# Stormwater Report for New Bedford, Track Corridor

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*MassDOT Contract No. 99771*
*May 30, 2018*
*July 10, 2018 Update*



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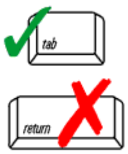
# CHECKLIST FOR STORMWATER REPORT

**Massachusetts Department of Environmental Protection**
Bureau of Resource Protection - Wetlands Program

# Checklist for Stormwater Report

## A. Introduction

**Important:** When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.



A Stormwater Report must be submitted with the Notice of Intent permit application to document compliance with the Stormwater Management Standards. The following checklist is NOT a substitute for the Stormwater Report (which should provide more substantive and detailed information) but is offered here as a tool to help the applicant organize their Stormwater Management documentation for their Report and for the reviewer to assess this information in a consistent format. As noted in the Checklist, the Stormwater Report must contain the engineering computations and supporting information set forth in Volume 3 of the Massachusetts Stormwater Handbook. The Stormwater Report must be prepared and certified by a Registered Professional Engineer (RPE) licensed in the Commonwealth.

The Stormwater Report must include:

- The Stormwater Checklist completed and stamped by a Registered Professional Engineer (see page 2) that certifies that the Stormwater Report contains all required submittals.[1] This Checklist is to be used as the cover for the completed Stormwater Report.
- Applicant/Project Name
- Project Address
- Name of Firm and Registered Professional Engineer that prepared the Report
- Long-Term Pollution Prevention Plan required by Standards 4-6
- Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan required by Standard 8[2]
- Operation and Maintenance Plan required by Standard 9

In addition to all plans and supporting information, the Stormwater Report must include a brief narrative describing stormwater management practices, including environmentally sensitive site design and LID techniques, along with a diagram depicting runoff through the proposed BMP treatment train. Plans are required to show existing and proposed conditions, identify all wetland resource areas, NRCS soil types, critical areas, Land Uses with Higher Potential Pollutant Loads (LUHPPL), and any areas on the site where infiltration rate is greater than 2.4 inches per hour. The Plans shall identify the drainage areas for both existing and proposed conditions at a scale that enables verification of supporting calculations.

As noted in the Checklist, the Stormwater Management Report shall document compliance with each of the Stormwater Management Standards as provided in the Massachusetts Stormwater Handbook. The soils evaluation and calculations shall be done using the methodologies set forth in Volume 3 of the Massachusetts Stormwater Handbook.

To ensure that the Stormwater Report is complete, applicants are required to fill in the Stormwater Report Checklist by checking the box to indicate that the specified information has been included in the Stormwater Report. If any of the information specified in the checklist has not been submitted, the applicant must provide an explanation. The completed Stormwater Report Checklist and Certification must be submitted with the Stormwater Report.

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[1] The Stormwater Report may also include the Illicit Discharge Compliance Statement required by Standard 10. If not included in the Stormwater Report, the Illicit Discharge Compliance Statement must be submitted prior to the discharge of stormwater runoff to the post-construction best management practices.

[2] For some complex projects, it may not be possible to include the Construction Period Erosion and Sedimentation Control Plan in the Stormwater Report. In that event, the issuing authority has the discretion to issue an Order of Conditions that approves the project and includes a condition requiring the proponent to submit the Construction Period Erosion and Sedimentation Control Plan before commencing any land disturbance activity on the site.

# Checklist for Stormwater Report

## B. Stormwater Checklist and Certification

The following checklist is intended to serve as a guide for applicants as to the elements that ordinarily need to be addressed in a complete Stormwater Report. The checklist is also intended to provide conservation commissions and other reviewing authorities with a summary of the components necessary for a comprehensive Stormwater Report that addresses the ten Stormwater Standards.

*Note:* Because stormwater requirements vary from project to project, it is possible that a complete Stormwater Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the item is not applicable (N.A.) and provide the reasons for that determination.

A complete checklist must include the Certification set forth below signed by the Registered Professional Engineer who prepared the Stormwater Report.

