Route 6 Stormwater and Vegetation Management Plan

Version 1- September 30, 2016

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September 30,2016- Version 1

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Image: Route 6 Eastbound Mile Marker 88

CHAPTER 1

INTRODUCTION

Route 6 Stormwater and Vegetation Plan

Project Background and Purpose

This report describes existing regulations, policies and guidelines that govern stormwater and vegetation management within the Route 6 right-of-way and makes suggestions for potential improvements to these systems with consideration for the maintenance conventions and policies currently utilized at MassDOT. Route 6, or the Mid-Cape-Highway corridor, is a critical aesthetic gateway to the Cape and an environmental linkage that passes through an ecosystem with sensitive drinking water and coastal resources. Although this MassDOT owned roadway has been updated and maintained over the years, much of the stormwater functions and vegetation management practices along the Route 6 corridor are guided by a system developed over 50 years ago. The additional volume of both cars and precipitation over the years has heightened potential impacts to both local ecologies and water quality. The stormwater challenge is compounded by Route 6's location on top of the Cape's sole source aquifer which produces over 80% of all public drinking water on the cape. The goal of this plan is to provide stormwater and vegetation management recommendations that maintain the character and ecological structure of the corridor intact while also providing a useful document that can steer management techniques from an ecological, human and environmental health perspective.

In the built environment of Route 6, many different site influences release pollutants that affect environmental quality. In addition to stormwater running over paved surfaces, emissions from cars and trucks can form particulate matter air pollution that moves through the air and settles in dust that can be transferred into water bodies. The purpose of this report is to consider natural alternative technologies, phytoremediation concepts, and vegetation management approaches to improve the ecological functioning of stormwater and vegetation systems along the corridor while also considering aesthetics of this important gateway to Cape Cod. Stormwater Best Management Practices (BMPs) have the ability to mitigate nutrients and other contaminants such as heavy metals and petroleum compounds. The purpose of this report is to not only consider what BMPs may be appropriate along Route 6 to benefit water cleansing, but also may create a layered multi-functional landscape that serves other ecological plant and wildlife systems and enhancing the built environment. The large scale ecological system of Route 6 is summarized within this document and suggestions to create site specific interventionshhp that operate at many scales to benefit multiple systems are provided.

Included is guidance for Route 6 stormwater practices, native plant preservation and protection, invasive plant control and vegetation maintenance for the section of Route 6 between the Sagamore Bridge and the Orleans Rotary. The included recommendations meet the goals of the Cape Cod Commission's Regional Policy Plan and the 208 Water Quality Plan update while also considering the maintenance conventions and polices currently utilized at MassDOT in order to provide the greatest long term benefits. The goal of these recommendations is to encourage low impact changes in the corridor that enhance both ecological systems and scenic character.

Project Scope, Project Team & Methodology

The scope of this project covers the Route 6 right-of-way from the Sagamore Bridge to the Orleans/Eastham Rotary. For the purposes of this study, we identify segments of the roadway referred to by Exit number and delineated by east-bound (EB) or west-bound (WB).

The study area includes approximately 36 linear miles along the Route 6 Right-of-Way (ROW) corridor from the south side of the Sagamore Bridge extending to the rotary in Orleans. The section travels through eight different towns, including, from west to east: Bourne, Sandwich, Barnstable, Yarmouth, Dennis, Harwich, Brewster and Orleans.

The highway through the study area consists of a four-lane (two lane each direction) east/west bound highway divided by a vegetated median of varying width between the Sagamore Bridge and exit 9. The width of the median ranges from approximately 15' to 300'. Typically the farther east towards exit 9, the wider the median. From just after exit 9 to the Orleans rotary, it becomes a two-lane (one lane in each direction) east/west bound highway with a small paved median. The entire length has limited gravel and grass shoulders. Roads besides Route 6 that are within the ROW include: a service road that runs to the south of Route 6 between exits 2 and 6, the majority of White's Path between exits 8 and 9, parts of Old Chatham Road and Factory Road between exits 9 and 10, part of Long Pond Drive between exits 10 and 11, part of Baker's Pond Road between exits 11 and 12 and parts of Skaket Beach Road and Rock Harbor Road between exit 12 and the rotary. The study area consists of the following:

- 2,146 acres
- Approximately 36 linear miles of paved roadway
- Approximately 26% percent of impervious cover which is predominantly comprised of the roadway surfaces, but also includes at least parts of approximately 20 parking lots, and some building roofs located within the ROW.
- The remaining area (approximately 74%) is comprised of the following:
  - 73% woods and grass
  - 1% wetlands
  - <1% water surfaces (ponds and rivers)

Route 6 Sagamore Bridge to Orleans Rotary Study Area Calculations
R.O.W.
2,146.07 Acres
190,389.25 Linear feet
36.06 Miles
IMPERVIOUS COVER
547.94 Acres
26% Impervious
WOODS/GRASS
1,598.12 Acres
WATER BODIES
7.68 Acres within R.O.W.
IMPAIRED WATER BODIES
5.07 Acres

The Route 6 Hydroplaning Crash Analysis and Alternatives Development Study, completed by the Cape Cod Commission in 2013, examined the sources of wet-weather related crashes on Route 6 and recommended improvements to facilitate stormwater off the roadway, while improving water quality. For the purposes of the study, Route 6 was categorized into 4 distinct analysis segments (see Table 3): Sagamore Bridge to Exit 6; Exit 6 to Exit 9; Exit 9 to Exit 12; and Exit 12 to Orleans Rotary. These same segments have been used in this report for consistency and data from the Hydroplaning Study was incorporated into this report's recommendations as well.

The project team comprised of Offshoots, Horsley Witten Group (HW) and Professional Environmental Services (PES) combines the complimentary disciplines of landscape architecture, civil engineering and vegetation management (arborists) to provide a well-rounded existing conditions analysis and stormwater and vegetation recommendations for the corridor. The team's methodology is described below.

Prior to beginning the assessment and fieldwork, our team compiled geo-spatial and cartographic data provided by the Cape Cod Commission (CCC) and the Office of Geographic Information (MassGIS). This data was used to determine the existing conditions and site constraints within the study area and included the Route 6 corridor boundaries, total study area in acres, length of roadway, surface cover types (i.e. impervious, woods and grass), topography, watershed boundaries, water bodies, wetlands soils, endangered species habitat, resources protection zones/buffers and general drainage patterns. The team also relied on information and data collected as part of Horsley Witten's (HW) on-going stormwater improvement project with the Massachusetts Department of Transportation (MassDOT). HW has been working with MassDOT on the stormwater design evaluation of approximately 8.6 miles of Route 6 from the Orleans Rotary to Exit 9 in the Towns of Dennis, Harwich, Brewster and Orleans, MA. To date, HW has reviewed existing information, including the existing highway drainage system network and existing environmental conditions (e.g., topography, soils, etc.), and has conducted field assessments to evaluate potential for stormwater improvements. Preliminary evaluations of field data have been performed to identify stormwater retrofit opportunities as well as maintenance needs. This detailed work in the project area is timely and findings have influenced the recommendations provided within this document.

Following the data collection, project team members from Offshoots, HW, and PES completed a "drive-by" or "windshield" assessment of the Route 6 corridor from the Sagamore Bridge to the Orleans rotary. Elements that were observed during the assessment include: overall visual health of existing vegetation, representative plant communities, landscape features and location of existing stormwater management areas. The general assessment of existing conditions in the corridor is documented in Chapter 2 of this document.

Following the site analysis, recommendations for how beneficial stormwater practices can be prioritized along the corridor are provided in Chapter 3. A matrix of stormwater practice options best suited to the corridor and utilizing low impact development and phytoremediation techniques is provided to help prioritize sites and identify the most suitable practices for those areas. This work builds upon MassDOT work already completed for the area after Exit 9 towards the Orleans Rotary and considers stormwater practice types that will benefit plant communities, landscape aesthetics and other corridor functions.

Lastly, in Chapter 4, vegetation management strategies for long term maintenance are suggested to improve the corridor.

Image: Route 6 Eastbound, 1 mile before Exit 11

CHAPTER 2

SITE ANALYSIS & EXISTING CONDITIONS

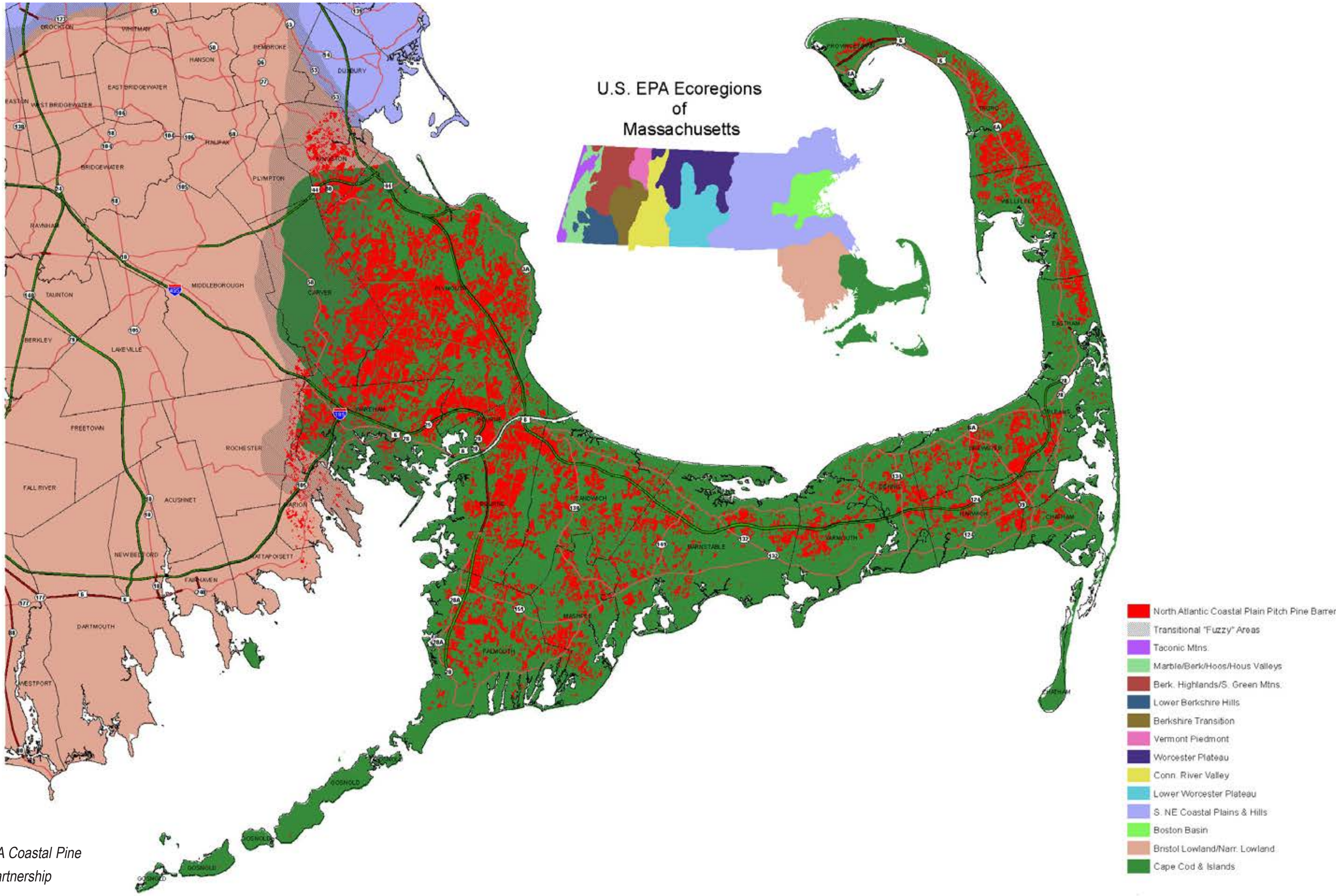
Route 6 Stormwater and Vegetation Plan

Existing Vegetation

The Route 6 corridor contains several plant communities ranging from disturbed landscapes of invasive species to mature pine barrens that represent a unique landscape of the coastal north-east from Cape Cod to southern New Jersey. Southeastern Massachusetts contains the second largest remaining Atlantic Coastal Pine Barren, just behind New Jersey's Pinelands. (SEMPBA) (Forman, 1998). The ecoregion between Duxbury and Provincetown, including the Route 6 Right-of-Way (ROW) is a diverse, dynamic but fragile Pine Barren region threatened by development. Arising from the most recent ice age, the coastal plain was left a sheet of sand, gravel and boulders on-top of bedrock, leaving behind the distinctive kettle-hole ponds, natural depressions and frost holes that are spotted throughout the Cape landscape. The pine barren (pitch-pine-scrub-oak forest upland ecosystem) is a designated plant community identified by the Massachusetts Division of Fisheries and Wildlife Natural Heritage and Endangered Species Program (NHESP) and it is a unique ecological condition, important to preserve. This ecosystem paired with Route 6's positioning over the Cape's sole-source aquifer makes the stormwater and vegetation management discussion important for management and conservation.

WHAT ARE PITCH PINE/SCRUB OAK BARRENS?

Pitch pine/scrub oak communities are an open shrub-land plant community that occurs on outwash sandplains. These communities, (called pine barrens), typically have an open canopy of pitch pine (Pinus rigida) and a frequently dense understory of scrub oaks (Quercus ilicifolia) up to 2-3 meters (7-10 feet) tall and shorter huckleberry/blueberry cover about a meter (3 feet) tall. Pitch pine/scrub oak communities are not floristically very diverse; the combination of few species plus the physical structure of the vegetation defines the natural community. A pine barren can consist of a canopy of 100 percent pitch pine or scrub oak or a combination of both. There is often a mosaic of pitch pine, scrub oak, heaths such as huckleberry, lowbush blueberry, and bearberry, broom crowberry, birds foot violet or lichen, which is the condition of much of the native vegetation along the Route 6 corridor. Closer to the coast, scrub oak usually dominates. pine barrens are characterized by chemistry and acidity in the sandy soil systems. This causes the substrate to be extremely porous and although rainfall averages about 48 inches per year on Route 6, water drains very quickly. (USGS). Minerals such as nitrogen, phosphorus and sulfur travel through the soils leaving pine barren soils typically devoid of nutrients. The sands in summary are acidic, nutrient poor and drought prone which favors this vegetation type. In pitted outwash plains or rolling moraines, some low bowls, or kettles, are frost pockets and have more heath and lichen and less oak and pine. Deeper kettles that intersect the water table may have a Coastal Plain Pond.



Source: MA Coastal Pine Barrens Partnership

WHAT IS HAPPENING TO THE PINE BARRENS OF SOUTHEASTERN MASSACHUSETTS?

Pitch pine/scrub oak communities change into other plant species types if there is no disturbance such as fire.

Barrens communities are dependent on periodic disturbance to prevent them from becoming overgrown by taller hardwoods such as black oak, white oak, black cherry, and shadbush. On Cape Cod, many former barrens communities have already reverted to upland forests because of the lack of periodic fire or other disturbances. Due to increased human habitation of Cape Cod over the last fifty plus years, fire suppression activities to protect communities from wildfires were increased thus allowing the closure of the tree canopies and the increased nutrient loading of the forest floor. These conditions are slowly changing the face of the forest type on Cape Cod. As shown on the map, the pine barrens as they exist today on Cape Cod are indicated in red.

Wildlife

WHAT ARE THE IMPORTANT WILDLIFE DIVERSITY SPECIES SUPPORTED BY A PINE BARREN?

Pine barrens support a diversity of birds, insects, reptiles and mammals, many of which are on the Endangered Species list or the list of Species of Special Concern. Animals in the road corridor can be a safety concern for vehicles, but if properly managed, animals may also be able to safely use the corridor for habitat and connectivity between larger core habitat areas.

Pine barren birds:

- Eastern Towhee, Eastern Bluebird, Pine Warbler, Prairie Warbler, Prairie Warbler and the Whip-poor-will.

Pine barren insects:

- Persius Duskywing, Frosted Elfin, Slender Clearwing Sphinx, Barrens Buck Moth, Melsheimer’s Sack -Bearer Moth, Gerhard’s Underwing, Barrens Tiger Beetle and the Antlion.

Pine barren reptiles:

- Northern Red-bellied Cooter, Eastern Box Turtle, Eastern Hognose snake

Pine barren mammals:

- Fisher- not necessarily restricted to pine barren landscapes, but were once completely eliminated from the state due to land clearing for agriculture and are now beginning to move back. They find sustenance in many of the pine barren plant materials such as blueberries but preference squirrels, porcupines, mice, birds and fish. (Nature Conservancy)
- Cottontail rabbit

In addition to these species, there are a number of insects that support the unique habitat as well as some which threaten the survival of tree species within the corridor, such as the gypsy moth.

The widespread gypsy moth defoliation of deciduous trees in Massachusetts in 2016 is a result of lack of rain in the spring which normally spurs a fungus keeping the moths in check. The dry conditions in 2016 have led to large infestations of gypsy moths feeding on both their preferred oak trees as well as other deciduous tree species and coniferous pine trees. Trees are resilient to defoliation if they have time to recover in following years. However, if gypsy moths begin appearing in concurrent years, the Route 6 tree canopy could see a notable change in mortality that could be devastating to the landscape and ecology in the region. It is important to think of the Route 6 corridor for desirable species but also as a potential conveyance of unwanted species as well.

Existing Plant Communities

An analysis of existing plant communities was derived from a "drive-by" assessment of vegetation completed in July 2016. (Large scale maps of the existing plant communities identified (by segment) can be found in the appendix on page 5:10.)

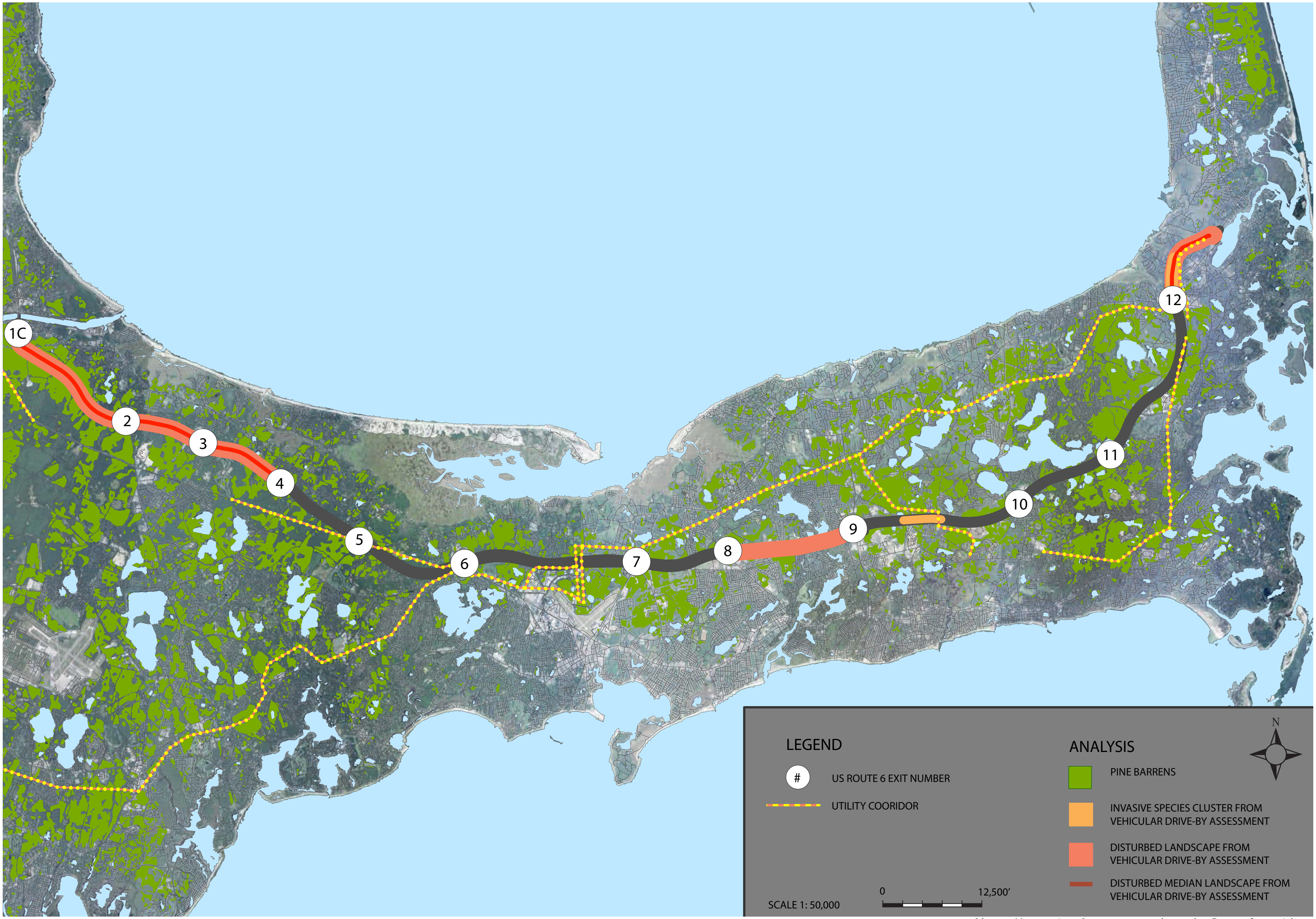
SEGMENT 1

SAGAMORE BRIDGE TO EXIT 6

This section of Route 6 R.O.W. in both EB & WB directions is the most disturbed landscape within the study area in terms of vegetation analysis. From the bridge to Exit 2, the roadway is 4 lanes and approximately 200 feet wide with the median area around 30', which is a smaller median than most other areas of the corridor. As noted in the Route 6 Hydroplaning Crash Analysis, (CCC, 2013) since the median width is small, there are occasional guard rails for safety reasons. The median in this area contains very few native plants and opportunities for vegetated stormwater management systems within the small median area may be minimal. The area has the typical signs of disturbed landscapes, with invasive species, specifically knotweed, black locust, norway maples, tree of heaven, muti-flora rose and Japanese bittersweet creating a very sparse tree canopy of mostly emergent species in the median. In the Clear Zones along the edges of the roadway, a thick cover of invasive understory plants is present. (See page 2:18 for Clear Zone definition.) A utility corridor passes over the highway right of way just after Exit 1C EB and again a few hundred yards later. Where the utility lines pass overhead, the species underneath are distinctly invasive due to soil disturbance, repeat cuts, soil nutrient loading and height management.

