Water Quality Certification, the general permit for municipal separate storm sewer systems (MS4) requires compliance with the Stormwater Management Standards. As an MS4 permit operator, the Massachusetts Department of Transportation (MassDOT) must abide by the Massachusetts Stormwater Management Standards.

The Massachusetts Stormwater Standards are comprised of 10 standards that:

1. Prohibit untreated stormwater discharges
2. Ensure peak discharge rates do not increase with development
3. Encourage infiltration by ensuring annual recharge does not decrease with development
4. Require stormwater management systems are designed to remove 80% of the average annual post-construction load of TSS.
    a. A long-term pollution prevention plan is implemented and maintained
    b. BMPs are sized to capture required volume (per Massachusetts Stormwater Handbook)
    c. Pretreatment is provided (per Massachusetts Stormwater Handbook)
5. Eliminate or reduce stormwater discharges to the maximum extent practicable (MEP) for land uses with higher potential pollutant loads.
6. Require the use of the specific source control and pollution prevention measures for discharges in Zone IIs, IWPAs, and near/to "critical areas" (defined below).
7. Require a redevelopment project to meet some of the Stormwater Management Standards and improve existing conditions. Existing stormwater discharges shall comply with Standard 1 only to the MEP.
8. Develop and implement a construction period erosion, sedimentation, and pollution prevention plan.

9. Develop and implement a long-term operation and maintenance to ensure that stormwater management systems function as designed.

10. Prohibit all illicit discharges to the stormwater management system.

Demonstrating compliance with the Stormwater Management Standards to the MEP requires:

1. Making all reasonable efforts to meet each of the Standards

2. Conducting a complete evaluation of possible stormwater management measures (e.g. LID techniques that minimize land disturbance and impervious surfaces, BMPs, pollution prevention, erosion and sedimentation control, and proper operation and maintenance of stormwater BMPs)

3. That if full compliance with the Standards cannot be achieved, they are implementing the highest practicable level of stormwater management.

CRITICAL AREAS

According to Standard 6, specific source controls and pollution prevention measures are required for "critical areas," as defined in MassDEP's Stormwater Management Handbook. MassDOT needs to identify discharges to the following resources areas as a priority and indicate in their stormwater management plan how storm water controls will be implemented. The "Critical areas" defined in MassDEP's Stormwater Management Handbook, with associated references to the Code of Massachusetts Regulations (CMR), are as follows:

- Outstanding Resources Waters (314 CMR 4.00)
- Special Resources Waters (314 CMR 4.00)
- Recharge areas for public water supplies as defined in 310 CMR 22.02 (Zone Is, Zone IIs and IWPAs for groundwater sources and Zone As for surface water sources)
- Bathing beaches (105 CMR 445.000)
- Cold-water fisheries (310 CMR 10.04 and 314 CMR 9.02)
- Shellfish growing areas (310 CMR 10.04 and 314 CMR 9.02)

Designers of roadway improvements should recognize the special nature of "Critical Areas" (especially surface water drinking water reservoirs and other ORWs). In general, roadway improvements in these areas warrant additional efforts to protect water quality than may apply in other less sensitive areas.

Certain BMP design considerations are important to ensuring adequate performance in critical resource areas. The MassDEP Stormwater Management Policy uses TSS removal as an indicator for BMP performance. In some critical areas, however, TSS may not be the only parameter (or even the primary parameter) of concern. For example:

In shellfish growing areas and public swimming beaches, bacterial contamination is of concern. Therefore, designers should evaluate BMPs for their ability to capture bacteria or limit their growth. BMP technologies that retain water under conditions that promote bacteria growth (such as enclosed spaces that can become "septic" during extended no flow periods) should be avoided in these areas.

In cold water fisheries, water temperature is a critical parameter. Therefore, if a BMP discharges directly to temperature sensitive waters, the BMP should not retain water in such a manner that raises its temperature (as may occur in a shallow wet pond, for instance). Alternatively, BMPs can sometimes be designed to account for the temperature effects; for example, in a deeper wet pond, water can be discharged from lower levels of the pond, or re-introduced to the downstream resource area through groundwater recharge.