## Registered Professional Engineer's Certification

I have reviewed the Stormwater Report, including the soil evaluation, computations, Long-term Pollution Prevention Plan, the Construction Period Erosion and Sedimentation Control Plan (if included), the Long-term Post-Construction Operation and Maintenance Plan, the Illicit Discharge Compliance Statement (if included) and the plans showing the stormwater management system, and have determined that they have been prepared in accordance with the requirements of the Stormwater Management Standards as further elaborated by the Massachusetts Stormwater Handbook. I have also determined that the information presented in the Stormwater Checklist is accurate and that the information presented in the Stormwater Report accurately reflects conditions at the site as of the date of this permit application.

Registered Professional Engineer Block and Signature


Signature and Date

## Checklist

**Project Type:** Is the application for new development, redevelopment, or a mix of new and redevelopment?

☐ New development

☒ Redevelopment

☐ Mix of New Development and Redevelopment

## **Checklist** (continued)

**LID Measures:** Stormwater Standards require LID measures to be considered. Document what environmentally sensitive design and LID Techniques were considered during the planning and design of the project:

- ☐ No disturbance to any Wetland Resource Areas
- ☐ Site Design Practices (e.g. clustered development, reduced frontage setbacks)
- ☐ Reduced Impervious Area (Redevelopment Only)
- ☒ Minimizing disturbance to existing trees and shrubs
- ☐ LID Site Design Credit Requested:
  - ☐ Credit 1
  - ☐ Credit 2
  - ☐ Credit 3
- ☒ Use of "country drainage" versus curb and gutter conveyance and pipe
- ☐ Bioretention Cells (includes Rain Gardens)
- ☐ Constructed Stormwater Wetlands (includes Gravel Wetlands designs)
- ☐ Treebox Filter
- ☐ Water Quality Swale
- ☒ Grass Channel
- ☐ Green Roof
- ☐ Other (describe): ____________________

**Standard 1: No New Untreated Discharges**

- ☒ No new untreated discharges
- ☒ Outlets have been designed so there is no erosion or scour to wetlands and waters of the Commonwealth
- ☒ Supporting calculations specified in Volume 3 of the Massachusetts Stormwater Handbook included.

## Checklist (continued)

**Standard 2: Peak Rate Attenuation**

- ☐ Standard 2 waiver requested because the project is located in land subject to coastal storm flowage and stormwater discharge is to a wetland subject to coastal flooding.
- ☐ Evaluation provided to determine whether off-site flooding increases during the 100-year 24-hour storm.
- ☐ Calculations provided to show that post-development peak discharge rates do not exceed pre-development rates for the 2-year and 10-year 24-hour storms. If evaluation shows that off-site flooding increases during the 100-year 24-hour storm, calculations are also provided to show that post-development peak discharge rates do not exceed pre-development rates for the 100-year 24-hour storm.

**Standard 3: Recharge**

- ☐ Soil Analysis provided.
- ☐ Required Recharge Volume calculation provided.
- ☐ Required Recharge volume reduced through use of the LID site Design Credits.
- ☐ Sizing the infiltration, BMPs is based on the following method: Check the method used.

  ☐ Static ☐ Simple Dynamic ☐ Dynamic Field[1]

- ☐ Runoff from all impervious areas at the site discharging to the infiltration BMP.
- ☐ Runoff from all impervious areas at the site is *not* discharging to the infiltration BMP and calculations are provided showing that the drainage area contributing runoff to the infiltration BMPs is sufficient to generate the required recharge volume.
- ☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume.
- ☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume *only* to the maximum extent practicable for the following reason:
  - ☐ Site is comprised solely of C and D soils and/or bedrock at the land surface
  - ☐ M.G.L. c. 21E sites pursuant to 310 CMR 40.0000
  - ☐ Solid Waste Landfill pursuant to 310 CMR 19.000
  - ☐ Project is otherwise subject to Stormwater Management Standards only to the maximum extent practicable.
- ☐ Calculations showing that the infiltration BMPs will drain in 72 hours are provided.
- ☐ Property includes a M.G.L. c. 21E site or a solid waste landfill and a mounding analysis is included.

[1] 80% TSS removal is required prior to discharge to infiltration BMP if Dynamic Field method is used.