About 1 mile before exit 2, the tree cover increases in density within the median but the species are still showing signs of a disturbed landscape. The lack of berms and a narrow median in this area can be a problem for visibility with blinding headlights in either direction. The Clear Zones in this area are populated with both grasses and invasives species. Between exits 2 and 4, the median landscape is characterized by pockets of trees alternating with

Table 1. Route 6 Segments							
SEGMENT	**# LANES**	**R.O.W. WIDTH**	**DATE CONSTRUCTED**	**SHOULDERS**	**PAVEMENT EDGE**	**MEDIAN**	**STORMWATER**
Segment 1: Bridge to Exit 6	4, divided	200-500 ft	1950,1954	Hardened and graded	Paved berm	30-60 ft graded in places, natural	Catch basins
Segment 2: Exit 6 to Exit 9	4, divided	400-500 ft	1955, 1967, 1971	12 ft paved to Exit 7, hardened and graded	None, granite, or paved berm	70 ft, graded in places, natural	Outflow channels, catch basins, country drainage
Segment 3: Exit 9- Exit 12	2, undivided	300 ft	1956, 1958	Hardened and graded	Paved berm	Paved berm	Catch basins
Segment 4: Exit 12 to Orleans Rotary	2, undivided	200 ft	1959	Hardened and graded	Paved berm	Paved berm	Catch basins



Source: Disturbed landscape layers from drive-by analysis completed by project team in July 2016. Utilites: Mass GIS Pine Barrens: MA Coastal Pine Barrens Partnership

Above: Vegetation Assessment along the Route 6 corridor .

For larger scale map, please see the seperate map atlas provided with this document.

large open swaths of minimal vegetation and wider medians between 40-60 feet. It is also the location of overcutting performed by a MassDOT contractor in 2014 of approximately 2.5 acres within the 1.2-mile median segment. While 350 trees were replaced with evergreens, flowering and deciduous vegetation due to public outcry, the area remains disturbed, with both pine barrens and invasive species beginning to fill in. Many of the planted trees are not related to the pine barrens landscape and are not performing well, and prior vegetation is rebounding around them. The Clear Zone in this area again has a significant number of non-native species, but beyond the Clear Zone where vegetation has not been cut, significant stretches of pine barren vegetation are present. The area between exits 5 and 6 EB was identified in the Hydroplaning Study as having a large number of wet weather crashes. However, in terms of vegetation, we begin to see a more mature forested landscape after exit 4, with representative pine barren species such as scrub oak, pitch pine and understory such as blueberry and huckleberry shrubs.

There are three utility corridor crossings between Exit 5 and 6 in Hyannis, and a larger number of invasive species are present where these crossings occur, as well as wherever bridges cross the highway and soil disturbance has taken place.

SEGMENT 2
EXIT 6 TO EXIT 9

This section of roadway traverses a largely developed portion of landscape, through the towns of Hyannis, Barnstable, Yarmouth and Dennis. The immediate roadway edges show loose aggregates and grasses and mowing has kept the native understory from creeping out below the tree line. This area has very wide median areas ranging from 400-500 feet wide. The Bayberry Hills Golf Course is in close proximity to the southern R.O.W. as is a number of industrial uses. A wide utility corridor crosses Route 6 just before Exit 7 EB to connect to a transmission plant. Buffering between the road and this development is sparse, especially in the segment between Exit 8 and 9 EB.

SEGMENT 3
EXIT 9 TO EXIT 12

According to the hydroplaning analysis, the WB lanes between Exit 11 and 10 have widespread drainage issues that contribute to wet weather crashes. This area is in a narrow section between large wetlands and kettle hole ponds. There are also large clumps of invasive species present- at mile marker 79 a large prevalence of knotweed exists on both sides of the roadway. There is a utility crossing in North Harwich between exit 9 and 10 and the Cape Cod Rail trail passes over the highway a few hundred yards before exit 10; in both of these locations, significant stands invasives are present at the crossings.

SEGMENT 4
EXIT 12 TO ORLEANS ROTARY

The section between exit 12 and the Orleans Rotary has similarities to the Sagamore Bridge to exit 4 section, in which mostly disturbed invasive landscape species are present in the median rather than native pine barrens species. This section of median is heavily populated with Robinia (Black Locust), around mile marker 89. When entering the rotary EB, there is a commercial property within close proximity to the road that is visible and would benefit from additional screening vegetation. This section also includes several transmission line outlets which are mowed for maintenance by utilities but should be tied into any management plan with MassDOT.

This area is also noted for its proximity to Cedar Pond, just before the Orleans Rotary to the South of Rt 6. The pond has faced a number of issues related to high nutrient content over the years, and sits adjacent to a mature Atlantic white cedar swamp. The most recent impact on water quality is due to cormorants roosting on wires above the pond. Eversource is currently proposing a plan to underground the wires that run over the pond to improve the water quality at a cost of nearly $1 million which is being reviewed by the Town of Orleans and the Department of Environmental Protection. Entering the rotary, the landscape is overgrown and tangled with many vine species and remnants of a more deliberate planting, with junipers, bayberry, hollies and some grasses mixed in. The rotary center appears to show a depression and may present an opportunity for both stormwater management and an attractive landscape gateway treatment. Leaving the rotary and moving WB, there is significant Black Locust mixed with grape, knotweed and scrub oak. In general, this section of the road corridor contains numerous species indicating a disturbed landscape with fewer native pine barrens species.

Invasive Species Site Analysis

Mature pine barrens have low nutrient content, low soil pH and low water holding capacity making it an undesirable habitat for most invasive plants. However, roadsides are prone to disturbance by nature and any fill materials, construction practices, erosion control, drainage interventions, especially compaction and the addition of new loam, lime or fertilizer, make these areas highly susceptible to a shift in plant community toward invasive species.

Invasive species can spread along a roadway and even into a forest system nearby based on a number of factors. Wind can move seeds, as can birds and other animals that eat the seeds or catch them on their fur. In addition, substrates can be carried on vehicles or transported through drainage systems. In cold climates, road salt can perpetuate the growth of plants that are saline or salt adapted, shifting the species mix away from the natural systems that previously existed. Turbulence from moving vehicles and snow removal can combine with natural wind or storm events to further move seeds around. Disturbed areas near many of the on and off-ramps in the study area, utility lines and along cut areas of the median and highway show significant signs of invasive species becoming the dominant plant community. These species are typical of roadway disturbance and are found along corridors throughout the country.

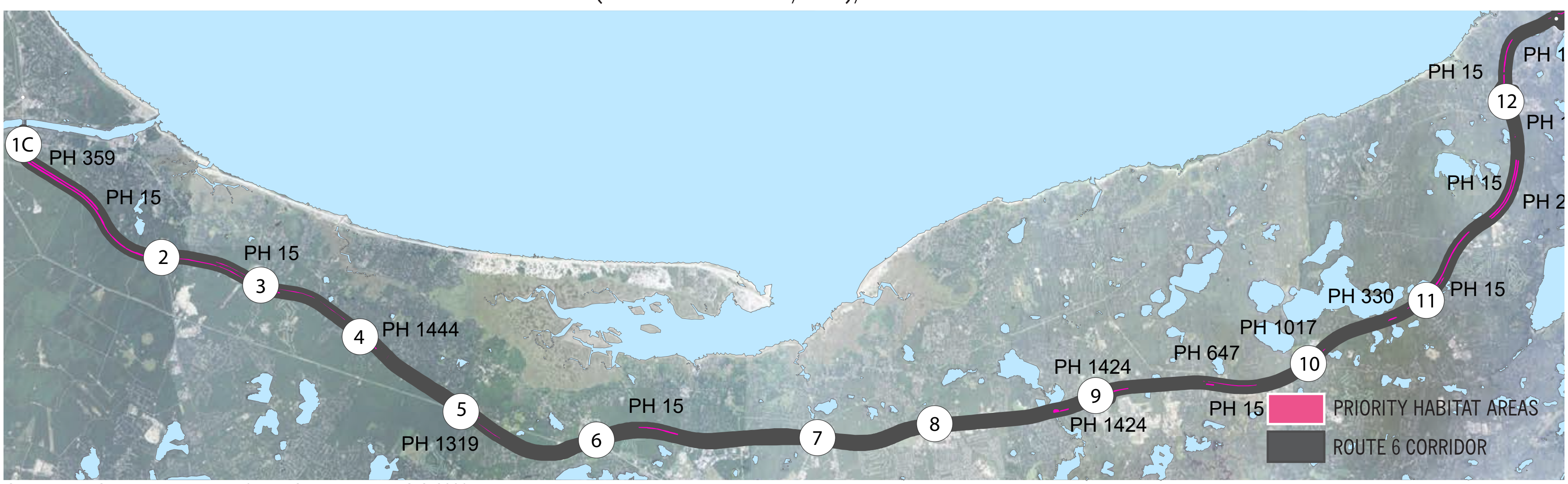
ROBINIA

Robinia pseudoacacia (Black Locust) is an invasive hardwood tree in North America that is prevalent in disturbed areas along the Route 6 corridor and alters soil N cycling. It is a shade tolerant species native to

Above: Invasive species along Route 6 from top, Norway Maple, Multi-flora Rose, Black Locust the Central Appalachian and Ozark Mountains that is considered by many to be a detrimental invasive species on Cape Cod. One study found that even 14 years after Hurricane Bob destroyed *Robinia* populations on Cape Cod, they left a legacy of changes to soil nitrogen (N) cycling. In coastal forests such as Cape Cod, higher soil nitrate concentrations and nitrification rates have potential to increase leaching and N loss to groundwater. The study also found that nonnative species richness was significantly higher with any present and former *Robinia* stands than in pine oak stands. The study concluded that nonnative species that lead to elevated nutrient levels increase the likelihood that other non-native species will invade the habitats. (Von Holle et al, 2013) In order to control these species and promote the preservation and reestablishment of the pine barren plant community, a suggested vegetation management plan is provided in Chapter 4.

Natural Heritage & Endangered Species Program (NHESP)- 15%

According to NHESP and published in the 13th Edition of the Massachusetts National Heritage Atlas (effective October 1st, 2008), there are approximately 319 acres (15% of the study area) of mapped Priority and Estimated Habitat within the study area, with the Estimated Habitat areas all overlapping the Priority Habitat areas. There are ten different types of designated Priority Habitat areas and nine different types of Estimated Habitat areas of state listed rare species in Massachusetts. The areas are located in small and large patches all along the corridor with the largest break halfway between exits 6 and 7 to halfway between exits 8 and 9. Any proposed projects occurring within these areas must be reviewed by NHESP for compliance with the Massachusetts Endangered Species Act (MESA) and its implementing regulations.



Source: NHESP Priority Habitats of Rare Species – MassGIS 2009, NHESP Estimated Habitats of Rare Wildlife – MassGIS 2009

Above: Natural Heritage & Endangered Species along the Route 6 corridor . For larger scale map, please see the seperate map atlas provided with this document.

Tables 2 & 3- NHESP Priority and Estimated Habitat Areas within the Study Area	
PRIORITY HABITAT	
PRIHAB_ID	ACRES
PH 15	208.12
PH 1424	30.59
PH 359	24.96
PH 1319	21.75
PH 278	19.64
PH 1444	8.55
PH 647	2.48
PH 330	2.45
PH 1017	0.55
PH 1336	0.16
TOTAL:	319.25
ESTIMATED HABITAT	
ESTHAB_ID	ACRES
EH 79	199.30
EH 19	26.70
EH 217	24.96
EH 174	19.64
EH 163	11.72
EH 144	8.55
EH 624	7.87
EH 571	2.48
EH 230	2.45
TOTAL:	303.67

Vegetation Policy & Regulation

The Massachusetts Department of Transportation (Mass DOT) provides guidance through a Vegetation Management Plan that is updated every 4 years. The next update will be in 2018 and this document is an opportunity to provide recommendations to Mass DOT prior to that release. First and foremost, the agency's primary objective is to "provide safe use of and access to roadways, sidewalks and facilities and to preserve the integrity of highway infrastructure" (Mass DOT, 2014). However, the plan also notes the importance of providing stormwater control, habitat protection, managing native plants and enhancing the scenic quality of the roadside.

The MassDOT Roadside Vegetation Management Plan 2014-2018 describes three zones within the MassDOT right-of-way where varying degrees of vegetation maintenance is required: Roadway & Guardrail zone (ROW); Operation/Clear Zone; and Highway Buffer Zone. In certain cases a fourth class, Priority Landscape, is discussed.

ROADWAY & GUARDRAIL RIGHT-OF-WAY:

The Roadway and Guardrail Zone (ROW) is the area closest to travel lanes and containing guardrail, curbs, barriers and medians. It is currently shown as low vegetation or no vegetation and herbicide is used frequently alongside mowing in this zone to keep vegetation from interfering with visibility. If management on Route 6 were to shift, the roadsides of the Route 6 corridor could provide an opportunity to re-stitch the unique pine barrens landscape of the Cape that is disappearing with development over time. Vegetation is an important component of reducing stormwater runoff and increasing the amount of contaminant remediation in stormwater system design. However, if improperly maintained, vegetation can create dangerous conditions such as reduced visibility from overgrowth and damage existing infrastructure (e.g. guardrails & signage). The current primary method of vegetation control is by mowing, line trimming and herbicide application. When mowing is difficult due to infrastructure, herbicide application is the preferred method, as set forth in 333 CMR 11.00. For double-faced guardrail in the median, spraying is typically a 4 foot swath, 2 feet on each side. Vegetation that is low-growing or contained such that it does not interfere with visibility or structural integrity and is not unsightly is acceptable.

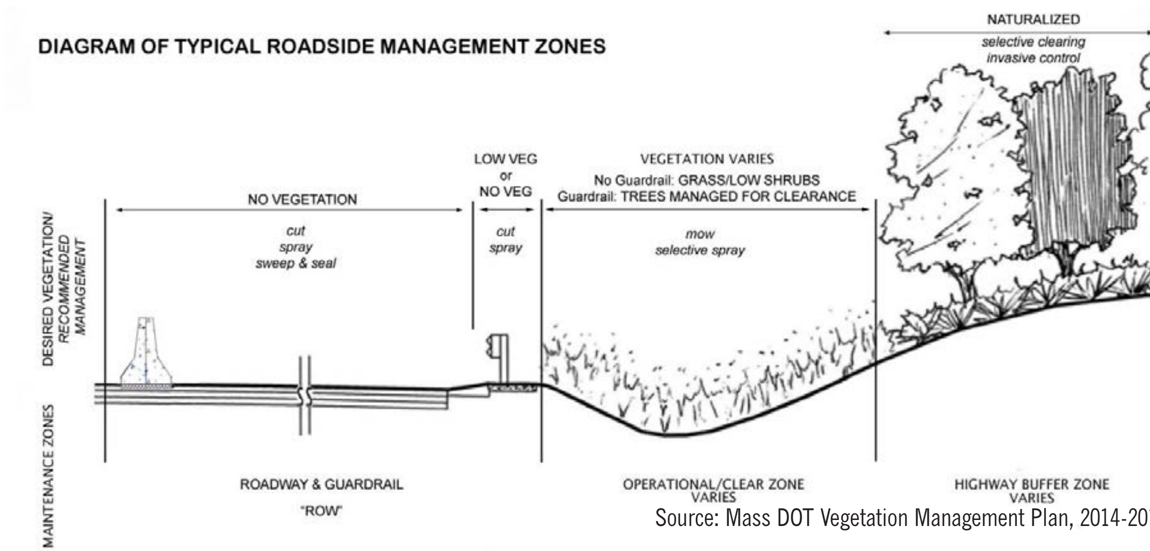
OPERATIONAL CLEAR ZONES:

The operational zone or clear zone, extends from the end of the ROW zone to a 20-30 foot setback as required for errant vehicle recovery, sight distances and other safety functions. The clear zone width depends on certain factors such as the presence of guard rails and the posted speed. Plant material is controlled if stem diameter can grow to greater than 4 inches and stormwater drainage and infiltration is often addressed in this zone. Current management consists of mowing 2 – 4 times per year. Grass, herbaceous species and low shrub groundcover or a mix is acceptable. Invasive perennial and woody plants are frequently problematic in this zone. Any trees are currently considered undesirable in this zone.

HIGHWAY BUFFER ZONE:

The Highway Buffer Zone extends from the clear zone to the edge of the right-of-way and the goal is to maintain and preserve a self-sustaining plant community, in the case of Route 6, the pine barren landscape. (Mass DOT, 2014). These areas are typically not managed except for tree cutting and for control of invasive plant species. The management objective in this zone is to maintain and preserve a self-sustaining plant community that provides: screening of the roadway for abutters, a continuous green corridor for roadway users, a protective buffer for rivers, wetlands and water bodies, and stormwater and habitat benefits.

Vegetation in the highway buffer zone is typically a variety of plant types (trees, shrubs, groundcover) and varies throughout the Commonwealth, consisting of primarily native plants to being highly infested with invasive plants such as bittersweet, knotweed, autumn olive, multiflora rose, buckthorn and Tree of Heaven.



Source: Mass DOT Vegetation Management Plan, 2014-2018

PLANTING & SENSITIVE AREA RESTRICTIONS:

For all herbicide applications, MassDOT and the application must follow existing regulatory requirements with the Massachusetts Department of Agricultural Resources (DAR), the Town Conservation Commission, MassDEP, and NHESP. MassDOT will be transitioning to GIS mapping to delineate application routes and restricted zones along transportation corridors. These GIS data layers will be made available to other agencies. Prior to the application of herbicides, maintenance crews will be provided topographic maps to confirm the boundaries of appropriate buffer zone in sensitive areas. These setbacks and restrictions, per 333 CMR 11.04, are shown on the included chart.

Stormwater Systems Site Analysis

U.S. Route 6 is an essential transportation corridor. However, based on the impervious nature of the asphalt and outdated stormwater management systems, heavy precipitation events can result in both environmental impacts and safety issues. While some portions of the highway have been altered since its initial construction in the 1950's, generally the stormwater systems incorporated into the original Route 6 design do not reflect current Best Management Practices (BMPs). Additionally, they may not reflect consideration for current and anticipated design flows.

The study area includes a section that HW evaluated for stormwater designs to support MassDOT Project No. 606179. That section is approximately 8.6 miles of Route 6 in the towns of Dennis, Harwich, Brewster and Orleans and spans between exit 9 to the Orleans rotary. To date, HW has reviewed existing information, including the existing highway drainage system network and existing environmental conditions (e.g., topography, soils, etc.), and has conducted field assessments to evaluate potential for stormwater improvements. Preliminary evaluations of field data have been performed to identify stormwater retrofit opportunities as well as maintenance needs and 25/75% design plans have been submitted for 6 BMPS for MassDOT Project No. 608201.