MASSHIGHWAY STORMWATER HANDBOOK

MassDEP and MassHighway collaborated on the MassHighway Stormwater Handbook, which provides guidance on developing storm water management strategies for highway projects in order to comply with the Massachusetts Stormwater Management Standards. The handbook describes how to determine whether the MassDEP Stormwater Management Policy applies to a particular project and how standards may apply to particular projects. The handbook also addresses design strategies that may facilitate compliance, and source control measures for controlling stormwater pollutant loads from stormwater runoff. Also provided is a process for screening and selecting BMPs for roadway improvement projects that meet the objectives of the MassDEP Stormwater Management Policy. The handbook is primarily intended for roadway designers, public works personnel, and other persons involved in the design, permitting, review, and implementation of highway and bridge improvement projects in Massachusetts.

MassDOT MS4 Permit

Phase II of EPA's National Pollutant Discharge Elimination System (NPDES) program applies to both roadway construction and existing roadways. Construction projects exceeding one acre of soil disturbance require filing a Notice of Intent with EPA under the NPDES Construction General Permit. NPDES Phase II Rule also applies to MassHighway, as it considers MassDOT to be an operator of an MS4. MassDOT currently holds an EPA NPDES Phase II Small MS4 General Permit (Permit #: MA043025), with a new MassDOT MS4 permit to be issued in the near future. The MS4 general permit requires MassDOT to:

- Develop and implement a storm water management program to reduce discharge of pollutants to the MEP.
- Develop measurable goals for the implementation of the stormwater management program and report on its progress on meeting those goals.
- Implement 6 "minimum control measures" :

- Public education and outreach
- Public involvement and education.
- Illicit discharge detection and elimination.
- Construction site runoff control program.
- Post-Construction stormwater management.
- Pollution prevention and good housekeeping in municipal operations.

MASSDOT'S STORMWATER MANAGEMENT PLAN

In MassDOT's *NPDES Stormwater Management Plan for MassHighway Owned and Operated Highways*, MassDOT explains how BMPs and associated goals are addressing each of the six minimum control measures laid forth in the MS4 permit. MassDOT's MS4 Permit also requires MassDOT to evaluate its discharges that fall within a watershed of a 303(d) listed water body. When a discharge drains to a listed waterbody for which a TMDL has been developed, the MS4 Permit requires MassDOT to comply with additional requirements. Discharges to impaired and TMDL watersheds are being addressed by MassDOT's Impaired Waters Program and MassDOT's TMDL Watershed Review Program, respectively.

IMPAIRED WATERS PROGRAM

Starting in June 2010, MassDOT committed to assess all impaired water body segments that receive (or potentially receive) stormwater runoff from MassDOT roadways located in urban areas within five years. "Impaired" water body segments are those listed as Category 4a or 5 in MassDEP's Integrated List of Waters (referred to as the 303(d) list). MassDOT plans to complete assessment of all the identified impaired waters by June 2015. The program initially included approximately 684 impaired waters, which include all 303(d) waters whose sub-basins contain some portion of MassDOT's urbanized area roadways. To date, MassDOT has assessed 561 water bodies, 82 assessments have moved into design, 11 sites are under construction and 16 are completed. By identifying 303(d) waters that lie within 500 feet of at least one stormwater outfall from an urbanized roadway, MassDOT prioritized assessment by the total number of outfalls within this 500-feet area.

The assessment includes identifying impairments related to highway stormwater runoff, mapping locations of MassDOT outfalls relative to 303(d) waters, conducting site survey of discharge points and drainage infrastructure, identifying control measures and BMPs to ensure stormwater discharges will not cause exceedances in water quality standards, and designing and implementing BMPs.

The assessment also determines whether stormwater runoff from the roadways drains to the water body, and whether existing BMPs effectively treat runoff from the roadways. The assessment then sets a treatment target. When the target is not met, MassDOT will design and construct additional water quality BMPs where technically feasible. MassDOT is implementing this program through two initiatives: the Retrofit Initiative and the Programmed Projects Initiative. The Retrofit Initiative identifies locations where BMPs could be added along existing roadways, while the Programmed Projects Initiative explores where BMPs are warranted within planned roadway construction projects. MassDOT has developed an impaired waters geospatial database to track BMP design and construction, as well as the status of water body assessments.

TMDL WATERSHED REVIEW

MassDOT will assess TMDL reports wherever a TMDL has been approved for a water body into which MassDOT's urbanized roadways discharges storm water.

MassDOT has conducted an initial review of these 41 final TMDL reports to determine whether the TMDL WLA, BMP recommendations, or other performance requirements for storm water discharges that are applicable to MassDOT.