## **Checklist** (continued)

**Standard 3: Recharge** (continued)

☐ The infiltration BMP is used to attenuate peak flows during storms greater than or equal to the 10-year 24-hour storm and separation to seasonal high groundwater is less than 4 feet and a mounding analysis is provided.

☐ Documentation is provided showing that infiltration BMPs do not adversely impact nearby wetland resource areas.

**Standard 4: Water Quality**

The Long-Term Pollution Prevention Plan typically includes the following:

- Good housekeeping practices;
- Provisions for storing materials and waste products inside or under cover;
- Vehicle washing controls;
- Requirements for routine inspections and maintenance of stormwater BMPs;
- Spill prevention and response plans;
- Provisions for maintenance of lawns, gardens, and other landscaped areas;
- Requirements for storage and use of fertilizers, herbicides, and pesticides;
- Pet waste management provisions;
- Provisions for operation and management of septic systems;
- Provisions for solid waste management;
- Snow disposal and plowing plans relative to Wetland Resource Areas;
- Winter Road Salt and/or Sand Use and Storage restrictions;
- Street sweeping schedules;
- Provisions for prevention of illicit discharges to the stormwater management system;
- Documentation that Stormwater BMPs are designed to provide for shutdown and containment in the event of a spill or discharges to or near critical areas or from LUHPPL;
- Training for staff or personnel involved with implementing Long-Term Pollution Prevention Plan;
- List of Emergency contacts for implementing Long-Term Pollution Prevention Plan.

☐ A Long-Term Pollution Prevention Plan is attached to Stormwater Report and is included as an attachment to the Wetlands Notice of Intent.

☐ Treatment BMPs subject to the 44% TSS removal pretreatment requirement and the one inch rule for calculating the water quality volume are included, and discharge:

☐ is within the Zone II or Interim Wellhead Protection Area

☐ is near or to other critical areas

☐ is within soils with a rapid infiltration rate (greater than 2.4 inches per hour)

☐ involves runoff from land uses with higher potential pollutant loads.

☐ The Required Water Quality Volume is reduced through use of the LID site Design Credits.

☒ Calculations documenting that the treatment train meets the 80% TSS removal requirement and, if applicable, the 44% TSS removal pretreatment requirement, are provided.

## Checklist (continued)

**Standard 4: Water Quality** (continued)

☒ The BMP is sized (and calculations provided) based on:

- ☒ The ½" or 1" Water Quality Volume or
- ☐ The equivalent flow rate associated with the Water Quality Volume and documentation is provided showing that the BMP treats the required water quality volume.

☐ The applicant proposes to use proprietary BMPs, and documentation supporting use of proprietary BMP and proposed TSS removal rate is provided. This documentation may be in the form of the propriety BMP checklist found in Volume 2, Chapter 4 of the Massachusetts Stormwater Handbook and submitting copies of the TARP Report, STEP Report, and/or other third party studies verifying performance of the proprietary BMPs.

☐ A TMDL exists that indicates a need to reduce pollutants other than TSS and documentation showing that the BMPs selected are consistent with the TMDL is provided.

**Standard 5: Land Uses With Higher Potential Pollutant Loads (LUHPPLs)**

☐ The NPDES Multi-Sector General Permit covers the land use and the Stormwater Pollution Prevention Plan (SWPPP) has been included with the Stormwater Report.

☐ The NPDES Multi-Sector General Permit covers the land use and the SWPPP will be submitted ***prior to*** the discharge of stormwater to the post-construction stormwater BMPs.

☐ The NPDES Multi-Sector General Permit does ***not*** cover the land use.

☐ LUHPPLs are located at the site and industry specific source control and pollution prevention measures have been proposed to reduce or eliminate the exposure of LUHPPLs to rain, snow, snow melt and runoff, and been included in the long term Pollution Prevention Plan.

☐ All exposure has been eliminated.

☐ All exposure has ***not*** been eliminated and all BMPs selected are on MassDEP LUHPPL list.

☐ The LUHPPL has the potential to generate runoff with moderate to higher concentrations of oil and grease (e.g. all parking lots with >1000 vehicle trips per day) and the treatment train includes an oil grit separator, a filtering bioretention area, a sand filter or equivalent.