Table 4. Sensitive Area Restriction Guide (333 CMR 11.04)

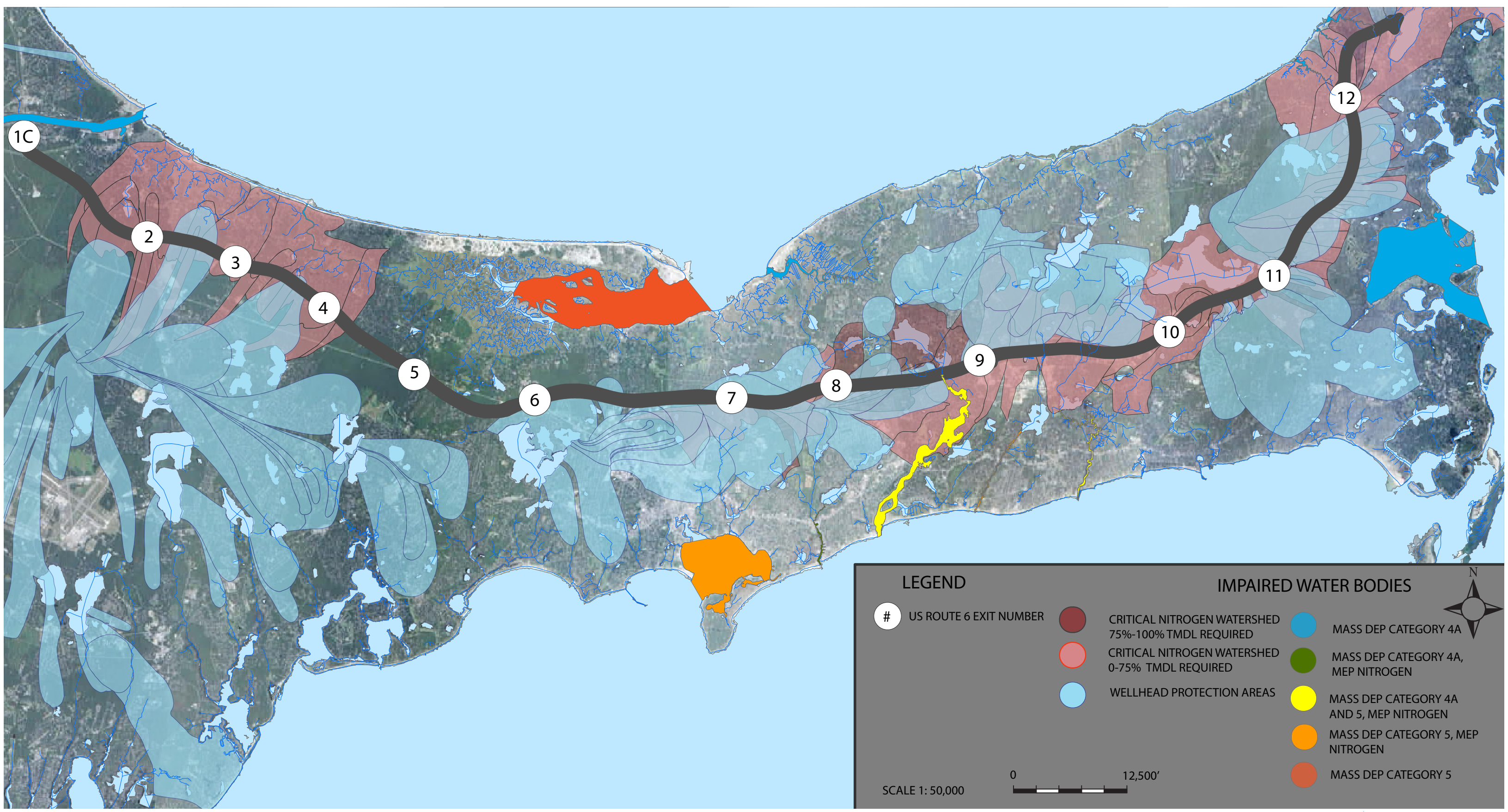
SENSITIVE AREA	NO SPRAY AREA	LIMITED SPRAY AREA
Wetlands and Water over Wetlands	Within 10 feet	10-100 feet; 12 months must elapse between applications
Certified Vernal Pool	Within 10 feet	10 feet to the outer boundary of any Certified Vernal Pool Habitat; 12 months must elapse between application
Public Ground Water Supply	Within 400 feet (Zone I)	Zone II of IWPA (Primary Recharge Area; 24 months must elapse between applications
Public Surface Water Supply	Within 100 feet of any Class A Public Surface Water Source	100 feet to the outer boundary of the Zone A; 24 months must elapse between applications.
Private Water Supply	Within 50 feet	50-100 feet; 24 months must elapse between application
Surface Waters	Within 10 feet from mean annual high-water line	10 feet from the mean annual high water line and outer boundary or waterfront area; 12 months must elapse between application
State-listed Species Habitats	No application within habitat areas except in accordance with a Yearly Operation Plan approved in writing by the Division of Fisheries and Wildlife	

As described in the Route 6 Hydroplaning Crash Analysis and Alternatives Development study, segments of the existing roadway do not always drain adequately during storm events. Depending on storm conditions, portions of the roadway may flood with significant sheet flow over the surface, pond in low areas, and/or retain large volumes of water at the road edge-of-pavement. Most of Route 6 does not have a paved shoulder. Instead, the edge of pavement is typically finished with a low paved curb, which has the effect of collecting and channelizing stormwater. Sheet flow off of the roadway, or traditional country drainage, is inhibited by the presence of this paved curb, and/or grading at the roadside that slopes up from the roadway rather than down. Below is a general description of each segment and general findings related to potential improvements:

SEGMENT 1 Segment one contains the highest number of wet weather-related crashes. While this section does not pass through nitrogen sensitive watersheds, there are several Wellhead Protection Areas (WHPA) which are susceptible to the byproducts of crashes.

SEGMENT 2 Nearly the entire length of segment two traverses through WHPAs, as well as several nitrogen-sensitive watersheds. Segment two includes wider median areas and roadside buffer zones protecting abutting residences with vegetation from the highway for safety precautions.

SEGMENT 3 Segment three contains the most significant ponding of water on the roadway between exits 10 and 11. This ponding can in part, be attributed to changes in the design of the segment



Source: Cape Cod Commission, September 2014, Impaired Water Bodies: MassDEP 2014 Integrated List of Waters (305(b)/303(d)), MassGIS 2016

Above: Water Quality Assessment: Impaired Watersheds, Impaired Water Bodies and Wellhead Protection Areas
For larger scale map, please see the seperate map atlas provided with this document.

as the roadway narrows to two lanes without vegetated medians. Segment three also passes through several nitrogen sensitive watersheds.

SEGMENT 4 The Eastham rotary portion of segment four contributes to Rock Harbor, a watershed requiring a 79% reduction in the septic nitrogen load.

Watersheds

The study area is located within seventeen different watersheds with the largest areas (starting with the largest) within the Barnstable Harbor, Bass River, Scorton Harbor, Herring River and Pleasant Bay watersheds. See Table 5 for a list of all the watersheds that the study area intersects from largest to smallest. The water bodies within the ROW total approximately 7.68 acres, with 5.07 acres considered impaired according to MassDEP's 2014 Integrated List of Waters. Those are the Bass

Table 5. Watersheds within Study Area

MAJOR SYSTEM	MINOR SYSTEM	TOWN(S) IT INTERSECTS	ACRES WITHIN STUDY AREA	(TYPE OF) IMPAIRED WATERBODY WITHIN WATERSHED
Barnstable Harbor	Barstable Harbor	Barnstable, Yarmouth	593.56	MassDEP, Category 5
MEP-Bass River	Bass River	Yarmouth, Dennis	335.37	MassDEP Category 4a and 5, MEP Nitrogen
MEP- Scorton Harbor	Scorton Harbor	Sandwich	233.05	MassDEP Category 4a, (Scorton Creek)
MEP- Herring River (Harwich)	Herring River	Harwich	224.00	MassDEP Category 4a and 5, MEP Nitrogen
MEP- Pleasant Bay	Pleasant Bay	Harwich, Brewster, Orleans	219.83	MassDEP Category 4a
MEP-Sandwich Harbor	Sandwich Harbor	Sandwich	147.73	
Direct Discharge	Canal South	Bourne, Sandwich	100.92	MassDEP Category 4a (Cape Cod Canal)
MEP- Little Namskaket Creek	Little Namskaket Creek	Orleans	73.84	MassDEP Category 4a
Chase Garden Creek	Chase Garden Creek	Dennis, Yarmouth	60.72	MassDEP Category 4A
MEP- Lewis Bay	Lewis Bay	Barnstable, Yarmouth	42.63	MassDEP Category 5, MEP Nitrogen
MEP- Rock Harbor	Rock Harbor	Orleans	30.25	MassDEP Category 4a
MEP Nauset	Nauset Marsh	Orleans, Eastham	26.93	
MEP-Swan Pond River	Swan Pond River	Dennis	22.57	MassDEP Category 5, MEP Nitrogen
MEP Namskaket Creek	MEP Namskaket Creek	Orleans	20.21	MassDEP Category 4a
Boat Meadow River	Boat Meadow River	Orleans, Eastham	10.01	MassDEP Category 5
MEP-Red River	Red River	Harwich	1.08	
MEP- Parkers River	Parkers River	Yarmouth	0.11	MassDEP Category 4A, MEP Nitrogen

River, Rock Harbor Creek and Cedar Pond (which is also in the Rock Harbor watershed). Almost all of the watersheds that Route 6 runs through contain impaired water bodies. Six watersheds are listed as having a Category 5 water body (Waters requiring a TMDL) and ten are listed as having a Category 4a water body (TMDL is completed). Furthermore, nitrogen loading threshold evaluations conducted through the Massachusetts Estuaries Program (MEP) have indicated that five of the watersheds require reductions of nitrogen to restore the estuarine systems.

Wetlands 1%

The study area includes 21 acres of wetlands (1% of the study area), which includes ten types of wetlands (See Table 2). The majority of the wetlands acreage is located in the vicinity of exit 9 and the Orleans rotary. By exit 9, between Kelley's Bay and the Bass River, there is open water, salt marsh and coastal bank bluff or sea cliff. A section of Dinah's Pond and a small portion of coastal bank bluff or sea cliffs are just west of Kelley's Bay and a shrub swamp and a cranberry bog are along the edges of the roads west of Dinah's Pond. Inside the rotary is a shallow marsh meadow or fen. Nearby there are a couple other shallow marsh meadows or fens, multiple deciduous wooded swamps to the west and open water at Cedar Pond.

The remainder of the wetlands are small areas along the corridor that include open water at exit 2, a deep marsh close to exit 5, a shallow marsh meadow or fen by exit 5, a deep marsh and open water in the median between exits 5 and 6, a shallow marsh meadow or fen at the Hyannis Golf Course between exits 6 and 7, a wooded swamp at exit 8, a couple shrub swamps, some cranberry bog, a deciduous wooded swamp and a deep marsh surrounded by shrub swamp between exits 9 and 10, a shrub swamp between exits 10 and 11, open water and a deep marsh adjacent to exit 11, deep marsh, wooded swamp with mixed trees, coniferous wooded swamp and shrub swamp just south of exit 12, a series of shrub swamps between exit 12 and the rotary.

Soils

The majority of the soils in the study area are either excessively drained hydrologic soil group A or well drained hydrologic soil group B. Some very poorly drained D soils are located within the corridor, but comprise less than 1% of the study area. 95% of

Above Left: Cranberry Bog, Right: Salt Marsh the acreage within the study area is made up of four soils: Carver, Barnstable, Plymouth and Eastchop. All of those soils are in hydrologic soil group A except for Barnstable which is soil group B. Along the corridor, Carver outwash plains soils are found on the eastern end between exits 7 and the rotary. Barnstable soils tend to be on the west portion from the Sagamore Bridge to mid way between exits 5 and 6. Plymouth soils are found sprinkled throughout the corridor mostly in smaller patches in the western portion and larger portions around exits 6 and 7. Eastchop soils are predominantly located in the central portion of the study area between exits 6 and 7.

Table 7. Types of Soils within Study Area

NAME	DRAINAGE	GEOM DESCRIP	HYDROGROUP	ACRES
Barnstable	Well drained	moraines	B	522.15
Carver	Excessively drained	ice-contact slopes	A	344.90
Carver	Excessively drained	outwash plains	A	572.91
Deerfield	moderately well drained	outwash plains	B	8.93
Dumps	NA	NA	NA	4.25
Eastchop	Excessively drained	outwash plains	A	133.48
Freetown	Very poorly drained	bogs	D	4.06
Ipswich	Very poorly drained	marshes	D	0.45
Pits	NA	NA	NA	0.79
Plymouth	Excessively drained	ice-contact slopes	A	8.09
Plymouth	Excessively drained	moraines	A	457.19
Plymouth	Excessively drained	outwash plains	A	0.36
Udipsamments	NA	leveled land	A	46.93
Urban land	NA	NA	NA	35.22
Water	NA	NA	NA	3.84
Water, saline	NA	NA	NA	2.51

Source: NRCS SSURGO-Certified Soils – MassGIS 2012

Above: Soils along the Route 6 corridor

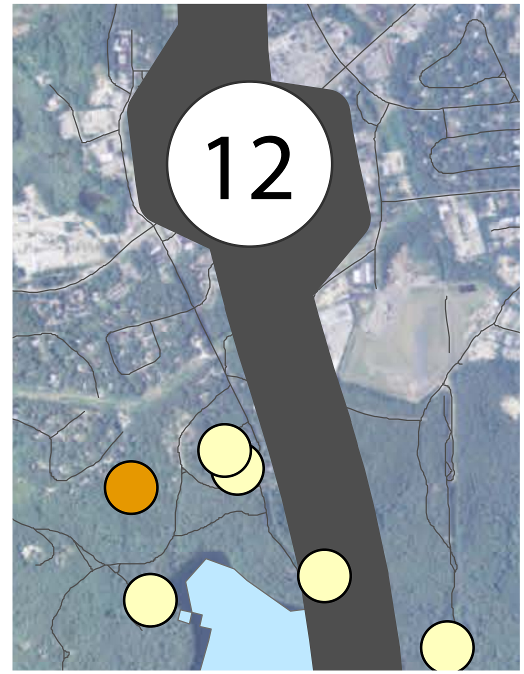
For larger scale map, please see the seperate map atlas provided with this document.

Vernal Pools-2%

There are approximately 38 acres (2% of the study area) of vernal pools, potential vernal pools, and their associated 350' buffer zones within the study area. Over 7 acres are located within the 350' buffer zone of certified vernal pools and 31 acres are within the 350' buffer of potential vernal pools. There is some overlap between the certified and potential vernal pool areas and three of the potential vernal pool areas are identified as various types of wetlands noted above. A portions of the Route 6 corridor at exit 2 and south of exit 12 are within the buffer zone for potential vernal pools with the remainder located between exits 4 and 6, in close proximity to exit 5.

Vernal pools include those areas mapped and certified by NHESP as well as those areas identified in the field as eligible for certification by a professional wildlife biologist or other expert. Where a project site is located adjacent to a vernal pool, development shall be prohibited within a 350-foot undisturbed buffer around these resources. New stormwater discharges shall be located a minimum of 100 feet from vernal pools. (Cape Cod Commission Model Bylaws and Regulations and the Cape Cod Regional Policy Plan, 2012.)

Above: Exit 2 Vernal pools



Above: Exit 12 Vernal pools

Source: Potential Vernal Pools: NHESP Potential Vernal Pools – MassGIS 2000
Certified Vernal Pools: NHESP Certified Vernal Pools – MassGIS 2016

Above: Exit 5 Vernal pools along the Route 6 corridor

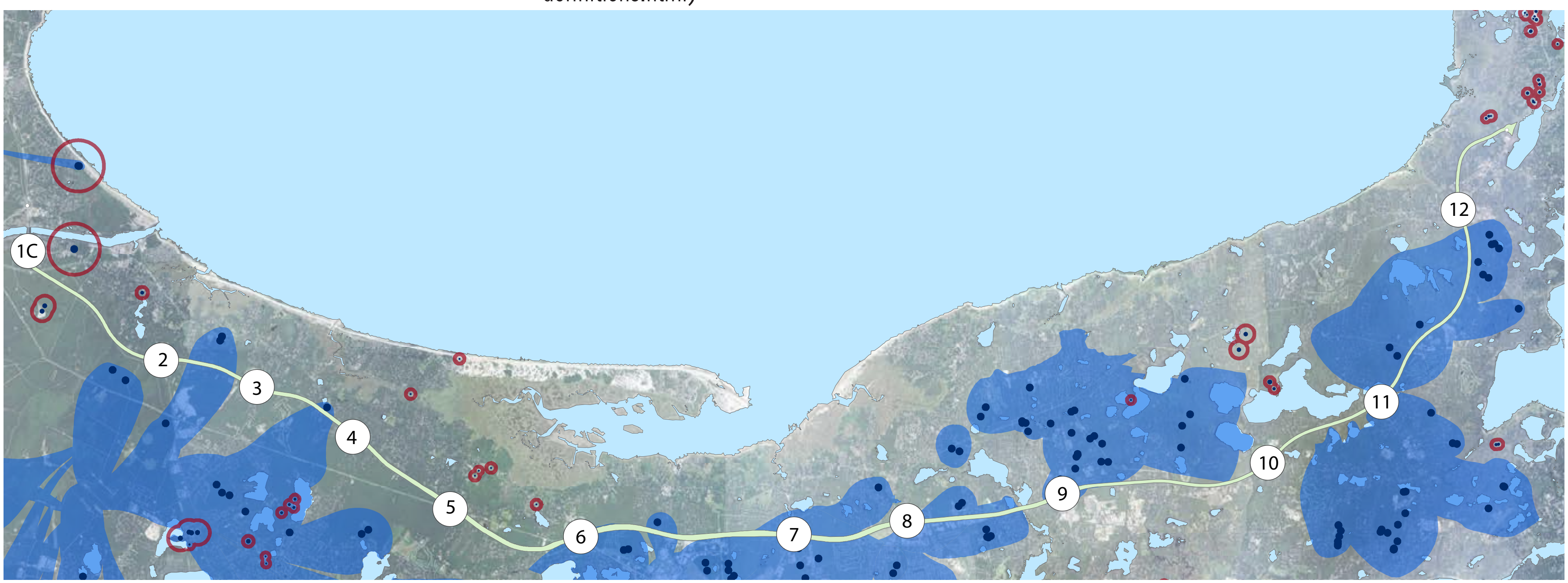
Wellhead Protection Zones-39%

There are approximately 848 acres (39% of the study area) of Wellhead Protection Areas within the study area which are comprised of three different categories of wellhead protection areas:

- Zone I - the protective radius required around a public water supply well or wellfield.
- Zone II - the area of an aquifer which contributes water to a well under the most severe pumping and recharge conditions that can be realistically anticipated.
- Interim Wellhead Protection Area (IWPA) - For public water systems using wells or wellfields that lack a Department approved Zone II, the Department of Energy and Environmental Affairs will apply an interim wellhead protection area.

(http://www.mass.gov/eea/agencies/massdep/water/drinking/water-supply-protection-area-definitions.html)

Within the study area there are 834 acres (39%) within a Zone II protection area, about 10 acres (.45%) in a Zone I and under 5 acres (.2%) in an IWPA . All of the Zone I areas within the study area are within either a Zone II area or an Interim Protection area. The Zone II wellhead protection areas are between exits 2 and 3, exits 3 and 4, much of the area between exits 6 and 9 and much of the area between exits 11 and 12. The Zone I areas are a sliver between exits 3 and 4, and small areas at exits 5, 7 and 9. The only IWPA is at exit 5.



Source: MassDEP Wellhead Protection Areas (Zone II, Zone I, IWPA) – MassGIS 2016

Above: Wellhead protection along the Route 6 corrido0
For larger scale map, please see the seperate map atlas provided with this document.

Topography

The topography along Route 6 is generally higher to the west and lower to the east with elevations ranging from about 250' above sea level around exit 2 to 10' at the rotary. The land is undulating beyond the relatively flat gravel or grass shoulder on the sides of the road. There are gentle sloping hills and depressions but also steeper climbs and drops off the main travel corridor. Though the elevation gets lower to the east, there are still valleys that drop down below 100' on the west side, and hills that climb above 100' on the east. Within the median between the Sagamore Bridge and exit 9, the topography is also gently undulating with small berms and depressions. There is no median from exit 9 to the rotary.

Top: Power lines dissecting the Route 6 corridor Eastbound just after Exit 1C. Bottom: Typical median depression
Source: Google

Existing Drainage

HW's assessment of Route 6 between Dennis at exit 9 and Orleans at the rotary identified stormwater drainage infrastructure that consisted of closed drainage systems of catch basins and drainage pipes that discharged to outfalls within the ROW. Of the outfalls assessed, most (70%) discharged to natural depressions. Other sites generally discharged to paved asphalt swales (27%) that flowed to natural depressions; most paved swales appeared to be in good condition. Sedimentation and erosion were common at all observed outfalls; the intensity of scour generally increased with contributing drainage area.

Based on data available from the previous assessment, MassGIS, and drive-by and virtual site observations, we expect existing drainage infrastructure along Route 6 from the Sagamore Bridge to exit 9 to be similar to what HW has observed, with the exception of the presence of a median which appears to capture a portion of the runoff. The drainage infrastructure visible along road throughout the study area consists of catch basins as well as paved flumes that direct runoff to depressions along the sides of the road and within the median via overland flow.

Stormwater Policy & Regulation

Progress in the field of stormwater management has been facilitated by federal regulations contained in the seminal 1972 amendments to the Federal Water Pollution Control Act known as the Clean Water Act (CWA). In general, the CWA prohibits discharge of pollutants to navigable waters from a point source unless authorized through the National Pollution Discharge Elimination System (NPDES). Based on the CWA, the Water Quality Act (WQA) of 1987 created the framework for current regulations governing stormwater management. These regulations were promulgated in two increments (Phase I and Phase II) and were written to include an expanded scope of stormwater discharge permits previously exempted in the CWA. Expanded uses include industrial stormwater and municipal separate storm sewer systems (MS4's) serving a population over 100,000. Based off of the 1987 WQA, the Environmental Protection Agency (EPA) initiated

Drainage flume and catch basins along the Route 6 corridor
Source: Google

Phase I of the National Stormwater Permit Program. Phase I required NPDES permits for industrial stormwater, the above mentioned MS4 communities and construction sites greater than 5 acres (EPA, 2000).

Between the initiation of Phase I and Phase II of the 1987 WQA the EPA issued a strategy where municipalities were required to address combined sewer overflow (CSO) systems, a form of stormwater/wastewater management in existence since the early to mid-nineteenth century. Phase II became effective in 2003 and further broadened the scope of controls on stormwater to include MS4 communities serving a population less than 100,000, construction sites of 1 acre or more and large property owners (EPA, 2000). In addition, Phase II considers MassDOT to be an operator of MS4's and, as such, MassDOT must meet all requirements for MS4's as defined under the Phase II rule.