The assessment includes identifying TMDL Waters to which MassDOT's urbanized roadways may potentially discharge stormwater, conducting a site survey of discharge points and drainage infrastructure, calculating loading from MassDOT Stormwater as it compares to the WLA, assessing whether the WLA is being met through existing storm water control measures or if additional control measures may be necessary, and finally selecting, designing, and implementing BMPs.

PRIORITIZATION OF BMP INSTALLATION

MassDOT has developed a BMP Summary Matrix, comparing BMPs as they perform in regards to managing peak flows, recharge, TSS removal, pollutant loadings, and soil infiltration capacity, as well as other parameters such as drainage area, clearance to bedrock, clearance to high water table, setback requirements, land area, slope, and maintenance sensitivity.

MassHighway's policy is to give "critical" waters (which includes Class A waters and Zone I WPAs) higher priority in terms of implementing storm water BMPs.

MASSDOT EFFORTS RELATED TO CAPE COD TMDLS

MassDOT reports on its stormwater related activities in annual reports under the 2003 NPDES Phase II Small MS4 General Permit (available at https://www.epa.gov/npdes-permits/2003-small-ms4-general-permit-archives-massachusetts-new-hampshire#ma). As of the most recent report (Permit Year 15, April 2017-March 2018) MassDOT completed its statewide review of TMDL watersheds and assessed the need for additional BMPs to meet TMDL recommendations. Construction of a stormwater BMP to address the Herring River nitrogen TMDL was scheduled for Fall 2017, and other TMDL related projects may be planned in concert with future construction activities. Table 5, adapted from a table in the PY11 Annual Report, shows MassDOT stormwater work that has been completed or is planned in TMDL watersheds.

TABLE 5. MassDOT Actions in Cape Cod TMDL Watersheds

BASIN/ TMDL NAME	POLLUTANT	MASSDOT ACTIONS COMPLETED	TO DO
Final Pathogen TMDL for the Buzzards Bay Watershed	Pathogens	MassDOT has reviewed outfalls for potential illicit discharges and found that the linear nature of their roads leads to minimal chances for illicit connections. MassDOT has focused on education of staff and following up on potential illicit connections and focusing reviews on sensitive receiving waters. MassDOT is currently prioritizing watersheds for focused illicit discharge review.	TMDL identifies potential sources of bacteria as illicit sewer connections and stormwater runoff, among others. Recommendations are to prioritize dry weather bacteria source tracking. Further recommendations include evaluating impaired waterbody segments for BMPs starting with intensive application of less costly non- structural practices such as street sweeping and monitoring of their success
Allen, Wychmere & Saquatucket Harbors	Nitrogen	The TMDL suggests that compliance with MS4 permit requirements will contribute to the goal of reducing the nitrogen load for Allen, Wychmere, and Saquatucket Harbors watersheds	MassDOT will continue to comply with its Stormwater Management Plan under the NPDES MS4 Permit
Final Pathogen TMDL Report for the Cape Cod Watershed	Pathogens	MassDOT is currently prioritizing watersheds for focused illicit discharge review. Remaining potential pollution sources to Oyster Pond are believed to be several large stormwater discharges discharging into the east end of the pond. These stormwater discharges drain from Route 28, and Main St. MassDOT has plans to fix the problems coming off Route 28, and the Town of Chatham has performed engineering projects to eliminate/treat the stormwater components coming off Main St.	1. Development of comprehensive stormwater management programs, particulary in close proximity to each embayment, including identification and implementation of BMPs 2. Illicit discharge detection and elimination (where applicable).
Final Pathogen TMDL for the Three Bays Watershed	Pathogens	MassDOT has completed the statewide review of TMDL watersheds for additional BMPs were identified, they have been or will be included in future construction projects.	Determine the Route 28 roadway drainage area discharging to the Marstons Mills River and install best management structures and/or operational practices to the maximum extent practicable. Infiltration structures and devices that have been installed to control the road runoff from Route 28 into