**Standard 6: Critical Areas**

☐ The discharge is near or to a critical area and the treatment train includes only BMPs that MassDEP has approved for stormwater discharges to or near that particular class of critical area.

☒ Critical areas and BMPs are identified in the Stormwater Report.

## **Checklist** (continued)

**Standard 7: Redevelopments and Other Projects Subject to the Standards only to the maximum extent practicable**

☒ The project is subject to the Stormwater Management Standards only to the maximum Extent Practicable as a:

- ☐ Limited Project
- ☐ Small Residential Projects: 5-9 single family houses or 5-9 units in a multi-family development provided there is no discharge that may potentially affect a critical area.
- ☐ Small Residential Projects: 2-4 single family houses or 2-4 units in a multi-family development with a discharge to a critical area
- ☐ Marina and/or boatyard provided the hull painting, service and maintenance areas are protected from exposure to rain, snow, snow melt and runoff
- ☐ Bike Path and/or Foot Path
- ☒ Redevelopment Project
- ☐ Redevelopment portion of mix of new and redevelopment.

☐ Certain standards are not fully met (Standard No. 1, 8, 9, and 10 must always be fully met) and an explanation of why these standards are not met is contained in the Stormwater Report.

☐ The project involves redevelopment and a description of all measures that have been taken to improve existing conditions is provided in the Stormwater Report. The redevelopment checklist found in Volume 2 Chapter 3 of the Massachusetts Stormwater Handbook may be used to document that the proposed stormwater management system (a) complies with Standards 2, 3 and the pretreatment and structural BMP requirements of Standards 4-6 to the maximum extent practicable and (b) improves existing conditions.

**Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control**

A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan must include the following information:

- Narrative;
- Construction Period Operation and Maintenance Plan;
- Names of Persons or Entity Responsible for Plan Compliance;
- Construction Period Pollution Prevention Measures;
- Erosion and Sedimentation Control Plan Drawings;
- Detail drawings and specifications for erosion control BMPs, including sizing calculations;
- Vegetation Planning;
- Site Development Plan;
- Construction Sequencing Plan;
- Sequencing of Erosion and Sedimentation Controls;
- Operation and Maintenance of Erosion and Sedimentation Controls;
- Inspection Schedule;
- Maintenance Schedule;

☐ A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan containing the information set forth above has been included in the Stormwater Report.

## **Checklist** (continued)

**Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control** (continued)

☐ The project is highly complex and information is included in the Stormwater Report that explains why it is not possible to submit the Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan with the application. A Construction Period Pollution Prevention and Erosion and Sedimentation Control has ***not*** been included in the Stormwater Report but will be submitted ***before*** land disturbance begins.

☐ The project is ***not*** covered by a NPDES Construction General Permit.

☐ The project is covered by a NPDES Construction General Permit and a copy of the SWPPP is in the Stormwater Report.

☒ The project is covered by a NPDES Construction General Permit but no SWPPP been submitted. The SWPPP will be submitted BEFORE land disturbance begins.

**Standard 9: Operation and Maintenance Plan**

☐ The Post Construction Operation and Maintenance Plan is included in the Stormwater Report and includes the following information:

- ☐ Name of the stormwater management system owners;
- ☐ Party responsible for operation and maintenance;
- ☐ Schedule for implementation of routine and non-routine maintenance tasks;
- ☐ Plan showing the location of all stormwater BMPs maintenance access areas;
- ☐ Description and delineation of public safety features;
- ☐ Estimated operation and maintenance budget; and
- ☐ Operation and Maintenance Log Form.

☐ The responsible party is ***not*** the owner of the parcel where the BMP is located and the Stormwater Report includes the following submissions:

- ☐ A copy of the legal instrument (deed, homeowner's association, utility trust or other legal entity) that establishes the terms of and legal responsibility for the operation and maintenance of the project site stormwater BMPs;
- ☐ A plan and easement deed that allows site access for the legal entity to operate and maintain BMP functions.