MASS DOT PHASE II MS4 REQUIREMENTS

MassDOT currently holds an EPA NPDES Phase II Small MS4 General Permit (Permit #: MA043025). A new draft MassDOT MS4 permit is expected to be issued in the fall or winter of 2016 (Permit year 13). The MS4 General permit currently requires MassDOT to:

- Develop and implement stormwater management programs to reduce discharge of pollutants;
- Develop measurable goals for the implementation of a stormwater management program and report on its progress in meeting those goals;
- Implement six "minimum control measures":
  - Public education.
  - Public involvement
  - Illicit discharge detection and elimination
  - Construction site runoff control programs.
  - Post-construction stormwater management.
  - Pollution prevention and good housekeeping in municipal operations.

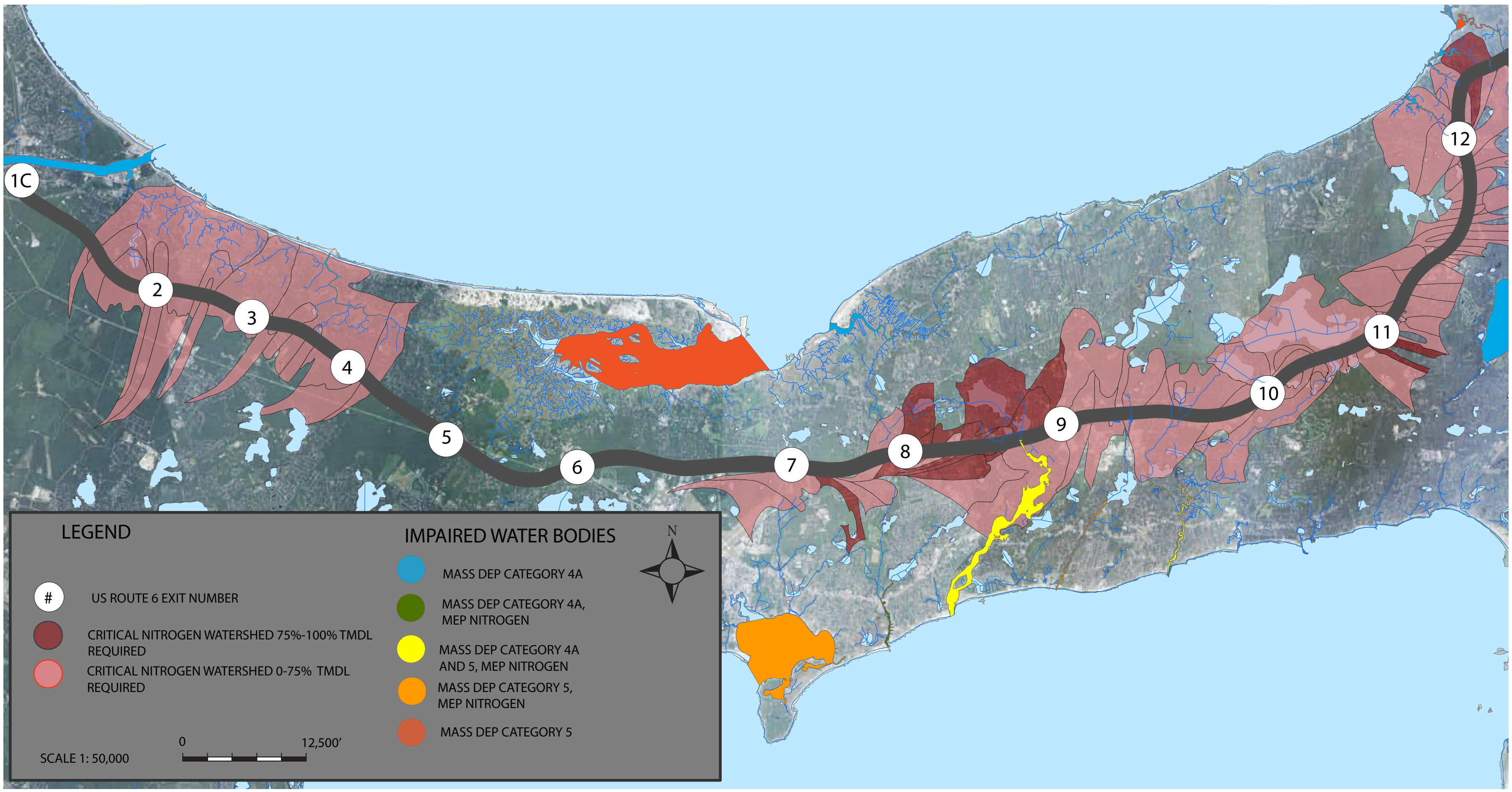
MassDOT is required to complete an annual self-assessment of progress towards meeting these goals and measures. In the 2014 – 2015 NPDES Phase II Small MS4 General Permit Annual Report, MassDOT determined that they are in compliance with the conditions of their permit. Under each section of "minimum control measures", MassDOT identifies: Best Management Practices; responsible department or individual; measurable goals; progress on goals; and planned activities for the following permit year.

MassDOT's MS4 Permit also requires that they evaluate their discharges that fall within a watershed of a 303(d) listed waterbody. 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. These discharges to impaired and TMDL watersheds are being addressed by the Impaired Waters and TMDL Watershed Review Program, respectively.

MASS DOT 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). The program initially included approximately 684 impaired waters, which included all 303(d) waters whose sub-basins contain some portion of MassDOT's urbanized area roadways. An additional 142 water bodies were added to the analysis based on updates to the 303(d) list, road acquisitions by MassDOT, and 2010 US Census Data. 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-foot 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 determined 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 plans to design and construct additional water quality BMPs where technically feasible. MassDOT is implementing this program through two initiatives: the Retrofit Initiative and the Programmed



Source: Embayments: Cape Cod Commission, September 2014, Impaired Water Bodies: MassDEP 2014 Integrated List of Waters (305(b)/303(d)), MassGIS 2016

Above: Impaired Watersheds & Impaired Water Bodies

For larger scale map, please see the seperate map atlas provided with this document.

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 assesses TMDL reports whenever a TMDL has been approved for a water body into which MassDOT urbanized roadways discharge stormwater. MassDOT developed a methodology to assess water bodies located on Cape Cod, the Islands, and other parts of southeastern Massachusetts that do not have a TMDL and are located in watersheds mainly driven by groundwater instead of surface water. The "MassDOT's Nitrogen 7U Method" relies on research performed by the USGS for the Massachusetts Estuaries Program and Buzzards Bay National Estuaries Program and conservatively assumes that the entire nitrogen load from MassDOT property runoff that infiltrates in the USGS determined watershed contributes to the target water body without a load reduction. The methodology was used for numerous assessments submitted this permit year. To date, MassDOT maintains that all loads within Barnstable County are negligible and no further action is necessary.

The Commonwealth of Massachusetts has demonstrated its commitment to reducing the pollution of surface waters and groundwater through a myriad of policies and regulations. In 1996, the Massachusetts Department of Environmental Protection (MassDEP) issued a stormwater policy that established Stormwater Management Standards aimed to increase recharge of stormwater, promote the use of Low Impact Development (LID), ensure redevelopment improves existing conditions, and provide better environmental protection. These ten Stormwater Management Standards listed below, are only lawfully enforceable in areas safeguarded by the Massachusetts Wetland Protection Act Regulations, 310 CMR 10.05(6)(k). Any major activity within 100 feet of a jurisdictional wetland area requires the filing of a notice of intent and is subject to review by local conservation commissions (issuing authority). Therefore, any major activity along segments of the highway that fall within the 100 buffer zone are subject to review by the local conservation commission. A preliminary analysis of the Massachusetts Department of Environmental Protection Detailed GIS Wetlands Data shows that within the Route 6 Right-of-way, roughly 27 parcels are within 100 feet of the highway.

Activities that meet the statute's (310 CMR 10.02(2)) definition of a "minor activity", however, are not subject to the Wetlands Protection Act. The following "minor activities" are relevant to potential components within the Route 6 project: Planting of native species of tree, shrubs, or ground cover; or pavement repair, resurfacing and reclamation of existing roadways, provided that either the roadway and/or shoulders are not widened.

STORMWATER MANAGEMENT STANDARDS

The Massachusetts Stormwater Management Standards require that:

- no new conveyances (outfalls) may discharge untreated stormwater directly into wetlands or cause erosion;
- stormwater systems shall be designed to ensure that post-development discharge rates do not exceed pre-development rates;
- loss of annual recharge to groundwater shall be reduced through appropriate design;

- stormwater management systems should be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS);
- for land uses with higher pollutant loads, source control and pollution prevention shall be implemented with the Massachusetts Stormwater Handbook;
- discharges to Zone 1 or Zone A are prohibited, discharges within a Zone II or near any critical resource area (314 CMR 4.00) require specific control measures;
- redevelopment projects must meet the following standards only to the maximum extent practicable: Standard 2, standard 3, and the pretreatment and structural BMP requirements of Standards 4,5, and 6;
- a plan to control construction related impacts including erosion, sedimentation and other pollutant sources shall be developed and implemented;
- a long term operation and maintenance plan shall be developed and implemented to ensure that systems function as desired;
- all illicit discharges to the stormwater management systems are prohibited.

STANDARDS APPLICABLE TO ROUTE 6

Under Stormwater Management Standard 7, redevelopment projects are defined to include the following: maintenance and improvement of existing roadways, including widening less than a single lane, adding shoulders, correcting substandard intersections, improving existing drainage systems and repaving; and remedial projects specifically designed to provide improved stormwater management systems. Recommendations discussed within the Route 6 Hydroplaning Crash Analysis and Alternatives Development Study all fall under the Handbook's definition of a redevelopment project. Redevelopment projects must fully comply with the provisions of the Stormwater Standards, requiring the development and implementation of a construction period erosion and sedimentation control plan, a pollution prevention plan, and an operation and maintenance plan. Furthermore, as previously mentioned, redevelopment projects are required to meet the following Standards only to the maximum extent practicable: Standard 2, standard 3, and the pretreatment and structural BMP requirements of Standards 4,5, and 6. For definitive purposes, "To the maximum extent practicable" means that proponents of redevelopment projects have made all reasonable efforts to meet the standard; made a complete evaluation of possible management measures including Low Impact Development strategies (LID); and if full compliance cannot be achieved, that they are implementing at the highest practical level. The maximum extent practicable standard also applies to redevelopment projects with existing stormwater discharges to Zone Is, Zone As, Outstanding Resource Waters, and Special Resource Waters subject to Standard 6.

Standard 2 may be waived in areas subject to coastal storm flowage, (land subject to any inundation caused by coastal storms up to and including that caused by the 100-year storm, surge of record or storm of record, whichever is greater) otherwise, to prevent damage, the post-development discharge rate must be equal to or less than the pre-development rate from the 2-and 10-year 24-hour storms.

Standard 3 intends to ensure that infiltration volume of precipitation under post development conditions is equal to or more than the infiltration volume under pre-development. MassDEP allows MassDOT to use the macro approach, which allows MassDOT to recharge additional runoff at certain locations along a portion of the highway within a sub-watershed to compensate for sections of the roadway where it may be difficult to recharge the entire required volume.

CHAPTER 3

STORMWATER MANAGEMENT

Route 6 Stormwater and Vegetation Plan

Approach

To effectively manage the impacts of stormwater and prevent adverse impacts to water quality, plant communities, flooding and habitat within the Route 6 Right-of Way, the following prioritized areas for stormwater improvements have been selected and guidelines for choosing practices to implement have been developed.

Remove the Berms

First, it is recommended both by this study and the Hydroplaning Study completed in 2013 that the roadside curbing and berming be removed from the entire corridor as projects are implemented to reduce the concentrated volume of stormwater runoff on roadways. As an alternative to complete removal of curbing, more frequent curb cuts would also help facilitate water off the roadway. Expansion of the road shoulder should be considered in areas where additional grading will not adversely affect the existing vegetation. The addition of vegetated bioswales (see page 3:11) along the edge of these expanded shoulders would help treat this runoff before it enters any waterbody. Installation of BMPs and expansion of the shoulder in the right areas could increase safety and improve the rate of infiltration and treatment of stormwater.

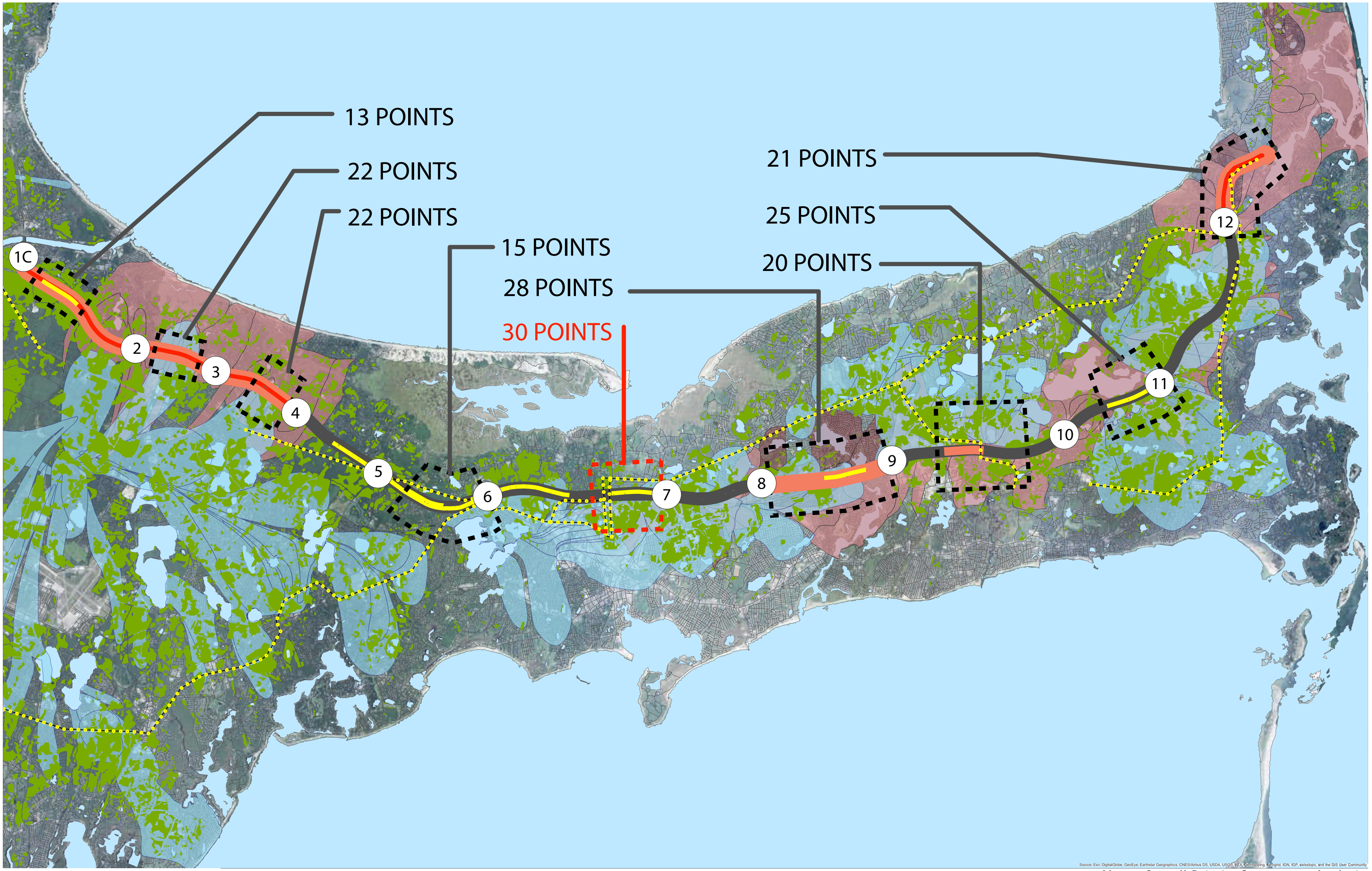
Stormwater Priority Areas

Second, a map of selected priority areas for stormwater intervention defines recommended first areas for implementation (see p. 3:2). Areas of the ROW that should be prioritized for stormwater improvement were ranked by the following criteria:

1. Areas of the roadway that are within watersheds with elevated levels of nitrogen were prioritized. If the area of roadway is in a watershed with a TMDL for nitrogen, it was assigned a score of 10. Additionally if the watershed requires >75% of its nitrogen load to be reduced, an additional 5 points was added.

2. Areas of roadway that were identified as having 2-5 crashers per year in the Hydroplaning Study completed by CCC in 2013 were prioritized and given a score of 5. Stormwater improvements in these areas will not only help water quality, but will improve human safety as well.

3. Areas of roadway landscape identified in the drive-by vegetation analysis (completed in July 2016) as significantly non-native and disturbed along the roadway edges were prioritized and given a score of 5. This includes areas where a utility line crosses the highway ROW. In addition, if the median was disturbed, a point value of 1 was added. Ideally, new stormwater practices shall be created where the landscape is already disturbed, so that invasive vegetation can be eliminated and new native vegetation introduced to improve local ecologies.



Source: Offshoots, Inc, 2016- Crash data from CCC Hydroplaning Study- 2013

Above: Overall Priority Stormwater Analysis

For larger scale map, please see the seperate map atlas provided with this document.

In addition, where valuable pine barrens species already exist, the objective is to avoid disturbance of these areas with construction activities.

4. Portions of the ROW that are withing Wellhead Protection Areas were prioritized and assigned a score of 3. These areas recharge valuable drinking water wells. Stormwater retrofits will not only improve nitrogen loading in watersheds, but treat other contaminants as well.

5. Larger intact pine barrens patches have the opportunity to create corridors for wildlife and ecological movement. Areas of the ROW that are adjacent to large existing swaths of pine barrens outside of the ROW were prioritized, so that new native vegetation introduced might provide greater connectivity and prevent non-natives from spreading. ROW areas adjacent to existing larger pine barrens patches were assigned a value of 2.

IN SUMMARY:

1. TMDL= 10pts + 5pt for 75% or more nitrogen removal required.

2. 2-5 Crashes= 5pts

3. Disturbed Landscape = 5pts (5pts for Utility crossings) + 1pt for median disturbance

4. WPAs= 3pts

5. Pine barrens nearby= 2pt

TOTAL Potential Score= 31 pts

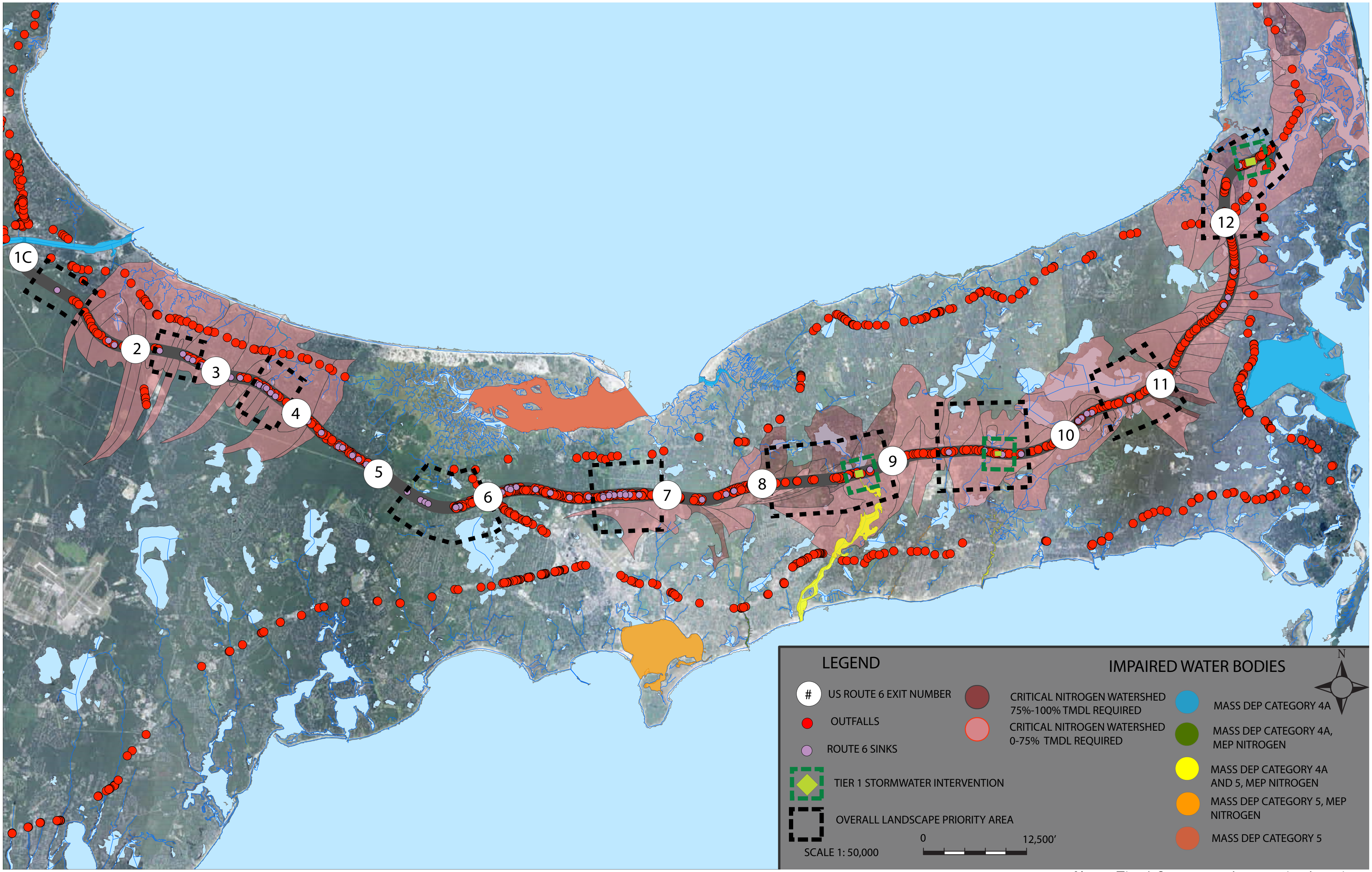
As shown in the map on the left, nine priority areas for intervention emerged from the analysis. A section of roadway west of exit 7 and another section between exits 8 & 9 ranked the highest in priority for stormwater intervention. In addition, it is recommended that two locations within these priorty areas be considered for implementation sooner since they have the potential to create new aesthetic gateway landscapes for Cape Cod.