			the Marstons Mills River should be inspected to determine their performance and condition. MassDOT should also continue to identify and implement to the maximum extent practicable best management practices so that the water quality standard for bacteria in SA waters is met.
Final TMDL Report of Bacteria for Frost Fish Creek, Chatham	Bacteria	MassDOT has completed the statewide review of TMDL watersheds for additional BMPs were identified, they have been or will be included in future construction projects.	Determine the Route 28 roadway drainage discharging to Frost Fish Creek and install best management structures and/or operational practices to the maximum extent practicable with a goal of meeting the water quality standard for bacteria in SA waters.
Final TMDL Report of Bacteria for Muddy Creek, Chatham	Bacteria	The Route 28 culvert over the MuddyCreek has been replaced through a project funded by Massachusetts Department of Environmental Restoration. The new roadway crossing eliminated the tidal restriction and included leaching basins to treat stormwater discharge before entering Muddy Creek. This project has implemented all improvements feasible to improve water quality of MuddyCreek as it relatesto Route 28.	Will review TMDL and determine if additional controls are needed. Should determine drainage area discharging to Muddy Creek and install BMPs that are designed to meet TMDL.
Herring River	Nitrogen	TMDL states that runoff from impervious surfaces is a negligible source of nitrogen load to the river when compared to other sources. The TMDL suggests that compliance with MS4 permit requirements will contribute to the goal of reducing the nitrogen load for the Herring River Estuarine System.	MassDOT will continue to comply with its Stormwater Management Plan under the NPDES MS4 Permit. MassDOT has designed and is planning to construct a stormwater BMP (water quality swale) to treat direct discharges to the Herring River fromRoute 6 at the Route 6/Herring River crossing. Construction is scheduled to begin in the Fall of 2017.
Final Nutrient	Total Nitrogen		

TMDL for Centerville River/East Bay	
Final Nitrogen TMDL for Little Pond	Total Nitrogen
Final Nitrogen TMDL for Oyster Pond	Total Nitrogen
Final Nitrogen TMDL for Phinneys Harbor	Total Nitrogen
Final Nitrogen TMDL for Pleasant Bay System	Total Nitrogen
Final Nitrogen TMDL Report for Five Sub-Embayments of Popponesset Bay	Total Nitrogen
Final Nitrogen TMDL Report for the Quashnet River, Hamblin Pond, Little River, Jehu Pond, and Great River in the Waquoit	Total Nitrogen

Bay System	
Final Nitrogen TMDL Report for the Three Bays System	Total Nitrogen
Final Nitrogen TMDL for West Falmouth Harbor	Total Nitrogen
Final Nitrogen TMDL Report for Five Chatham Embayments (Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor and Muddy Creek)	Total Nitrogen
Final TMDLs of Nitrogen for Great, Green, and Bournes Pond Embayment Systems	Total Nitrogen

Coordinating Transportation Stormwater Infrastructure with the 208 Plan

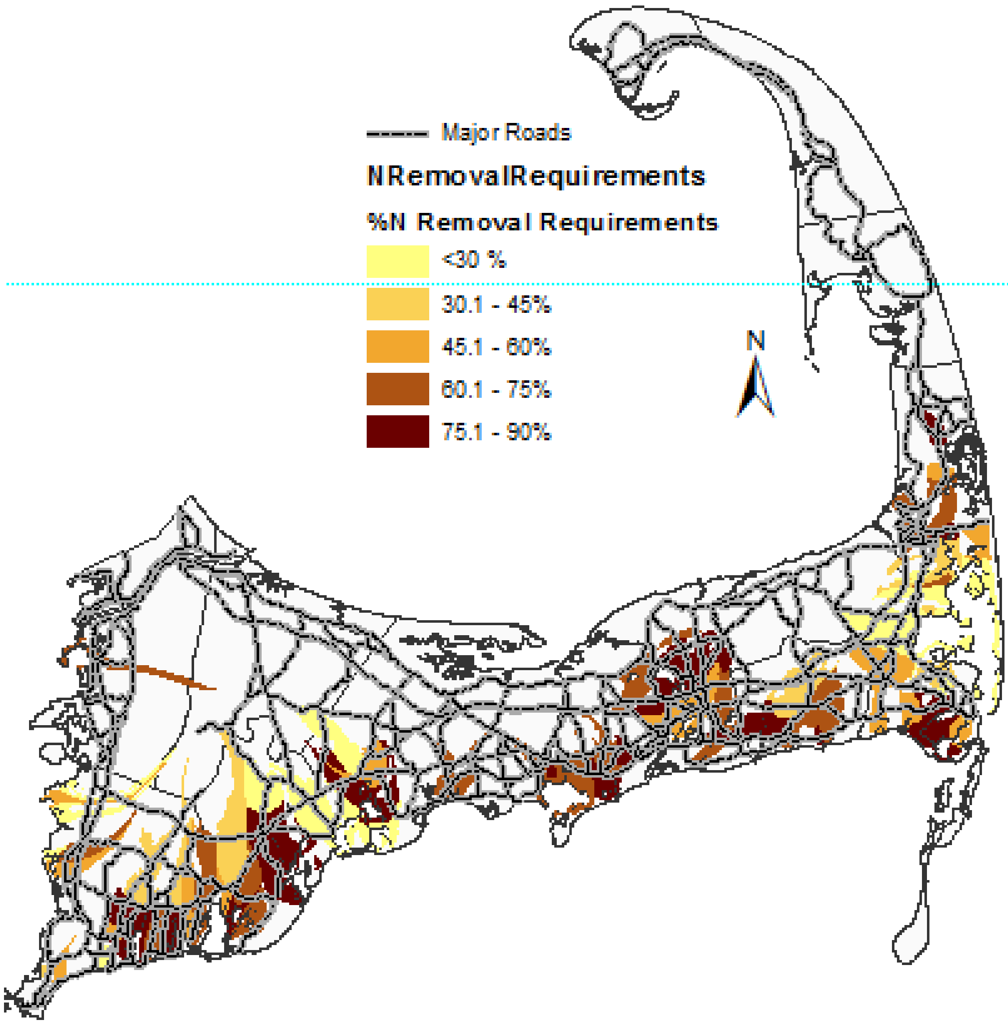
The Cape Cod Area Water Quality Management Plan Update, also known as the “208 Plan,” addresses options for Cape Cod communities to address nitrogen loading from controllable sources in Cape Cod watersheds. The 208 Plan outlines many options for addressing nitrogen loading that include the traditional approach of sewering, as well as many alternative approaches such as installing permeable reactive barriers, constructed wetlands, ecotoilets, aquaculture and shellfish bed restoration. There are ample opportunities where stormwater management design on Cape Cod roadways should be coordinated with nitrogen reduction goals of the 208 Plan.