**Standard 10: Prohibition of Illicit Discharges**

☐ The Long-Term Pollution Prevention Plan includes measures to prevent illicit discharges;

☐ An Illicit Discharge Compliance Statement is attached;

☒ NO Illicit Discharge Compliance Statement is attached but will be submitted ***prior to*** the discharge of any stormwater to post-construction BMPs.

# 1. INTRODUCTION

## 1.1 Objectives of Report

This report presents information about the Project's existing and proposed drainage systems and will demonstrate compliance with Massachusetts Department of Environmental Protection (DEP) Stormwater Management Policy. This report provides the technical information required to support the permit application process involving stormwater management activities.

It should be noted that additional design refinement of the project will proceed pending receipt of permits and approval of project funding. At that time, refinements to the proposed drainage systems may be made. Changes that will affect the proposed systems or their ability to comply with stormwater management standards will be submitted to the Conservation Commission.

## 1.2 Project Description

Description of Proposed Project

This project includes the reconstruction and upgrade of an existing railroad right-of-way corridor to provide improved operation for new passenger and existing freight service. The railroad track improvements will extend from the Freetown / New Bedford municipal border at the north end, to the vicinity of its crossing of Deane Street at its southerly limit, a length of approximately 5.4 miles, see Figures 1, 2 and 3. In this length, the existing railroad corridor typically contains a single-track system. However, the right-of-way can accommodate two tracks. The improvements proposed generally consist of slight modifications to the railroad track's horizontal and vertical alignments. At several locations a second track is to be installed, with associated switches and crossovers, to provide for more efficient rail operations.

The work of this project is generally contained within the existing narrow railway track corridor. The stormwater runoff to be dealt with in this corridor is for the most part generated from only within the track corridor itself. The proposed track drainage collection, conveyance and stormwater quality treatment systems typically will need to accommodate only track corridor watersheds.

The stormwater management system for the project has been conceptually designed in accordance with the criteria of the Commonwealth of Massachusetts Department of Environmental Protection with the primary consideration being the safety of the facility user, and the efficient and environmentally sensitive removal of stormwater from the trackbed. The stormwater management system includes Best Management Practices (BMPs) to enhance the quality of the runoff as prescribed in DEP's Stormwater Management Policy (SMP).

Site Description

The northern portion of the existing railroad right-of-way is located in undeveloped wooded areas. South of its crossing of Route 140, there are developed areas east of the rail corridor. South of Nash Road the right-of-way is within a fairly urbanized setting.

### 1.3 Stormwater Management / Drainage Design Guidelines / Criteria

The following highlights the key general criteria that have been adopted for the project.

- The proposed project will not increase post-construction peak flows. No additional paved or otherwise impervious surfaces are to be constructed which might cause an increase in post-construction peak flows. The scope of the railroad track corridor work is essentially to remove and replace the existing track, ties and foundation, and any earthwork associated with adjustments to the track alignments and re-establishing trackside ditches.
- Stormwater runoff will be treated utilizing accepted Best Management Practices prior to discharge to resource areas.
- Existing drainage patterns will be maintained as much as possible to minimize the impacts to adjacent properties and resource areas.

The drainage systems, consisting of trackside ditches, underdrains and piping, have been designed in accordance with the MBTA Commuter Rail Design Standards Manual.

Note: Unless noted otherwise all elevations presented in this document are referenced to the North American Vertical Datum of 1988 (NAVD 88).

## 2. EXISTING DRAINAGE CONDITIONS

### 2.1 Topography

In general, the railroad corridor right-of-way follows a fairly flat profile. The existing track was generally built somewhat close to the existing adjacent grades, with no pronounced cut or fill sections for any substantial lengths. In the vicinity of the Acushnet Cedar Swamp crossing, the railroad track was constructed on a low fill embankment.

### 2.2 Floodplains / Water Surface Elevations

For a length of approximately 5,000 feet, just north of its crossing of Route 140, the railroad corridor traverses a FEMA delineated regulatory flood zone, See Figure 4. This mapped Zone A area is on either side of the railroad corridor, however, the railroad track footprint itself is outside, i.e., above, this base flood zone. On the west side of the tracks this area is designated as the Acushnet Cedar Swamp State Reservation. The FEMA study of this area was by approximate methods, which means a specific elevation for the 100-YR flood water surface was not determined. Using the topographic field survey performed for the project, and matching that to the FEMA delineations, it was determined that the base flood water surface on the east side of the tracks was approximately elevation 71.0, and on the west side, approximately elevation 70.0.