- Orleans Rotary The center of the Orleans rotary is a high priority for stormwater retrofit since it is located within a priority area (which received 21 points) and is in a highly visible location that sets the character for the Lower Cape region. It would also serve as an excellent demonstration site to illustrate innovative practices.
- East of Exit 1C: This priority area (which received 13 points,) is located just after crossing the Cape Cod Canal, and defines visitors' immediate perception of the Cape. This priority area only score 13 points in the ranking system, but is also an important aesthetic gateway, so it is recommended that improvements here be considered as a higher priority.

The aesthetics of any new stormwater practices designed for the two locations noted above are particularly important.

Stormwater Practice Selection

Third, a methodology to choose which site-specific stormwater practice (or group of practices) for each location is outlined. The steps have been structured to first identify stormwater management goals beyond water quality, consider site constraints, and discuss operation and maintenance practices prior to selecting and designing a specific practice. This process will help to ensure that future projects will meet long-term goals and the vision for overall ecological improvements within the Route 6 Corridor. Existing vegetation can help infiltrate stormwater to reduce the volume of water and filter pollutants from entering the groundwater. Because of the sensitivity of the Cape's drinking water and coastal resources to nutrient and pollutant loading, stormwater solutions should include alternatives that address contaminants and improve water quality.



Source: Horsley Witten Group, 2016- Stormwater Outfalls Digitized in 2015 (not field verified), Mass DOT Outfalls from MassDOT 2012

Above: Tier 1 Stormwater Intervention Locations

For larger scale map, please see the seperate map atlas provided with this document.

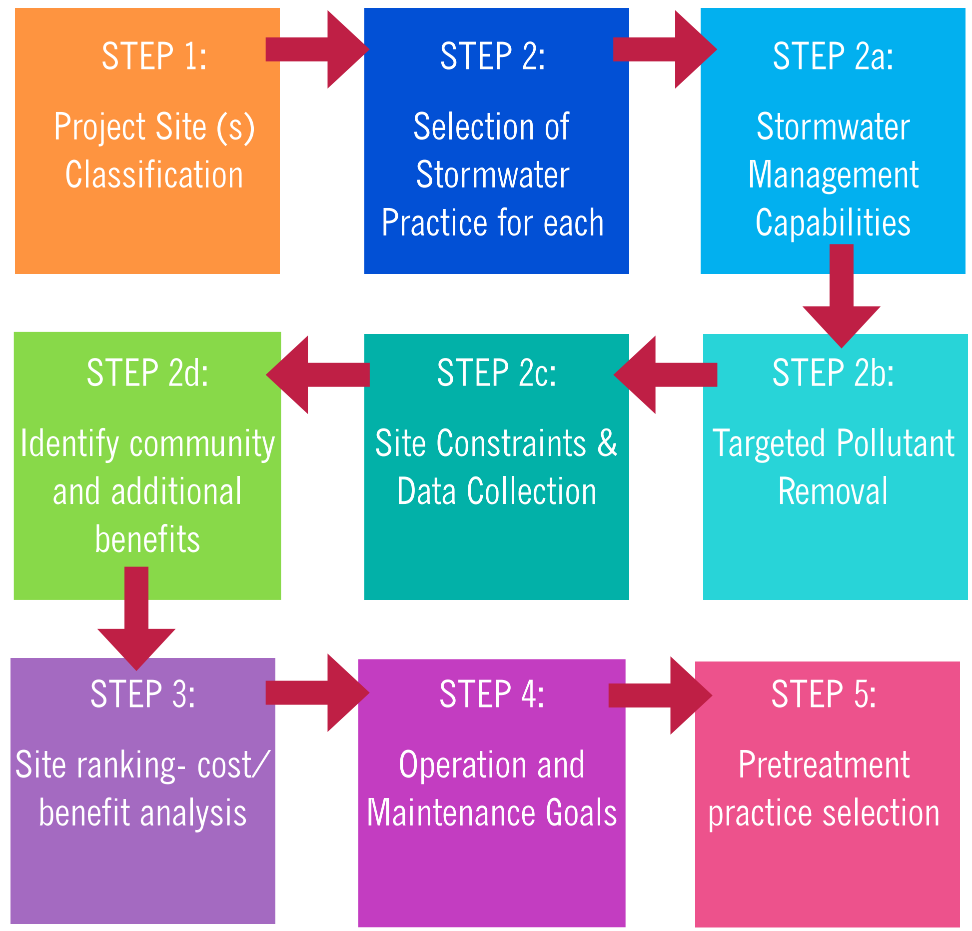
Step 1: Site Classification

To maximize the cost-benefit of any proposed landscape and stormwater improvements within the Route 6 corridor, it is recommended that each potential site be analyzed to ensure that the best locations are selected for a stormwater retrofit practice. Once potential stormwater retrofit sites are located through field investigation and GIS-based data collection, it is suggested that each potential site be ranked using a two-step process. Step-one includes the categorization of each site by a four-tiered approach based upon the following criteria:

- Is the stormwater from the project area contributing to a direct or indirect discharge?
  - A direct discharge is a discharge that enters a waterway or wetland directly. Stormwater that directly discharges can carry pollutants directly to waterbodies without any chance for natural remediation. Therefore, elimination of direct discharges is critically important.
  - An indirect discharge is a discharge that will likely reach a waterway or wetland via overland flow or groundwater.
- Is the discharge to an impaired water body? Impaired water bodies are the greatest

Table 1. Four Priority Tiers

TIER	DISCHARGE LOCATION (Relative to waterbody or wetland)	IS RECEIVING WATER BODY IMPAIRED?
1	Direct	Yes
2	Direct	No
3	Indirect	Yes
4	Indirect	No



priority. Therefore, stormwater drainage areas in impaired water bodies should take precedence over other waterbodies.

- What is the impaired water body pollutant of concern?
    - Nitrogen
    - Phosphorus
    - Other

The sites available for stormwater management within a project area should be categorized into four tiers as summarized in Table 1. Potential project sites meeting the Tier 1 or 2 criteria are considered the highest priority sites for stormwater practices to be implemented. It should be noted, in nitrogen-sensitive areas, Tier 3 sites (indirect discharge) could be prioritized over a Tier 2 direct discharge sites.

These maps identify potential priority Tier 1 sites that include areas with direct discharge into impaired water bodies. The possible locations of direct discharge are based on GIS data from MassDOT, infrastructure located by HW from their on-going stormwater improvement project with MassDOT, as well as historic plans provided by MassDOT. For a list of plans highlighting a discharge point, see below. All direct discharges should be verified in the field. The impaired

Table 2-Optional Stormwater BMPs for the Route 6 Corridor

GROUP	PRACTICE	DESCRIPTION
Existing Landforms	Depressions	Existing landforms refers to depressions created by the surrounding topography which can effectively be incorporated into a stormwater management system to hold, treat and infiltrate stormwater runoff
Wet Practice	Constructed Wetlands	A surface wet stormwater basin that provides water quality treatment primarily in a shallow vegetated permanent pool
	Gravel Wetland	A wet stormwater basin that provides water quality treatment primarily in a wet gravel bed with emergent vegetation.
	Wet Swale	An open vegetated channel or depression designed to retain water or intercept groundwater for water quality treatment.
Dry Practice	Infiltration Basin	A constructed landscape depression designed to store the water quality volume or stormwater volumes from larger rain events to allow for infiltration into the underlying soils.
	Infiltration Trenches	A below ground infiltration practice that stores the water quality volume in the void spaces of a perforated pipe and embedded in clean gravel allowing infiltration into underlying soils.
	Sub-surface Chambers	A below ground infiltration practice that stores the water quality volume in the void spaces of proprietary pre-fabricated chambers embedded in clean gravel allowing infiltration into underlying soils.
	Recharge Basin	A below ground, open bottom, perforated concrete chamber of varying size embedded in clean gravel allowing infiltration into underlying soils.
Filtration Practice	Sand Filter	A filtering practice that treats stormwater by settling out larger particles in a sediment chamber, and then by filtering stormwater through a surface or underground sand matrix.
	Bioretention	A shallow depression that treats stormwater as it flows through a soil matrix, and is returned to the storm drain system, or infiltrated into underlying soils or substratum.
	Bioswale	An open vegetated channel or depression explicitly designed to detain and promote filtration of stormwater runoff into an underlying fabricated soil matrix.

water bodies were identified from MassDEP 2014 Integrated List of Waters (305(b)/303(d)), and are color coded depending on type of impairment. Natural depressions can be utilized to re-direct water from these Tier 1 sites. If a natural depression is not available at a Tier 1 site, then depressions along the corridor can be utilized as BMPs to capture and treat the water within the watershed of the impaired water body.

Step 2: Selection of Stormwater Management Practices

Once a priority site has been selected in Step 1, the most appropriate stormwater management practice should be identified through a selection process outlined in the following Step 2 pages of this document. For the purpose of these guidelines, the stormwater management practices described in this section are divided into the following categories:

1. Existing Landforms
2. Wet Practices
3. Dry Practices
4. Filtration Practices

These four practice types were selected based upon the following criteria critical to the ecological success of the Route 6 corridor:

- Plant communities
- Landscape aesthetics
- Potential habitat

Although not every practice meets all of the criteria defined above (e.g. below ground recharge practices), each practice provides a different set of benefits which includes stormwater management, pollutant reduction, ease of maintenance, cost, scale, or ecological community creation. When properly located, designed, constructed and maintained, most of these practices can provide valuable native plant communities and thriving micro-habitats as well as stormwater treatment. Therefore, the descriptions provided below focus on the micro-ecosystem created within each category. A more detailed description of the function, feasibility, design and maintenance of each practice can be found in numerous stormwater manuals and publications including the Massachusetts Stormwater Handbook (MassDEP, 1997) and the Rhode Island Stormwater Design and Installation Standards Manual (RIDEM & CRMC, 2010). For this reason, this document focuses on the specific benefits each of these practices might have on the overall ecological health of the Route 6 corridor, and creates a series of guidelines for how to achieve the greatest environmental benefit from these systems.

EXISTING LANDFORMS

Existing landforms refer to existing natural depressions or swales found in the surrounding landscape of Route 6 that can effectively be incorporated into a stormwater management system to hold, treat and infiltrate stormwater runoff. Both large and small depressions within the roadway corridor can be used to take advantage of natural drainage patterns and disconnect or intercept the road runoff prior to collecting into pipes and discharging to a constructed stormwater management practice or outfall. Depending on the site soil conditions and depth to the groundwater, existing depressions can function similar to either a dry or filtration practice as described below. The most important benefit of utilizing existing landforms along Route 6 is the minimal disturbance of the surrounding landscape, thereby preserving existing plant communities and habitat as well as limiting the introduction of exotic invasive species during construction of a BMP. The amount of runoff directed to a depression should be in proportion to the receiving area to protect and maintain the existing ecological system and to ensure the site hydrology is not significantly altered. Sending large volumes of roadway runoff to one depression should be avoided to ensure the long-term health of the plant community To maintain an overall healthy plant community and minimize disturbance during maintenance, upgradient pre-treatment practices, or a treatment train, must be incorporated into the system to capture sediment and other debris prior to discharge to the depression. Ideally, the pretreatment is located close to the roadway edge where sediment can be collected and easily cleaned out. When natural depressions are incorporated into a stormwater management system, existing exotic invasive species should be removed and supplemental plantings added to improve the surrounding plant community and habitat value. Native plants similar to those found within the landscape should be used with consideration to given to the additional plants recommended for the practices described below. To preserve the existing landscape, the use of natural depression can be a cost-effective approach to treat and manage stormwater management as well as restore and protect native plant communities.

WET PRACTICES

Wet practices can be used to both treat and manage stormwater generated from Route 6. These practices take advantage of shallow depths to groundwater to create a permanent pool or saturated zone, which provides treatment by the flow of stormwater and settling through the practice and the plant/soil treatment processes. They are suitable for sites with a shallow water table or locations abutting freshwater wetlands and include constructed shallow wetlands, gravel wetlands, and wet swales. They can vary in size from large constructed or gravel wetlands to smaller "pocket" wetlands created by wet swales. The permanent wet condition maintained in these types of practices help create a thriving wetland community, which can provide habitat for various indigenous species including plants, animals, amphibians, reptiles, insect and micro-organisms. Several rare and endangered species along the Route 6 corridor may benefit from newly introduced wetland conditions including several types of turtles. Due to these conditions, wet practices are considered to have a very high habitat value and can be effective in restoring native habitat. Typical Cape Cod native plants for these practices are mainly herbaceous with some woody shrubs and occasional deciduous trees similar to a wet meadow plant community including Juncus effusus (Common Rush), Scirpus cyperinus (Woolgrass), Carex species (Sedges), Pontederia cordata (Pickerelweed), Vaccinium species (Blueberry), and Cephalanthus occidentalis (Buttonbush). Wet practices suitable for the Route 6 Corridor include the following:

CONSTRUCTED SHALLOW WETLAND

A shallow, wet, constructed system that provides water quality treatment primarily in a vegetated permanent pool. Constructed shallow wetland has the potential to provide the most biological diversity out of all the practices. It helps to create a wetland ecosystem, which serves as a home to numerous animal and plant species.

GRAVEL WETLAND

A constructed wetland that provides water quality treatment primarily in submerged, wet gravel bed with emergent vegetation. Although a gravel wetland can host many species, it would not provide the same surface material that some wetland species may depend on for survival.

WET SWALE

An open vegetated channel or depression designed to retain water or intercept groundwater for water quality treatment. A wet swale has the potential to create a small microhabitat for wetland species, but typically is unable to support the larger community that constructed wetlands would host.

DRY PRACTICES

Dry practices include both above and below ground practices that are designed to hold, treat, and infiltrate stormwater runoff. They are suitable for locations with well-drained, sandy soils and a deep water table. These practices can vary in size and include infiltration basins, infiltration trenches, recharge basins or dry wells and sub-surface chambers. They capture and temporarily store stormwater for short periods of time (typically 48 hours or less) and drain via infiltration through the soil and subsoil layers. They can be designed to hold varying amounts of collected stormwater both above and below ground and are effective in providing groundwater recharge. Due to varying depths and volume of stored stormwater runoff, as well as the fluctuation between dry and wet conditions, these practices typically do not provide as diverse a plant community and habitat as wet practices. The plant communities established in these types of practices typically include highly drought tolerant species, which can survive occasional flooding and inundation for short periods of time. The plantings for above ground practices on Route 6 will vary from native trees, shrubs, perennials and grasses to create a more natural appearance, such as the depressions described above, to a mowed lawn/meadow appearance. Each depends upon the design, desired aesthetics and maintenance practices desired in a particular location. Native Cape Cod plant species that thrive in these practices are similar to those used in filtering practices and can tolerate both periods of drought and inundation such as: Schizachyrium scoparium (Little Bluestem), Myrica pensylvanica (Bayberry), Viburnum dentatum (Arrowwood), Cornus sericea and Cornus racemosa (Red-Twig and Gray Dogwood) and Quercus bicolor (Swamp White Oak). Non-native but naturalized plant species include: Festuca rubra (Red Fescue), Panicum virgatum (Switchgrass), and Elymus virginicus (Virginia Wild Rye). Planting can also be a simple native low-mow or no-mow grass seed mixture that creates a meadow appearance and requires minimal ongoing maintenance. Most underground practices are also effective in providing ground-water recharge, which can be beneficial to the surrounding landscape. Proprietary sub-surface chambers can be used to create large below ground infiltration basins capable of handling large quantities of water. Although these underground structural practices provide little opportunity for habitat or plant community creation within the actual practice, they do allow for the creation of above ground usable landscape areas, such as fields and meadows. However, trees and shrubs cannot be established in the area directly above or within ten feet of the belowground infiltration field. Dry practices suitable for the Route 6 Corridor include the following:

INFILTRATION BASIN

A constructed landscape depression designed to store the water quality volume or stormwater volumes from larger rain events to allow for infiltration into the underlying soils.

INFILTRATION TRENCH

An at or below ground infiltration practice that stores the water quality volume in the void spaces of a perforated pipe embedded in clean gravel allowing infiltration into underlying soils.

SUB-SURFACE CHAMBERS

A below ground infiltration practice that stores the water quality volume in the void spaces of proprietary pre-fabricated chambers embedded in clean gravel allowing infiltration into underlying soils. Chambers can be placed under fields or lawn but are more frequently installed under pavement

RECHARGE BASIN

A below ground, open bottom, perforated concrete chamber of varying size embedded in clean gravel allowing infiltration into underlying soils. This practice is typically paired with a catch basin for pre-treatment.

FILTRATION PRACTICES

Filtration practices are used predominantly to treat stormwater runoff and not to manage increases in volume from larger rain events. They are suitable for locations with both shallow and deep water tables, varying types of soil, limited space, and where flooding is not a concern. These practices are typically vegetated shallow depressions or open channels, vary in size, and include bioretention areas, bioswales and vegetated sand filters. They use both vegetation and engineered soil matrices that can include soil, stone, organic matter or sand layers to provide treatment and can provide for infiltration/recharge or be underdrained. Due to shallow depth and volume of stored stormwater runoff, the fluctuation between dry and wet conditions and smaller area, these practices typically do not provide as diverse of a plant community and habit as the wet and dry practices. The plant communities established in these types of practices typically include highly drought tolerant species, which can survive occasional flooding, and minor inundation (3-9 inches of water) for short periods of time. Typical Cape Cod native plants for these practices include Panicum virgatum (Switchgrass), Iris versicolor (Blue Flag Iris), Schizachyrium scoparium (Little Bluestem), Rudbeckia hirta (Black-eyed Susan), and Cornus sericea (Red Twigged Dogwood), with a mix of species typically found in a wet meadow or grassland natural community. Depending upon the size of the practice and underlying soil conditions, trees can be incorporated into the planting mix. Native tree species for the Route 6 corridor include

Nyssa sylvatica (Tupelo), Acer rubrum (Red Maple), Quercus bicolor (Swamp White Oak), and Betula species (Birch). Filtering practices suitable for the Cape Cod Route 6 Corridor include the following:

BIORETENTION

A vegetated shallow depression that treats stormwater as it flows through a soil matrix, and is returned to the storm drain system, or infiltrated into underlying soils or substratum. A bioretention area can provide support for plant and animal species, but is limited to species that can tolerate the variable dry to wet conditions.

BIOSWALE

An open vegetated channel typically designed to hold, treat, and convey smaller amounts of stormwater, while promoting filtration of runoff into an underlying manufactured soil matrix. A bioswale would host similar species to a bioretention area, but generally would support more grassland than wet meadow species due to its conveyance properties.

VEGETATED SAND FILTER

A filtering practice that treats stormwater by filtering stormwater through a vegetated surface or underground sand matrix. A sand filter would typically appear as more of a grassland community due to the well-draining sand matrix and would support animal species that thrive in that habitat.

SELECTION CRITERIA FOR STORMWATER TREATMENT PRACTICES

Upon completion of the site classifications, stormwater practices can then be selected for each Tier 1 and 2 site. A series of matrices are provided to be used as a screening process for selecting the best stormwater practice or group of practices for stormwater management within the Route 6 ROW. It also provides guidance for locating practices on each site. The matrices presented can be used to screen practices in a step-by-step fashion, based upon the following factors:

- Step 2a: Stormwater Management Capabilities
- Step 2b: Pollutant Removal
- Step 2c: Site Constraints
- Step 2d: Community and Environmental Benefit

The four matrices presented here are not exhaustive. Specific additional criteria may be incorporated depending on site location and project goals. Caveats for the application of each matrix are included in the detailed description of each. These matrices are provided as guidance to help choose the most appropriate practices for their given conditions.

STEP 2A: STORMWATER MANAGEMENT CAPABILITY

Use Matrix 2a to determine if a particular practice can manage a wide range of storms. For example, the filtering practices are generally limited to water quality treatment and seldom can be utilized to meet larger stormwater management objectives.

This matrix examines the capability of each practice option to meet the following stormwater management criteria.

- Recharge: Does the practice provide groundwater recharge?
- Water Quality: Can the practice be used to provide water quality treatment effectively? For more detail, consult the pollutant removal table. (see Matrix 2b)
- Flood Control: Can the practice be used for larger stormwater events and extreme flooding criteria?

Note: If a particular practice does not meet one of these requirements, it does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one practice may be needed at a site (e.g., a bioretention area and a downstream stormwater detention basin).