Cape Cod communities that consider constructing sewers as part of their nitrogen mitigation strategy can simultaneously incorporate stormwater management efforts on Cape Cod roadways. For example, as roads are repaved, communities can inspect water and sewer conduits, storm drains, remove illicit connections to sewers and storm drains, repair leaks, and make any other necessary repairs.

Some of the alternative technologies in consideration for nitrogen management on Cape Cod as part of the 208 Plan are actually stormwater treatment systems that also provide significant nutrient removal. Examples of stormwater BMPs proposed for nitrogen management are bioretention/soil media filters, phytobuffers, vegetated swales, and stormwater constructed wetlands. All of these technologies provide physical filtration, uptake of pollutants within plant tissue, nitrification and denitrification, and other microbial biochemical processes that effectively remove a broad range of pollutants from the water column. According to the Draft MS4 Permit, Cape Cod communities need to consider installing BMPs that significantly reduce nitrogen where discharges occur in nitrogen TMDL watersheds.

For optimal effectiveness, sewer infrastructure and alternative nitrogen reduction technologies should be located in areas that contribute the most nitrogen loading to impaired embayments. Roadway development or upgrades within watersheds that require a high amount of nitrogen removal should consider opportunities to (1) include sewer infrastructure alongside current roadway plans and (2) implement stormwater BMPs to remove nitrogen.

FIGURE 13. Nitrogen Removal Requirements in Subembayments



Regional Policy Plan Considerations for Stormwater Management

Transportation infrastructure related to development or redevelopment may be subject to regional regulation by the Cape Cod Commission. If the development project meets a specific size or other threshold identified in the Cape Cod Commission's "Enabling Regulations for the Purpose of Reviewing Proposed Developments of Regional Impact (DRIs)," the project will be subject to review. In order for the project to be granted approval, the project must be consistent with the Goals and Objectives of the RPP (as well as local comprehensive plans, zoning, etc.). In its review, the Commission must also find that the probable benefits of the proposed project outweigh the probable detriments. The Commission may consider best practices and design elements that exceed minimum requirements in this analysis.

Design requirements related to Stormwater Quality are applicable to all DRI projects. Standards related to roadway runoff dictate on-site infiltration practices and devices, bioinfiltration practices, minimum of 2-foot separation to groundwater for infiltration basins or other stormwater leaching structures, and development of maintenance and operation plans. Additionally, the standards require limiting impervious surfaces by constructing overflow peak parking areas from pervious materials (porous pavement, permeable pavers, or grass pavers), and that bioremediation should be incorporated in to parking islands and roadway perimeters. Also in the RPP is the recommended practice of limiting roadway lane widths to 9 feet to minimize runoff from impervious surfaces.

CAPE COD COMMISSION

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