## 2.3 Surficial Geology and Soils

Surficial geology and soils information within the project area is presented in Appendix A. This data was acquired from the Natural Resource Conservation Service (NRCS). In the northern reaches of the project area the rail corridor passes through numerous soil types with varying drainage qualities, ranging from Hydrologic Soil Group A/D to D. The only predominant soil being Freetown Muck, classified in Hydrologic Soil Group B/D. South of Tarkiln Road essentially all the land the rail corridor passes through is classified as Urban Land with no drainage properties assigned to it.

## 2.4 Vegetation / Land Use

Within the more undeveloped northern portions of the project area, much of the land adjacent to the rail right-of-way is identified as forest or forested wetlands. Also found is a cranberry bog and a few industrial / commercial sites. The southern portion of the project passes adjacent to a wider variety of vegetation and land uses, including: forest, forested wetlands, median density and multi-family residential, commercial, industrial and urban public / institutional. See Appendix B for a graphic representation of the vegetation and land use along the railroad right-of-way.

## 2.5 Existing Drainage Areas

For most of the length of the railroad track corridor, stormwater runoff is conveyed from the trackbed area via shallow depth ditches, or just along the edge of the trackbed or fill slope, to numerous isolated untreated discharge points.

Where the corridor passes through the Acushnet Cedar Swamp, three stone box culverts convey water from one side of the track to the other, see Appendix C. These culverts are designated as CV-NB-1, CV-NB-2 and CV-NB-3. During dry weather or lesser intensity or duration storm events, these culverts appear to serve as equalization conveyances. For the larger events, these culverts convey runoff from the east side to the west side of the tracks. These are the only railroad cross culverts within the project area that convey natural waterways.

# 3. PROPOSED DRAINAGE CONDITIONS

## 3.1 Proposed Drainage Design and Layout

The drainage systems for the project have been designed to collect and convey the runoff from the 50-year storm. For this design storm, piped systems must not surcharge and flow depths in ditches are not to exceed 3-feet below top of rail. A 100-year return storm event was used as a check storm, which requires all storm drain systems to maintain flow levels no higher than 18-inches below the top of tie.

The proposed railroad track typical section details a trackside ditch that in many locations is deeper than what exists today. However, much of the proposed vertical realignment includes raising the track profile in the order of one to two feet. In most cases, this raised track profile will allow for the proposed ditches to still mimic the existing conditions, and thus duplicate drainage patterns. There are some instances where due to topography or other constraints, underdrain systems are proposed where ditches now exist. In these cases, the new piped underdrains will be eventually daylighted to discharge to the same flow path or outlet point as the existing ditch it replaced.

For most of project length, the watershed areas contributing to proposed track drainage systems are predominantly from just the track corridor itself, with minimum from offsite areas. Therefore, track drainage collection, conveyance and stormwater quality treatment systems generally need to be sized to only accommodate track corridor watersheds. Compared to highway stormwater runoff, runoff from a typical railroad track corridors tends to have a much lower concentration of total suspended solids.

The three existing stone box culverts crossing the railroad corridor in the Acushnet Cedar Swamp, CV-NB-1, CV-NB-2 and CV-NB-3, were analyzed to verify their operating condition during the 100-year return storm event. Analysis indicated that the existing culvert system is adequate for the design storm flow and they meet the maximum design headwater criteria, see Appendix C. The analysis also confirmed the interpretation of the FEMA base flood elevations. These culverts were most recently inspected in 2011. The inspection evaluations and engineering recommendations were similar for each of these three culverts. They were all categorized as “Monitor”, which included culverts that may have been generally performing satisfactorily, but showing signs of deterioration, which may worsen over time. Given the age of these culverts, the recommendation is to remove and replace them in-kind, essentially a footprint replacement.