STEP 2B: POLLUTANT REMOVAL

Use Matrix 2b to determine pollutant removal efficiencies for each practice. Select the practice with the highest removal efficiency for the targeted pollutant, based upon site classification. Matrix 2b outlines practice goals and restrictions based on the resource being protected. This set of factors involves screening out those practices that might contradict overall watershed protection strategies, or eliminating management requirements where they are unnecessary or inappropriate. Regulatory requirements under the Clean Water Act, TMDL reduction requirements and/or interests from watershed associations may influence the type, location, and design requirements for stormwater management practices.

The design and implementation of a stormwater management system is strongly influenced by the nature and sensitivity of the receiving waters. In some cases, higher pollutant removal, greater recharge or other environmental performance is warranted to protect the resource quality, human health and/or safety. Water resource areas include ground-water, freshwater ponds, lakes, wetlands, and coastal waters. Matrix 2b presents the key design variables and considerations that must be addressed for sites that drain to any of the above areas.

STEP 2C: SITE CONSTRAINTS

Use Matrix 2c to determine if the soils, water table, drainage area, slope or head conditions present at a particular development site might limit the use of a practice. For example, constructed wetlands

Matrix 2a- Stormwater Management Capability				
GROUP	**PRACTICE**	**RECHARGE**	**WATER QUALITY**	**FLOOD CONTROL**
EXISTING LANDFORMS	Natural Depressions	🟢	🟢	🟢
WET PRACTICES	Constructed Shallow Wetland	🔴	🟢	🟢
	Gravel Wetland	🔴	🟢	🟢
	Wet Swale	🔴	🟢	🔴
DRY PRACTICES	Infiltration Trench	🟢	⭕	◯
	Sub-surface chambers	🟢	⭕	◯
	Recharge chamber	🟢	⭕	◯
	Infiltration basin	🟢	⭕	◯
FILTRATION PRACTICES	Sand Filter	🟡	🟢	🔴
	Bioretention	🟡	🟢	🔴
	Bioswale	🟡	🟢	🔴

🟢: Practice generally meets this stormwater management goal.
🔴: Practice can almost never be used to meet this goal.
⭕: Only provides water quality treatment if bottom of practice is in the soil profile
🟡: Provides recharge only if designed as an exfilter system.
◯: Can be used to meet flood control in highly permeable soils

generally require a drainage area of 10 acres or more unless groundwater interception is likely, and can consume a significant land area.

This matrix evaluates possible options based on typical site constraints. More detailed testing protocols are often needed to confirm these conditions. The five primary factors that should be initially evaluated are:

- Soils: This column indicates if the practices is suitable for well, moderate or poorly drained soils. Initial evaluation of the soil conditions are based upon NRCS hydrologic soil groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.
- Water Table: This column indicates the if a shallow (< 4') or deep depth (> 4') the groundwater is required. Note that a site soil evaluation and infiltration testing is required to determine the design depth the SHWT.
- Drainage Area: This column indicates the minimum or maximum drainage area that is considered optimal for a practice. If the drainage area present at a site is slightly greater than the maximum allowable

Matrix 2b- Pollutant Removal

GROUP	PRACTICE	MEDIAN POLLUTANT REMOVAL EFFICIENCY (%)			
		TSS	TP	TN	Bacteria
EXISTING LANDFORMS	Depression	See Infiltration Basin			
WET PRACTICE	Shallow Wetland	85%[2]	48%[3]	30%[2]	60%[2]
	Gravel Wetland	86%[3]	53%[1]	55%[3]	85%[2]
	Wet Swale	85%[3]	48%[3]	30%[2]	60%[2]
DRY PRACTICE	Infiltration Basin	90%[2]	65%[3]	65%[2]	95%[2]
	Infiltration Trench	90%[2]	65%[3]	65%[2]	95%[2]
	Subsurface Chambers	90%[2]	55%[2]	40%[2]	90%[2]
	Recharge Basin	90%[2]	55%[2]	40%[2]	90%[2]
FILTRATION PRACTICE	Sand Filter	86%[3]	59%[3]	32%[3]	70%[2]
	Bioretention	90%[1]	30%[2]	55%[2]	70%[2]
	Bioswale	90%[1]	30%[2]	55%[2]	70%[2,6]

"ND" Specifies No Data

"NT" Specifies No Treatment

References:

1. (UNHSC, 2007b)
2. (CWP, 2007)
3. (Fraley-McNeal, et al., 2007)
4. (prescribed value based on general literature values and/or policy decision)
5. (50% of reported values of low end for extended detention basins)
6. Presumed equivalent to bioretention; will require diligent pollutant source control to manage pet wastes in residential areas.

drainage area for a practice, some leeway is warranted where a practice meets other management objectives. Likewise, the minimum drainage areas indicated for constructed wetland should not be considered inflexible limits, and may be increased or decreased depending on water availability (baseflow or groundwater), mechanisms employed to prevent clogging, or the ability to assume an increased maintenance burden.

- Slope: This column evaluates the effect of slope on the practice. Specifically, the slope guidance refers to how flat the area where the practice is installed must be and/or how steep the contributing drainage area or flow length can be without requiring retaining walls.
- Head: This column provides an estimate of the elevation difference needed for a practice (from the inflow to the outflow) to allow for gravity operation.

The criteria presented are planning level guidance and can vary depending upon site conditions, budget and creativity.

STEP 2D: COMMUNITY AND ENVIRONMENTAL BENEFIT

Use Matrix 2d to compare the practice options with regard to maintenance, cost, plant communities, habitat, and gateway/aesthetic value. Some practices can have significant secondary environmental benefits that may meet specific site goals beyond stormwater management. Likewise, some practices have frequent maintenance and operation requirements that are beyond the capabilities of the owner. For example, infiltration practices are generally considered to have the highest maintenance burden because of a high failure history and consequently, a higher pretreatment maintenance burden and/or replacement burden.

Matrix 2c-Site Constraints

GROUP	PRACTICE	SOILS	DEPTH TO WATER TABLE	DRAINAGE AREA (Ac)*	SITE SLOPE	HEAD (Ft)
Existing Landforms	Depressions	Native well drained to moderately drained	>3'	Small to large	Varying slope	3 ft
Wet Practice	Constructed Shallow Wetland	Native poorly drained	<3'	Large *if not intercepting gw	Flat	3-5 ft
	Gravel Wetland	Native poorly drained	<3'	Medium to large *if not intercepting gw	Varying slope	3-5 ft
	Wet Swale	Native poorly drained	<3'	Small to medium *to any 1 inlet, not limit if runoff enters via sheet flow	Flat	1 ft
Dry Practice	Infiltration Trench	Native well drained to moderatly drained	>3'	Small to medium	Relatively Flat	1 ft
	Sub-surface Chambers	Native well drained to moderately drained	>3'	Small to medium	Varying slope	1ft
	Recharge Basin	Native well drained to moderately drained	>3'	Small	Varying slope	1ft
	Infiltration Basin	Native well drained to moderately drained	>3'	Small to large	Varying slope	3ft
Filtration Practice	Sand Filter	Any soil type	< or >3'	Small to large	Relatively Flat	2-6 ft
	Bioretention	Any soil type	< or >3'	Small to medium	Relatively Flat	
	Bioswale	Any soil type	< or >3'	Small to medium	Varying slope	18 in-5 ft

Notes
Drainage Area: Small=<1 ac. Medium= 1-5 ac. Large= >.10 ac.
Slope: Flat: 0-2% Relatively flat: 2-5% Varying Slope 0-20%
*drainage area can be larger in some instances.

A green circle indicates that the practice has a high benefit, and a red circle indicates that the particular practice has a low benefit.

- Ease of Maintenance: Practices are assessed for the relative maintenance effort needed for a practice, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that all practices require routine inspection and maintenance.
- Affordability: The practices are ranked according to their relative construction cost per impervious acre treated. These costs exclude design, permitting, and other costs.
- Plant Community: Practices are evaluated on their ability to maintain certain plant community types.
- Habitat: Practices are evaluated on their ability to provide wildlife habitat, assuming that the proper plant communities are established. Objective criteria include size, water features, and vegetative cover of the practice and the surrounding area.
- Gateway/Aesthetic Value. Practices are assessed for their aesthetic value and appropriateness for use at identified gateways.

Step 3: Site Ranking

Upon completion of the practice selection, it is suggested that each site be subject to a refined ranking criteria to help further prioritize locations for potential stormwater management practices. Step two includes the further prioritization, which allows the identified sites to be compared to find the most cost-effective sites for implementation. Typically, the ranking system is based upon a 100-point scoring system, where the relative merit of each potential site is evaluated by assigning points based on the following criteria:

- Existing landform is used
- Water quality volume treated
- Percent targeted pollutant reduction
- Corrects an existing flooding/safety problem
- Vegetation Enhancement
- Access issues (for construction and/or maintenance)
- Maintenance burden

The criteria outlined above are not listed in order of importance and the points assigned to each of the above criteria may vary by projects. For example, if the project site is located within a designated gateway area within the Route 6 corridor, vegetation enhancement may be assigned a higher value than the estimated planning level construction cost or water quality volume treated. The ranking criteria and weighted values should be developed in consultation with the Cape Cod Commission to ensure priority criteria properly address the project goals.

Based upon the assigned ranking criteria, number scores shall be assigned for each criteria and entered into a spreadsheet. It is suggested that the sites be ranked from highest to lowest to establish the priority list. Summing the assigned points for each of the factors provides an overall site score. Sites with the highest score represent the best overall candidates for implementation.

Step 4: Operation and Maintenance Goals

Prior to the selection of pretreatment practices for the top ranked sites, operation and maintenance goals should be considered. The type of

Matrix 2d Community and Environmental Benefit

GROUP	LIST	EASE OF MAINTENANCE	AFFORDABILITY	PLANT COMMUNITY	HABITAT	GATEWAY/ AESTHETIC VALUE
EXISTING LANDFORMS	Depression	Medium	High	High	High	Low
WET PRACTICE	Constructed Shallow Wetland	High	Medium	High	High	Low
	Gravel Wetland	Medium	Low	Medium	High	Low
	Wet Swale	High	High	High	Medium	Medium
DRY PRACTICE	Infiltration Trench	Low	Medium	Low	Low	Low
	Infiltration Chambers	Low	Medium	Low	Low	Low
	Recharge Basins	High	High	Low	Low	Low
	Infiltration Basin	Low	Medium	Medium	Low	Medium
FILTRATION PRACTICE	Sand Filter	Low	Low	High	Low	Medium
	Bioretention	Medium	Medium	High	Medium	High
	Bioswale	Medium	Medium	High	Low	Medium

: High Benefit
: Medium Benefit
: Low Benefit

maintenance required or desired could have a significant impact on the long-term ecological health of the potential plant communities and habitat, which may be created. For example, at a project site, where habitat creation or preservation has been identified as a top priority, an above ground sediment forebay located within the practice may not be the best option because yearly continual clean out of sediment and disturbance will be required. A below ground oil and grit separator may be the preferred option to minimize future disturbance caused during regularly scheduled maintenance. The removal of sediment of debris from a below ground tank may be the preferred option to minimize disturbance to both plant communities and habitat.

Detailed Operations and Maintenance requirements of the different practices are provided in the Appendix for reference.

Step 5: Design Elements for Pretreatment Practices

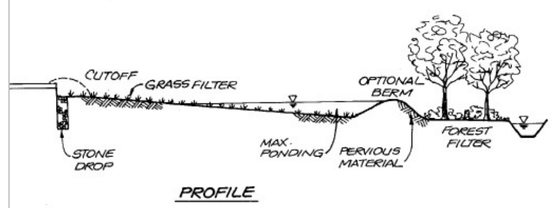
There are several stormwater management practices that do not meet the water quality performance Standard 3 and therefore cannot be used to treat the water quality volume, but may be useful to provide pretreatment. The incorporation of pretreatment practices into the stormwater management system can assist with the targeted pollutant removal, improve water quality and enhance the effective design life of practices by consolidating the maintenance to a specific location. Pretreatment practices must be combined with other stormwater practices and are not acceptable as standalone practices. The figures and images included in this section are schematic only. Design plans should be consistent with the schematic figures when using the method or practice described, but must be designed based upon site-specific conditions and construction purposes.

GRASS CHANNEL

Grass channels are similar to conventional drainage ditches, with the major differences being flatter side and longitudinal slopes, as well as a slower design velocity for small storm events. The best application of a grass channel is as pretreatment to other structural stormwater treatment practices (adapted from the CWP, 2008).

Grass channels can be applied in most development situations with few restrictions, and are well suited to treat highway or residential road runoff due to their linear nature. LUHPPL runoff should not be directed toward grass channels (particularly for pervious soils and shallow groundwater), unless they are lined to prevent infiltration.

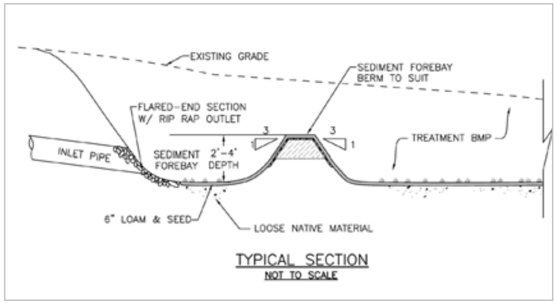
FILTER STRIPS



Source: Claytor and Schueler, 1996

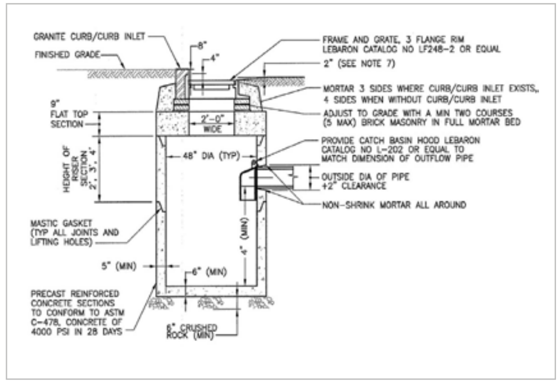
Filter strips (i.e., vegetated filter strips, grass filter strips, and grassed filters) are vegetated areas that are intended to treat sheet flow from adjacent impervious areas. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some infiltration into underlying soils. Filter strips are well suited to treat runoff from roads and highways and with proper design and maintenance, filter strips can provide effective pretreatment. One challenge associated with filter strips, however, is that it is difficult to maintain sheet flow. Consequently, urban filter strips are often "short circuited" by concentrated flows, which results in little or no treatment of stormwater runoff (adapted from the CWP, 2008).

SEDIMENT FOREBAY



A sediment forebay can be used as a pretreatment device to minimize maintenance needs for stormwater practices. The purpose of the forebay is to provide pretreatment by settling out sediment particles. This will enhance treatment performance, reduce maintenance, and increase the longevity of a storm water facility. A forebay is a separate cell within the facility formed by a barrier such as an earthen berm, concrete weir, or gabion baskets.

DEEP SUMP CATCH BASINS



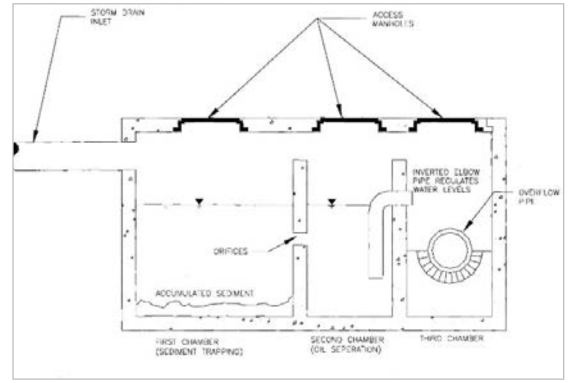
Source: MADEP, 2008

Deep sump catch basins are modified inlet structures that can be installed in a piped stormwater conveyance system to remove trash, debris, and coarse sediment. They can also serve as temporary spill containment devices for floatables such as oils and greases.

The deep sump catch basin must be designed in a catch basin-to-manhole configuration (NOT in a catch basin-to-catch basin configuration) to be used as pretreatment. The contributing drainage area to each deep sump catch basin shall not exceed 0.5 acres of impervious cover.

Potential site constraints include the presence of utilities, bedrock, and high groundwater elevations.

OIL AND GRIT SEPARATOR

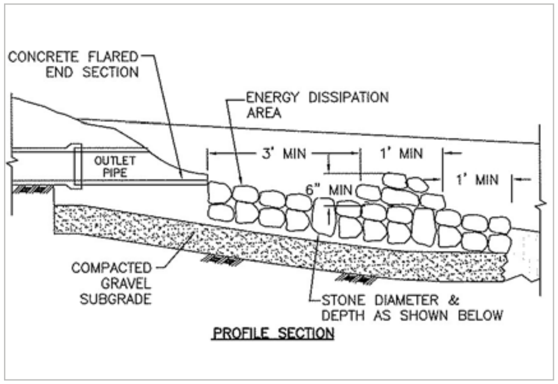


Source: MassDOT, 2004

Oil and grit separators can be used as a pretreatment device to minimize maintenance needs for stormwater practices. They are pre-cast concrete or pre-fabricated multi-chambered structures designed to remove course sediment, floating debris and oils from stormwater prior to discharge to a stormwater practice. They typically are used to enhance treatment performance, reduce maintenance, and increase the longevity of a storm water facility.

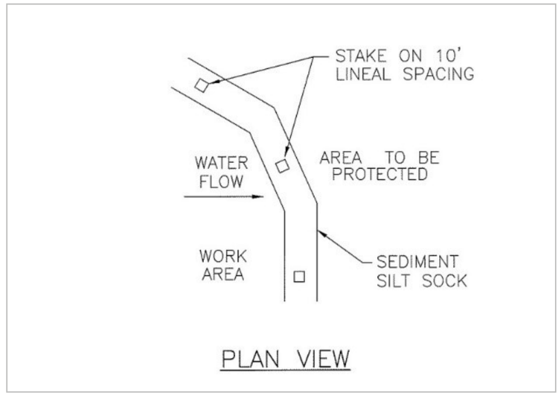
Each separator typically can be sized to receive runoff from a drainage area of less than 1 acre.

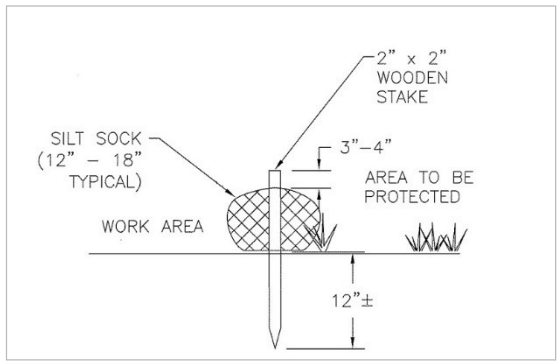
ENERGY DISSIPATION BASINS

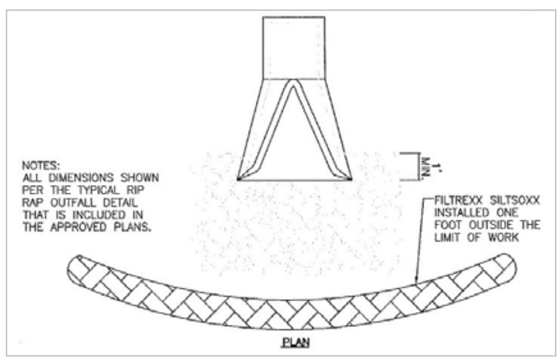


Energy dissipaters are pretreatment devices located at pipe outfalls use to protect downstream areas from erosion by reducing the velocity of flow and minimizing scouring. This practice is best suited for areas where site access for construction and maintenance would be such as natural depressions. Energy dissipaters could also be applied at existing outfalls into natural depression to stabilize the area around the outlet and reduce erosion and sediment build up within the surrounding landscape.

COMPOST FILTER SOCKS







Compost filter socks are recommended as a practical, temporary solution for areas where site access for construction and maintenance are difficult such as outfall locations. They can be easily designed and installed based on site requirements and have the following benefits:

- Reducing energy of runoff at the outlet and slowing velocity of flows on slopes
- Filtering of stormwater runoff, including reduction of sediment, nutrients, bacteria, heavy metals and petroleum hydrocarbons
- Improving potential maintenance requirements by removing the silt sock at the end of its design life or incorporating the compost sock as a natural berm at the site

A typical detail for a compost filter sock is shown in Figures 4 and 5. Compost filter socks are typically 12- to 18-inches in diameter and are staked in place (either through center as shown or on the downhill side) to ensure that flows do not move them. Compost filter socks may also be seeded at the time of installation to increase pollution filtration and restoration at the outfall.

PROPRIETARY DEVICES

Many proprietary stormwater treatment devices are available and may provide a cost-effective solution, particularly for retrofit situations, including oil/grit separators, hydrodynamic devices, and a range of media filtration devices, among others. Studies (Schueler, 2000; Claytor, 2000; UNHSC, 2007) have shown that these proprietary devices are not capable of achieving the required water quality performance and there is insufficient documentation to use these practices as stand-alone devices. However, they may provide pretreatment for stormwater before it is directed to a water quality practices if an independent third-party monitoring group (e.g., MASTEP, ETV, TARP) verifies that it is capable of a minimum of 25% TSS removal efficiency. Oil/grit separators are particularly useful pretreatment practices for runoff that may have high pollutant loads of oils and grease.

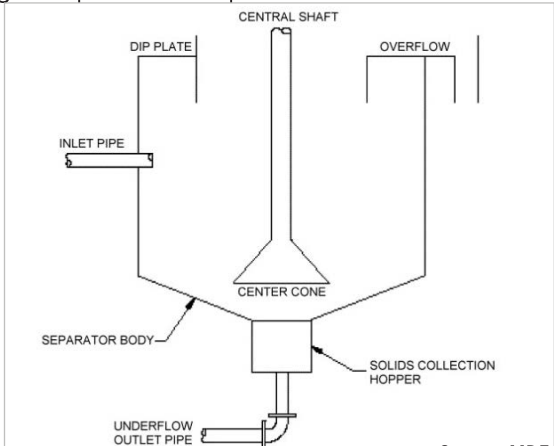
To qualify as an acceptable pretreatment device, a proprietary device must remove a minimum of 25% TSS, as verified by an independent third-party monitoring group. In certain retrofit cases where higher pretreatment standards may be appropriate, higher removal efficiency for TSS may be required in order to achieve stormwater treatment goals for the project.

In order to be used for pretreatment device, proprietary devices are designed, per the manufacturer's recommendations, as off-line systems or to have an internal bypass to avoid large flows and re-suspension of pollutants.

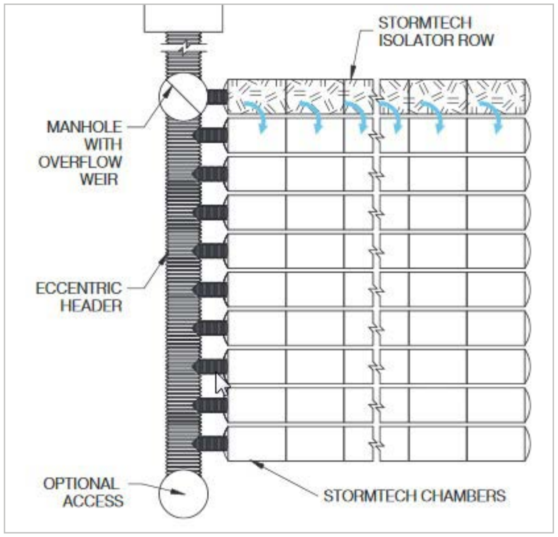
The contributing drainage area to each proprietary device should generally not exceed 1 acre of impervious cover. Potential site constraints include the presence of utilities, bedrock, and high water tables.

Hydrodynamic separators are small, flow-through devices that treat runoff by trapping sediment and debris and by separating floatable oils from the water. These devices primarily rely on a swirling action and particle setting to remove sediment and other pollutants. Hydrodynamics separators generally work best as pretreatment devices for other stormwater management practices such as bioretention areas or infiltration basins.

The Isolator Row is a manufactured system designed to provide subsurface water quality treatment and easy access for maintenance. It is typically used to remove pollution from runoff before it flows into unlined sub-surface infiltration chambers designed for detention and water quantity control. The Isolator Row consists of a series of chambers installed over a layer of woven geotextile, which sits on a crushed stone infiltration bed surrounded with filter fabric. The bed is directly connected to an upstream manhole for maintenance access and large storm bypass. The Isolator Row is well suited for locations where subsurface chambers are used and above ground pretreatment space is limited.



Source: MDE



Source: StormTech

Pretreatment Companion Practices

GROUP	LIST	GRASS CHANNEL	FILTER STRIP	SEDIMENT FOREBAY	DEEP SUMP CB	OIL/GRIT SEPARATOR	ENERGY DISSIPATER	COMPOST FILTER SOCK	PROPRIETARY DEVICES
EXISTING LANDFORM	Depression	🟡	🔴	🔴	🟢	🟢	🟢	🟢	🔴
WET PRACTICE	Constructed Wetland	🟢	🟡	🟢	🟡	🟢	🔴	🔴	🔴
	Gravel Wetland	🟡	🔴	🟡	🟡	🟢	🔴	🔴	🔴
	Wet Swale	🟢	🟢	🟢	🟡	🟡	🔴	🔴	🟡
DRY PRACTICE	Infiltration Trench	🟡	🟢	🟡	🟢	🔴	🔴	🔴	🔴
	Infiltration Chambers	🟡	🟡	🔴	🟢	🟢	🔴	🔴	🟢
	Recharge Basins	🔴	🔴	🔴	🟢	🟢	🔴	🔴	🟡
	Infiltration Basin	🟢	🔴	🟢	🟡	🟢	🔴	🔴	🟡
FILTRATION PRACTICE	Sand Filter	🟢	🔴	🟢	🟡	🟡	🔴	🔴	🟡
	Bioretention	🟢	🔴	🟢	🟡	🟡	🔴	🔴	🟡
	Bioswale	🟢	🟡	🟢	🟡	🟡	🔴	🔴	🟡

🟢 : Best option for most practice and site conditions
🟡 : Good-may depend upon the size of the practice, contributing watershed and site area
🔴 : Not practical, but could be used in certain applications.

CHAPTER 4

VEGETATION MANAGEMENT

Route 6 Stormwater and Vegetation Management

Approach

This plan recommends that the unique pine barren ecosystem, crossed by the Route 6 corridor, be maintained by MassDOT with practices that promote pine barren ecologies. This chapter reviews the varying management tools that are recommended to maintain and in some areas reestablish these pine barrens.

Maintaining the diversity of the pine barrens involves creating continued disturbances which are needed to maintain the dynamic nature of pine barrens habitats. Since pine barrens are a mid-succession landscape historically maintained by a natural cycle of fires, if fire or other types of disturbance are not part of a management practice, succession will continue and this niche ecological landscape will be lost. With today's dense settlement, fire suppression has caused many pine barrens to become thicker with vegetation such as shade- tolerant hardwoods; many pine barrens on the Cape have started transitioning to species such as Pinus strobus (White Pine). In addition to the loss of pine barrens, the lack of more frequent burns has actually put communities at higher risk for a larger uncontrolled wildfire; species are crowded in due to lack of controlled burns, and this creates more fuel which has repercussions for person and property. Fire risk is categorized by fuel types, and the pitch pine and scrub oak cover in Southern Massachusetts is considered high, so wildfire in addition to species conservation is a concern.

Vegetation management along the Route 6 corridor shall not only consider disturbance to influence species distribution, but also to address the potential for wildfire issues. Vegetation management strategies are recommended to be "ecologically-based and mimic the fire and cutting histories that created the hz ecosystem, in order to maintain the distribution of cover types, species, fuel structure, and soil structure patterns on the landscape. Forestry practices that mimic historic disturbance patterns can be defined by: return interval (the average time between occurrences of disturbances in a given stand); severity (the amount of vegetation and root system killed, and the type of growing space made available for new plants); landscape pattern (distribution of disturbance patch mosaic effects); the size and timing of fire and disturbances; cover types; age classes; and the demands, pressures and benefits placed upon forests by the human environment." (Pinelands Forestry Advisory Committee, 2006)

Threats to Ecological Values

"The problems associated with fostering healthy native pine barrens plant communities fall into two basic categories: 1) mowing regimes and 2) construction materials and post-disturbance soil erosion control practices. Repeated growing-season mowing has severely degraded native plant communities.

Construction materials and post-construction soil erosion control practices fundamentally alter soils by increasing soil pH and/or increasing soil nutrients, which shift the competitive balance to non-native species that destroy native plant communities. Construction materials that raise soil pH include trap rock gravel and pulverized concrete. The addition of nutrient rich topsoils, fertilizer and lime to prepare sites for sowing of non-native cool season grasses following construction or maintenance activities has significantly and perhaps permanently destroyed thousands of acres of roadside habitat." (Pinelands Preservation Alliance, 2009)

Recommendations

There are several management opportunities for the corridor that should be considered in two categories: Ongoing Vegetation Maintenance & Vegetation Management Construction Projects. The following section reviews the Ongoing Vegetation Maintenance options. Management is critical for public safety but also provides an opportunity to promote biodiversity and pine barrens conservation. Pine barrens are characterized by disturbance, historically due to fire, but some mechanical disturbance practices to renew the forest landscape may also considered when conducted in an appropriate manner. This report recognizes that prescribed burning is not a current practice for state roadway maintenance. However, given the unique ecology of the Route 6 right-of-way, prescribed burning and alternative mechanical control methods are presented for further consideration.

What are the effective management tools to maintain and increase the existence of pine barrens on Cape Cod?

Two of the management techniques that can be utilized to mimic this natural process are Prescribed Burning and Mechanical Control, or a combination of both. The following section details these management options.

PRESCRIBED BURNING

Pitch pine/scrub oak communities are prone to wildfires given their unique composition. Species of the community tend to be adapted to occasional light fires: scrub oaks and huckleberries sprout readily from their root crowns and pitch pine has thick bark that resists fire damage and produces some cones that release their seeds only when heated by fire. Once the fire has passed these species sprout back vigorously while most types of trees (including many invasive species) don't survive the fire. Some of the pine barrens herbaceous species have seeds that stay in the soil for years and only germinate after light fire; the plant may be abundant for a few years after a fire before larger plants shade them out. A pulse of nutrient availability after a fire results in lush growth of the plants in the first few years, with increased variety of insects that eat the plants, and birds that eat the insects and berries of the plants. This creates an ecological chain reaction adapted to a constantly changing landscape influenced by fire.

Many of the early inhabitants of the east coast used controlled burning to maintain ecosystem stability of the pine barrens and control wildfires. (Nature Conservancy) There are two examples of large pine barren forest cover in Southern Massachusetts that currently use this technique for management: Myles Standish State Forest in Plymouth and the Massachusetts Military Reservation in Bourne and Sandwich.

Massasoit National Wildlife Refuge is a piece of the Myles Standish state forest and part of the largest contiguous pitch pine/scrub oak forest north of Long Island Sound. Controlled burns have been held in this area for the past several years, with targets on underbrush such as needles, fallen twigs and leaves; these burns are carefully managed and are held both to renew the pine barrens plant community and simultaneously protect the adjacent communities by reducing the fuel that could ignite larger fires. Myles Standish State Forest began their controlled burn program in 2000 and Massasoit began shortly thereafter in 2007.

Controlled burns can be potentially much less disturbing to mineral soils, roots and wildlife than mechanical cutting, and stimulate natural regeneration of pitch pine seeds which require fire to open cones and germinate. In addition, controlled burns can allow the native vegetation to out-compete invasives that will not survive the burning process. (Pinelands Forestry Advisory Committee, 2006) These burns are typically completed in the dormant winter season (advantageously when visitor trips to the Cape are at their lowest.)

Controlled burns can initially be viewed as a threat to the public, dangerous and too difficult to consider. However, may public entities, such as the National Park Service have safely and effectively taken on this practice. Ecologically it can often be the most appropriate management technique, and the cost reduction associated with infrequent burns (on a 5-6 year cycle) as opposed to several cuts and herbicide applications during just one growing season can prove advantageous.

Outreach and educating the public regarding controlled burns, fuel-hazard reduction and planning must be addressed prior to any changes in forest management. Prescribed burning has been shown to be supported more strongly when the public understands the techniques involved. Strategies for implementing controlled burns on the Cape could include information distribution such as fliers, public meetings or television ads, but a demonstration project could have the potential to reach a wider public audience. In addition, educating homeowners on defensible space techniques and the benefits of fire in maintaining pine barrens ecology are critically important.

Any control burn needs to be carefully planned and prepared for and if considered for this corridor, should involve other entities besides MassDOT in the planning, preparation and implementation phases. Organizations that should be involved should include but not necessarily limited to; Municipal Fire Departments, Massachusetts Department of Conservation and Recreation Fire Control, Nature Conservancy, Natural Heritage & Endangered Species Program, The Cape Cod Commission, Division of Fisheries & Wildlife and local Conservation Commissions.

Currently The Massachusetts Department of Conservation and Recreation, Camp Edwards Military Reservation, Wampanoag Indian Reservation, Trustees of Reservations and the Nature Conservancy along with municipalities are doing their part to actively manage to preserve the pine barrens of Southeastern Massachusetts as they are impacted by their organizations. In addition, the Pinelands Preservation Alliance developed a document titled “Best Management Practices for pine barrens Roadside Plant Communities” in 2009, referenced in this appendix, which contains detailed roadside management opportunities to maintain pine barrens landscapes. In addition to the recommendations within this report, it is recommended that the practices of these organizations be studied by MassDOT to assess the success of management techniques before future maintenance practices are selected.

MECHANICAL CONTROL

Another way to manage for the promotion of the pine barrens ecology is with thoughtful, scheduled mowing practices and selective cutting of undesirable trees and understory invasive plants. The challenge with this technique is that it is annually labor intensive and time consuming.

MOWING

“The simplest way to improve the ecological health of roadside plant communities is to reduce mowing, which also provides tangible cost savings for roadside managers. Where necessary for road maintenance or provision of safe vehicle pull-off areas, regularly mown turf should be restricted to the Operational Zone (ca. 8 feet from the traveled lane edge). Annual dormant season mowing should be employed beyond the Operational Zone to foster native plants. Existing positive mowing regimes include the New Jersey Department of Transportation's GEMZ (Grassland Eco Mow Zone) program and New Jersey Burlington County's delayed mowing program along Route 563." (Pinelands Preservation Alliance, 2009) These programs should be reviewed as a precedent by MassDOT.

Typically, on roadsides, there is a variety of resistant plant species within the ROW that receive significant exposure to both vehicular toxins and maintenance regimes. Grass species have growing cells on the base of their stems, stimulating growth from mowing. However, other herbaceous species such as forbs have growing cells at the tip of their stems, hence, cutting and mowing can have serious effects on the roadside environment of native species. (Forman, 2003). Thriving roadside species have wide adaptability to disturbance, are usually prone to full sun and don't seem too affected by wet/dry or cool/ hot changes. Most plants are predominantly perennial with some annual species spread from seed. (Forman, 2003). Natural plant communities can and are often seen along roadsides, however, on over-mowed sites and those where nonnative plants surround the corridor, these plant communities can become lost. In a worst case scenario, monocultures of invasives or mowed grasses can form along roadsides. This type of habitat is early successional, and mowing practices and other types of human impacts keep this succession from moving past the herbaceous perennial stage. Paired with construction activities and repeated mowing, soils are fundamentally altered, often increasing soil pH or nutrients. These disturbance practices directly preference nonnative species. (Van Clef, 2009). In addition, roadsides are highly compacted by vehicles and heavy maintenance machinery. In many cases herbicides are used to break down woody plants or plants are used strategically as noise barriers, glare reducers and impact absorption for errant vehicles. (see MassDOT regulations). All of these vegetation practices greatly impact the native plant environment.

Mowing is a form of mechanical maintenance that is common along roadsides. However, there are two dimensions that should be considered when using mowing as a management tactic: timing and frequency. (Forman, 2003). Timing depends on season, nesting periods, pollination and unexpected extreme weather events such as droughts or heavy rains. It is well documented that mowing once or twice a year is a large cost savings over mowing 5 or 6 times a year. It also provides more opportunity for species richness in not favoring a few species that begin to out-compete others. There is also the concern of soil erosion with repeated mowing, especially on slopes exceeding 3 on 1 slopes. Reduction in mowing practices in both time and scale can have profound effects on both ecological systems and cost. It has been documented that mowing a maximum of twice a year in the beginning and end of growing cycles yields the highest plant diversity (Forman, 2003).

CLEAR ZONE

A reduction of mowing frequency in the Clear Zone will provide cost savings, habitat protection and increased stormwater infiltration, and reforestation of bowls or medians will help reduce snowdrift onto the roadway. Where applicable, eliminating mowing in areas beyond the clear zone will increase stormwater retention and transpiration. Integrating mowing with selective herbicide application to control invasive species is optimal, for both maintenance and ecological purposes. "The clear zone should be mowed on an annual basis during the dormant season. Whenever possible, all mowing should occur in March (ca. late winter / early spring) to allow the full, uninterrupted life cycle of plants including growth, flowering, seed production, seed dispersal and seedling establishment. Annual mowing will remove the tops of any woody plants that may have sprouted during the previous year and will weaken root systems to stunt future growth. Mowing height should be 6 inches above the ground to avoid damage to a suite of short-statured woody native species (e.g., Bearberry, Blueberry, Huckleberry which are excellent ground cover for roadsides). Fertilizer or other soil amendments should not be utilized to avoid impacts on native plants growing in any zone. Areas of any zone that are currently sparsely vegetated should not be mowed. This will reduce mower-generated soil erosion.

Practical considerations of a condensed mowing schedule may necessitate a wider mowing window (i.e., after November 30th and before March 30th) because personnel may not be able to perform all necessary mowing during a one month period. Even though personnel time constraints may not allow all mowing to occur in March, effort should be taken to delay mowing into late autumn to allow late-flowering species (e.g., Pine Barrens Gentian, Asters, Bonesets, and Goldenrods) to produce and begin dispersing their seeds.

The flowering and fruiting of pine barrens plants indicates a number of potential roadside species that begin flowering as early as April and flower/produce fruit through October. It is critical that mowing regimes preserve both early blooming and late fruiting plants.

Exclusive use of dormant season mowing may not be adequate to completely eliminate recalcitrant woody species, especially where establishment is already underway (e.g., pitch pine sprouts). In these cases, it may become necessary to mechanically or chemically remove woody species. Prescribed burning during the dormant season should also be considered in this area as a useful option to reduce woody plant establishment. However, low intensity prescribed burning should not be utilized on an annual basis and care should be given to understand the impacts of repeated burns on reducing desirable native species and/or increasing invasive species." (Pinelands Preservation Alliance, 2009)

HIGHWAY BUFFER ZONE

Management in the highway buffer zone is important to prevent the spread of invasive species into the Clear Zone and Roadway and Guardrail ROW and to prevent spread onto adjacent lands. Particular attention should be paid to areas that are adjacent to resource areas and priority habitat areas (as defined by the Massachusetts Department of Fish & Wildlife's Natural Heritage Endangered Species Program).

"Mowing is not recommended in this zone. However, invasives species management as well as fire management are strongly suggested. The primary tenets of invasive species management involve prevention, early detection and rapid response to newly forming infestations, and thoughtful control and restoration techniques. In all cases, the use of herbicides should be restricted or minimized to avoid impacts to non target species. Although mechanical control (e.g., hand pulling and cutting) is more labor intensive than chemical control methods, it is recommended." (Pinelands Preservation Alliance, 2009)

Mechanical pruning or selective cutting can reduce fire load and promote regrowth of understory species such as lowbush blueberry and huckleberry in this zone. Since crown wildfire is the most dangerous, thinning of the crown density to approximately 30 square feet basal areas per acre dramatically reduces risk. (Patterson, 2008) Selective thinning is also preferred to the current practice of clear cutting in areas such as utility corridors, which yield the highest numbers of invasive species grow back. Clear cutting without any selection can shift the ecology of these corridors away from the Pine Barren ecology. Without close attention to mechanical maintenance applications, the results can be detrimental to both public safety and the ecology of the region.

One typical mechanical fuel reduction method is the utilization of a brontosaurus. An advantage to using a brontosaurus is that it has tracks rather than wheels, so it doesn't compact the ground or do as much damage to low-growing plants as a wheeled vehicle would. The brontosaurus can make a trail into an area, then reach out 30 feet on each side with its boom – which ends in a tooth-studded drum spinning at high speed – and reduce standing trees and shrubs to scattered shards of wood and bark. (Doing this work in winter avoids harming box turtles and other reptiles that hibernate underground. Also, birds and mammals aren't breeding at that time.) This work needs to be completed sparingly without clearcutting an entire area. Additional fire mitigation techniques are suggested in the Barnstable County Wildlife Preparedness Plan, 2012.

MECHANICAL DISTURBANCE WITH PRESCRIBED BURNING

Controlled Burning in combination with mechanical reduction is a suggested pine barren vegetation management tool that should be strongly considered.

While mechanical techniques can be successful at providing a baseline of quality control, controlled burning can potentially be more successful, especially when combined with mechanical techniques, and can potentially provide a cost savings over repeat annual mowing and cutting as well.

This method of pine barren management is best utilized with the Control Burn technique because it produces groundcover biomass which increases the soil nutrient levels and overtime alters the soil type becoming less desirable to Pine Barren species.

There are a few additional approaches to the mechanical technique which include the use of a flail mower, Brontosaurus and a feller-buncher with a whole tree chipper and chip box truck. The brontosaurus is an excellent tool to use in combination with a control burn because it can selectively reduce the undesirable vegetation and reduce it to biomass groundcover for subsequent burning under the control burn technique. A flail mower can be utilized in areas immediately along road edges and interchange edges to control Knotweed, poison ivy and young invasive tree and shrub species that are growing in large land area spaces. The last mechanical technique is the feller-buncher in combination with the Whole tree chipper and chip box truck. This approach can be utilized somewhat effectively as an alternative to controlled burns in pine barren management. Under this approach, a forester/arborist marks the undesirable trees to be removed from the site. The feller-buncher shears or cuts the trees at the base and brings them to a landing where they are processed through the whole tree chip harvester and blown into a 40 foot chip box and hauled off site to an end use market. This approach removes the biomass from the site and subsequently reduces the nutrient loading litter, duff layer of the soil which will encourage the growth of pine barren species as opposed to other upland forest cover types that thrive on nutrient rich soils. Similar to recent public-private partnerships involving MassDOT to enhance monarch butterfly habitat, the CCC is willing to seek additional funding sources to pursue ROW maintenance techniques that promote pine barrens habitat.

MECHANICAL DISTURBANCE WITHOUT PRESCRIBED BURNING

When Control Burns are not a desirable technique, then the feller-buncher in combination with a whole tree chip harvester and forty foot chip box truck method would be the preferred method because it takes the biomass off site and does not contribute as much site specific nutrient loading as the Brontosaurus does or absence of management would do.

Vegetation Management during construction projects

NEW PLANTINGS, IMPLEMENTING STORMWATER PRACTICES AND SENSITIVE AREA RESTRICTIONS

New plantings are typically performed through construction contracts. Roadside plantings should be in groupings of diverse species. Close spacing of suckering species and shrubs is recommended to discourage invasion of weeds and invasive species, resulting in the reduction of herbicide application. It is paramount that the area be closely examined prior to initial planting to ensure that invasive species are not currently present.

RECOMMENDED PLANT SPECIES LIST

New plantings for any projects including stormwater practices in the Route 6 ROW shall only be comprised of pine barrens species specific to the micro-local. For example, if the site is primarily wet, local wet-adapted pine barrens species should be utilized, not just wetlands species native to Massachusetts in general. The idea is to create a connected background landscape that spreads seeds , habitat connections and the identitiy of the local pine barrens. Fragmented landscapes that include additional ornamental species are not ecologically connected and do more harm than benefit. Ornamental species not specifically native to the local pine barrens shall not be utilized. Following is a list of native Cape Cod pine barrens species that can be considered for projects along the Route 6. In addition, it is recommended that a local analysis of nearby native species be conducted prior to specifiying new plants so that mixes of native species locally present be prioritized. In addition, planting a broad range of species that host a diverse soil biology will result in maximum contaminant removal. Plants with high biomass production and fast growth rates typically mitigate contaminants more effectively than plants with slow growth rates, so biomass growth rate and ability to establish quickly to prevent intrusion of invasive plants should be factored into plant selection. (Kennen and Kirkwood, 2015)

Plant list below from: Swain, P.C. 2016. Classification of the Natural Communities of Massachusetts. Version 2.0. Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife. Westborough, MA.

Pitch Pine-Oak **Forest/Woodland** Community:

- Pitch Pine (Pinus rigida)
- Scarlet Oak (Quercus coccinea)
- Black Oak (Quercus velutina)
- White Oak (Quercus alba)
- Scrub Oak (Quercus ilicifolia)
- Dwarf Chinkapin Oak (Quercus prinoides)
- Black Huckleberry (Gaylussacia baccata)
- Dangleberry (Gaylussacia frondosa)
- Lowbush Blueberry (Vaccinium angustifolium)
- Early Blueberry (V. pallidum)
- Common Greenbrier (Smilax rotundifolia)
- Cat Greenbrier (Smilax glauca)
- Bracken Fern (Pteridium aquilinum)
- Wild Sarsaparilla (Aralia nudicaulis)
- Wintergreen (Gaultheria procumbens)
- Pennsylvania Sedge (Carex pensylvanica)
- Trailing Arbutus (Epigaea repens)
- Pink Lady's Slipper (Cypripedium acaule)

Pitch Pine-Scrub Oak /Scrub Oak **Shrubland** Communities:

- Scrub oak (Quercus ilicifolia)
- Pitch Pine (Pinus rigida) – sparse
- Dwarf Chinkapin oak (Quercus prinoides)
- Gray Birch (Betula populifolia)
- Black Chokeberry (Aronia melanocarpa)
- Sheep Laurel (Kalmia angustifolia)
- Black Huckleberry (Gaylussacia baccata)
- Lowbush Blueberry (Vaccinium angustifolium)
- Early Blueberry (V. pallidum)
- Bearberry (Arctostaphylos uva-ursi)
- Sweet Fern (Comptonia peregrina)
- Broom Crowberry (Corema conradii)
- Bracken Fern (Pteridium aquilinum)
- Birds-foot Violet (Viola pedata)
- Pennsylvania Sedge (Carex pensylvanica)
- Little Bluestem (Schizachyrium scoparius)

Species suitable for Wetter Areas (compatible with CC wetlands):

- Red Maple (Acer rubrum)
- Tupelo (Nyssa sylvatica)
- Gray Birch (Betula populifolia)
- Black Chokeberry (Aronia melanocarpa)
- Sheep Laurel (Kalmia angustifolia)
- Dangleberry (Gaylussacia frondosa)
- Dwarf Huckleberry (Gaylussacia dumosa)

Native Species suitable for Bioswales (including drought tolerant species that will survive inundation):

- Switchgrass (Panicum virgatum)
- Blue Flag Iris (Iris versicolor)
- Little Bluestem (Schizachyrium scoparium)
- Black-eyed Susan (Rudbeckia hirta)
- Red Twigged Dogwood (Cornus sericea)
- Tupelo (Nyssa sylvatica)
- Red Maple (Acer rubrum)
- Swamp White Oak (Quercus bicolor)
- Gray Birch (Betula populifolia)

Native species for Wet Practices:

- Common Rush (Juncus effusus)
- Woolgrass (Scirpus cyperinus)
- Native Cape Cod Sedges (Carex species)
- Pickerelweed (Pontederia cordata)
- Blueberry (Vaccinium species)
- Buttonbush (Cephalanthus occidentalis)

NEXT STEPS: RESOURCE MANAGEMENT PLAN

The Existing Mass DOT Vegetation Management Plan 2014– 2018 Plan is a good comprehensive overall plan covering areas such as; Roadside Management Zones, Mass DOT Vegetation Management Practices, Implementing Integrated Vegetation Management (IVM) Identification of Targeted Plants, Justification of the Use of Herbicides, Identification of Sensitive Areas, Herbicide Alternatives, Alternative Land Use and associated subtopics and Guidelines. It is a statewide plan and as such should be used as guiding principles with more comprehensive District Plans or target area specific plans with unique or special biological conditions warranting attention.

Although the plan has sections entitled "Implementing Integrated Vegetation Management (IVM)" and "Mass DOT Vegetation Management Practices", neither section incorporates pine barrens specific controls. In addition, control burning is not listed as a vegetation management tool. This plan recommends that MassDOT investigate adding control burning to the plan due to the unique biological conditions that exist, not only on Cape Cod, throughout the southeastern area of District 5. It is an effective management tool for this unique ecology and has the added benefit of reducing the potential for wildfires through the removal of forest fuels in a heavily populated section of Massachusetts. Besides removing forest fuels and enhancing the forest fire safety in this portion of the state it helps to promote the unique biological features which are an important ecological condition for the various endangered species and species of special concern.

Looking at the Route 6 corridor from the Sagamore Bridge to the Orleans Rotary, if properly managed, the corridor could become a manmade fire break separating the land mass on the north side of the highway from that on the south side.

Utilizing the vegetation management tool technique of controlled burns in concert with other integrated vegetation management tools such as mechanical and chemical tools, then the reduction in forest fuels (biomass) will enhance this fire barrier while encouraging the retention and potential expansion of a pine barren.

A Resource Management Plan for the pine barrens should be developed utilizing the expertise of the aforementioned recommendations may include:

- Develop and implement a comprehensive fire management program to include a combination of mechanical fuel reduction and prescribed fire to improve and maintain habitat quality for rare Pine Barrens species, as well as to reduce the potential for an uncontrollable wildfire.
- Develop and implement a plan to remove tree plantations consisting of non-native species to reduce fire danger and improve Pine Barrens habitat. Following cutting, controlled burning should be implemented to stimulate development of native Pine Barren habitat.
- A timetable for the mechanical removal of undesirable plant species that will eliminate any potential for impact on other wildlife habitat and define the extent of the mechanical removal operation which should coincide with the control burn area.
- A timetable for the Control prescribed burn that will eliminate any potential for impact on other wildlife habitat and define the extent of the annual burn.

Through a Route 6 corridor sub-committee of the Cape Cod Commission, an integrated vegetation management planned approach could be developed and implemented which will meet Mass DOT roadway management needs while enhancing the Pine Barrens and minimizing the potential wildfire situation. This sub-committee should have representation at minimum by Mass DOT Officials, Municipal Fire Departments, Massachusetts Department of Conservation and Recreation Fire Control and Forestry, Nature Conservancy, Natural Heritage & Endangered Species Program, Division of Fisheries & Wildlife and local Conservation Commissions.

Operations and Maintenance

The maintenance objective for implementing stormwater practices includes maintaining the hydraulic and pollutant removal capacity of the systems and maintaining healthy native, vegetative cover. This section describes the required O&M measures for each practice. This information is provided as an appendix so that maintenance goals can be considered during the practice selection process.

During the six months immediately after construction, all stormwater practices require monthly inspection as well as after precipitation events of at least 1.0 inch to ensure that the system is functioning properly. The following activities are recommended during the first six months after construction for all types of stormwater practices:

- Inspection of flume inlet, sediment forebay weir, and side slopes for erosion gullying. Repair/re-vegetate as necessary.
- Proper grass seed establishment and satisfactory growth. Additional loam and overseeding may be required within the first 6 months to correct bare spots and thin growth.
- Watering as required to establish and maintain new plantings.
- Loam and seed any void areas or washouts along swale and infiltration beds caused by precipitation runoff.

Thereafter, inspections should be conducted on an annual basis and after major storm events, which are those greater than or equal to the 1-year, 24-hour (Type III) precipitation event (~2.5" in Barnstable County).

The following tasks are recommended as specified or as needed basis and broken down by practice type.

NATURAL PRACTICE

Additional text to be added here in future versions

WET PRACTICES

CONSTRUCTED WETLAND

- Additional text to be added here in future versions

GRAVEL WETLAND

- Additional text to be added here in future versions

WET SWALE

Wet swales should be inspected annually and after storms of greater than or equal to the 1-year precipitation event. During inspection, the structural components of the system, including check dams, and overflow spillway structures, should be checked for proper function. Maintenance work consists of the following:

- Trash and debris should be removed and properly disposed.
- Sediment should be removed from the bottom of the swale.

- Any clogged openings should be cleaned out and repairs should be made where necessary.
- Embankments should be checked for stability, and any burrowing animals should be removed according to State or local Animal Control requirements.
- Vegetation along the side slopes should be mowed annually.
- Woody vegetation along those surfaces should be pruned where dead or dying branches are observed, and reinforcement plantings should be planted if less than 50 percent of the original vegetation establishes after two years.

DRY PRACTICE

INFILTRATION BASINS AND TRENCHES

An infiltration basin is a shallow impoundment that is designed to treat and infiltrate stormwater into the soil. These basins are sized to provide storage and exfiltration for recharge volume and treatment for water quality. Infiltration basins are designed to

Wet Swale Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/ sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Mowing	Min. twice per year or as necessary. Maintain 4"-6" grass height	Spring thru Fall
Watering	Drought conditions only	July- August
Overseeding	As required	Spring or Fall preferred
Fertilizing	Not required	
FILTER BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Tilling	As needed	If standing water does not drain after 48 hours
Soil Media Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

maximize pollutant removal efficiency, and can also help recharge the groundwater, thus restoring low flows to stream systems. They also attenuate peak discharges.

- Remove materials deposited along the basin floor (e.g., trash and litter) manually on a quarterly basis.
- Correct side slope erosion gullying, animal burrowing or slope slumping, and replanting as necessary.
- If standing water is observed more than 48 hours after a storm event, perform the following steps:
  - Aerate the basin floor
  - If aeration does not work, remove the top 12 inches and replace with new soil. If discolored or contaminated material is found below this removed surface, then remove and replace material until all contaminated sand has been removed from the filter chamber. Dispose of the soil in accordance with all applicable federal and local regulations.

Infiltration Basins & Trenches Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/ sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Mowing	Not required	Not required
Watering	Drought conditions only	July- August
Overseeding	As required	Early Spring or Fall preferred
Fertilizing	Not required	Not required
BASIN BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Aeration/Tilling	As needed	If standing water does not drain after 48 hours
Soil Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

- Loam and reseed with the originally specified seed mix. The basins and depressions are intended to be part of the landscape and vegetated practices. Mowing is not recommended.
- Cut back and thin vegetation annually. The seed mix specified is a low mow seed mix and the grass should be allowed to grow to depths of 12" to maintain a meadow appearance.
- Fertilizing: NOT REQUIRED. The grass seed selection should eliminate the need for fertilizers and pesticides.
- Watering: Watering is necessary during the initial grass establishment period (30 days min.), and during extreme drought conditions.

SUBSURFACE CHAMBERS

- Additional text to be added here in future versions

RECHARGE BASIN

- Additional text to be added here in future versions

FILTERING PRACTICE

BIORETENTION & BIOSWALES

- Removal of any trash and/or debris.
- Correction of any side slope erosion gullying, animal burrowing or slope slumping, and replanting as necessary.
- If standing water is observed in the bioretention 48 hours after a storm event, the top 6 inches of the bioretention soil/mulch area shall be rototilled or cultivated to breakup any hard-packed sediment, and replenished with mulch and replanted. The underdrain system shall be snaked and/or flushed. Replant with species as shown on Construction Plans.
- In a worst-case scenario, the entire filter bed may need to be re-installed. Upon failure, excavate bioretention soil, rake the pea gravel to loosen, inspect underdrain trench to determine if it has been compromised, repair as necessary, replace soil, replant, and mulch.

Plant maintenance is critical to the function of the bioretention area and should include the following:

- Cut back grasses, sedges, and rushes annually in the spring.
- Remove and replace vegetation as necessary, using the appropriate species as shown the Construction Plans. If at least 50 percent vegetation coverage is not established after two years, a reinforcement planting should be performed. When replacing a plant, place the new plant in the same location as the old plant, or as near as possible to the old location. The exception to this recommendation is if plant mortality is due to initial improper placement of the plant (i.e., in an area that is too wet or too dry) or if diseased/infected plant material was used and there is risk of persistence of the disease or fungus in the soil. The best time to plant is in early to mid-fall or early to mid-spring. Plants should be planted as soon as possible after purchase to ensure the best chance of survival. If possible, new plants should be approximately the same size as those that are being replaced. If surrounding plants have already become well established, care may need to be given to the new plants to ensure successful growth.
- Plant Thinning: Separation of herbaceous vegetation rootstock should occur when over-crowding is observed, or approximately once every 3 years.
- Mowing: Mowing of the bioretention area is NOT necessary or recommended. By design, plants in bioretention areas are meant to flourish throughout the growing season, leaving dry standing stalks during the dormant months. When mowing near bioretention areas, either use a mulching blade, or point the mower away from the bioretention area. Fresh grass clippings are high in nitrogen and should not be applied to bioretention areas, as they will compromise he facility's pollutant reduction effectiveness.
- Weeding: Weeding should be limited to invasive and exotic species, which can overwhelm the desired plant community. However, native non-invasive volunteer species are often desirable, as they add to the diversity of the plant community. Non-chemical methods (hand pulling and hoeing) are preferable; chemical herbicides should be avoided.
- Fertilizing: Proper selection of plant species and support during establishment of vegetation should eliminate the need for fertilizers and pesticides.
- Watering: Watering is necessary during the first few weeks after planting, and during

drought conditions. During drought conditions, plants should be watered a minimum of every seven to ten days.

- Mulching: Replace mulch every two years, in the early spring. The previous mulch layer should be removed, and properly disposed of, or roto-tilled into the soil surface. Mulch layers should not exceed 3" in depth. Avoid blocking inflow entrance points with mounded mulch or raised plantings. Once a full groundcover is established, mulching may

Bioretention & Bioswales Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/ sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Plant Cutting/Thinning	Annually	Early Spring
Weeding	As needed	April- October
Watering	Drought conditions only	July-August
Plant Replacement	As required	Spring or Fall preferred
Fertilizing	Should not be required	
MULCH MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Remove & replace existing mulch	Once every two years or as required	April
Re-mulch void areas	Min. 2x per year & after major storm events as needed	July & November
FILTER BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Tilling	As needed	if standing water does not drain after 48 hours
Soil Media Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

not be necessary. All barren areas within the extents of the facility shall be replenished with mulch and re-vegetated to the original design standards.

SAND FILTER

General maintenance of the seeded sand filter falls under landscaping practices. A general inspection of the bioretention area shall be conducted annually and after storm events greater than or equal to the 1-year, 24-hour Type III precipitation event (2.7 in).

Maintenance work consists of the following:

- Materials deposited on the surface of the sand filter (e.g., trash and litter) should be removed manually on a quarterly basis.
- Correction of any side slope erosion gullying, animal burrowing or slope slumping, and replanting as necessary.
- If standing water is observed more than 48 hours after a storm event, then the following steps should be taken:
  - The underdrain system shall be snaked and/or flushed.

Sand Filter Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Mowing	Min.twice per year or as necessary. Maintain 12" grass height	Spring thru Fall
Watering	Drought conditions only	July-August
Overseeding	As required	Spring or Fall preferred
Fertilizing	Not required	
FILTER BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Tilling	As needed	if standing water does not drain after 48 hours
Soil Media Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

- If the underdrain is not determined to not be clogged, the top 6 inches of sand should be removed and replaced with new materials. If discolored or contaminated material is found below this removed surface, then that material should also be removed and replaced until all contaminated sand has been removed from the filter chamber. The sand should be disposed of in accordance with all applicable federal and local regulations.

- Loam and reseed with the specified seed mix as shown on the Landscape Plan sheets of the Construction Plans as necessary.
- All structural components, which include the outlet structure, pipes, frame and grate, underdrain system, and timber check dams, should be inspected and any deficiencies should be reported.
- Mowing: The seed mix specified for the sand filter is a low mow seed mix and the grass should be allowed to grow to depths of 12" to maintain a meadow appearance. Mowing shall occur 4 times per growing season. When mowing near either use a mulching blade, or remove clippings from the filter bed area. Fresh grass clippings are high in nitrogen and should not be left in the filter bed as they will compromise he facility's pollutant reduction effectiveness or cause outlet structure clogging.
- Fertilizing: Proper grass seed selection during establishment of vegetation should eliminate the need for fertilizers and pesticides.
- Watering: Watering is necessary during the first grass establishment period 30 days min., and during drought conditions.

PRETREATMENT PRACTICES

GRASS CHANNEL AND FILTER STRIPS

Grass Channels and Filter Strips should be inspected on an annual basis and after storms of greater than or equal to the 1-year, 24-hour Type III precipitation event. Both the structural and vegetative components should be inspected and repaired. Maintenance work consists of the following:

- Trash and debris should be removed and properly disposed.
- When sediment accumulates to a depth of approximately 3 inches, it should be removed, and the swale should be reconfigured to its original dimensions.
- The vegetation in the dry swale should be mowed as required to maintain heights in the 4-6-inch range, with mandatory mowing once heights exceed 10 inches.
- If the surface of the dry swale becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the bottom should be roto-tilled or cultivated to break up any hard-packed sediment, and then reseeded.
  - Mowing: When mowing uses a mulching blade, or remove clippings from the swale area. Fresh grass clippings are high in nitrogen. Do not leave in the swale area as they can compromise he facility's pollutant reduction effectiveness or cause outlet structure clogging.

SEDIMENT FOREBAYS

The sediment forebay functions as pretreatment for the access drive runoff and prior to the infiltration basin. Conduct a general inspection of the forebay annually and after major storm events. Maintenance work consists of the following:

- Inlets at Sediment Forebays: Inspect annually and after major storm events to monitor for proper operation, collection of solids, litter and/or trash, and deterioration. Clean annually and inspect for sediment build-up at inlet, which may cause blockage and re-direction of flow away from the applicable facility. Remove accumulated sediment and dispose of properly.
- Removal of any trash and/or debris.
- Removal of sediment when buildup is greater than or equal to 3 inches. Remove sediment by hand to minimize damage to plants. Replace any plants damaged or removed during sediment removal with the same plant genus and species as originally specified. Dispose sediment off-site in a pre-approved location.
- Correct side slope erosion gullying, animal burrowing or slope slumping, and replant as necessary.
- Correct any settling of the swale between the sediment forebay and the infiltration basin treatment area. Ensure that weirs/check dams are level. Correct any erosion that has occurred around the edges of the weir.
- Remove and replace vegetation as necessary, using the appropriate species.

DEEP SUMP CATCH BASIN

- Cleanout 2x per year

OIL AND GRIT SEPARATOR

- Cleanout 2x per year

ENERGY DISSIPATION BASINS

- Additional text to be added here in future versions

COMPOST FILTER SOCKS

- Additional text to be added here in future versions

PROPRIETARY DEVICES

- Per manufacturer's recommendations

Dry Swale Maintenance Schedule

GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/ sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Mowing	Min.twice per year or as necessary. Maintain 4"-6" grass height	Spring thru Fall
Watering	Drought conditions only	July-August
Overseeding	As required	Spring or Fall preferred
Fertilizing	Not required	
FILTER BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Tilling	As needed	if standing water does not drain after 48 hours
Soil Media Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

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Map Atlas

A series of 30" x 42" full size maps have been provided as a seperate attachment. This includes all of the maps refereced earlier in the document. GIS data layers for these maps can be obtained by contacting Offshoots, Inc or Cape Cod Commission. The maps are provided in the following order:

- Vegetation Assessment along the Route 6 corridor
- Natural Heritage & Endangered Species along the Route 6 corridor
- Water Quality Assessment: Impaired Watersheds, Impaired Water Bodies and Wellhead Protection Areas
- Soils along the Route 6 corridor
- Wellhead protection along the Route 6 corridor
- Impaired Watersheds & Impaired Water Bodies
- Overall Stormwater Priority Analysis
- Tier 1 Stormwater Intervention Locations