The replacement culverts for CV-NB-1, CV-NB-2 and CV-NB-3 are proposed to be manufactured precast reinforced concrete boxes. The existing culverts were observed to function as wetland equalizer conveyances, and as such, Massachusetts River and Stream Crossing Standards do not apply for these culvert replacements. However, to maintain existing conditions, the culvert heights will be oversized to provide for embedment below the streambed elevation and placement of natural streambed substrate material in the culvert invert. Proposed box culvert sizes were chosen based upon matching the existing culvert opening size as close as possible to a commercially available size.

### 3.2 Proposed Stormwater Runoff Peak Flows

The proposed construction within this existing railroad corridor typically includes realignment of existing railroad tracks; no new impervious surfaces are to be constructed. As a result, post-construction peak runoff rates will be the same as the pre-construction runoff rates.

### 3.3 Proposed Stormwater Management

The project has been categorized as a Redevelopment Project for the purpose of complying with the DEPs Stormwater Management Standards. As that pertains to this project, the Standards need to be complied with to the maximum extent practicable and stormwater quality shall be enhanced. To adhere to these two requirements, the following guidelines were implemented for the track drainage components of the project. At runoff discharge points from trackside ditches upgrade of resource areas the flow will be treated via sediment forebays with check dams for suspended solids removal. Track corridor runoff that is collected and conveyed via a pipe underdrain will have received suspended solids removal treatment due to the geotextile filter fabric the flow must pass through prior to being intercepted by the underdrain. Unless protected by a sediment forebay and check dam, stone protection measures will be constructed at all pipe and ditch outlets to mitigate the effects of erosion. See Appendix D for supporting information relating to these items.

In the vicinity of track Station 2553+00 to 2559+00, the existing corridor passes through a buffer zone of a vernal pool. The vernal pool is considered an OWR and a stormwater critical area. Presently the precipitation runoff from the trackbed along this length is via overland / sheet flow with no point discharges. The limit of proposed grading and temporary impact will not encroach into the vernal pool limit. The existing drainage patterns in this area are proposed to be maintained with no new point discharges. This will result in no impact to the vernal pool resource.

## 4. ENGINEERING METHODS

### 4.1 Railroad Track Drainage

Drainage system design is dependent on an estimate of the magnitude, volume and distribution of storm runoff. The Rational Method was used to compute peak storm runoff flow rates generated from the contributory sub-areas along the track corridor. This method also provided the flow rates necessary to determine flow velocities and depths for sizing sediment forebays and stone end protection measures. Track drainage system components, such as ditches, swales and underground underdrains and pipe were sized hydraulically using standard hydraulic open channel flow formulae. See Appendix D for pertinent computations pertaining to the track drainage system components.

## 4.2 Culverts

For the three stone box railroad cross culverts in the Acushnet Cedar Swamp, during more extreme and infrequent storm events they all share a common water surface / headwater, based upon the FEMA base flood elevation delineations. Given this situation, the culverts, both existing and proposed conditions, were analyzed as a single multiple barrel crossing, however accounting for differing culvert sizes and invert elevations. Hydrologic analysis to determine the peak design flow tributary to these railroad cross culverts was by a USGS method named StreamStats, Version 3.0 and its National Streamflow Statistics Program Version 5. The culverts were hydraulically analyzed by the Federal Highway Administration (FHWA) HY-8 application to determine their adequacy during the design storm event.

# 5. REGULATORY COMPLIANCE

Introduction / Overview

In November of 1996, DEP issued a document: “Stormwater Management Policy” (SMP) with the stated goal to encourage recharge and prevent stormwater discharge from causing or contributing to the pollution of surface and groundwaters. The SMP contains ten standards that must be met to the extent that they apply to a particular project. If the standards are met there is a presumption that the stormwater design meets the requirements of several different State and Federal permitting authorities. Compliance with the SMP is typically triggered by a projects’ jurisdiction under the Wetlands Protection Act.

Stormwater Policy Standards

Each of the ten stormwater management standards is stated below followed by a discussion of its relation to this Project.

## 5.1 Standard 1 - Stormwater Discharges

“No new stormwater conveyances (e.g. outfalls) may discharge untreated stormwater directly to or cause erosion in wetlands or waters of the Commonwealth”.

No new stormwater outfalls are to be created by the project.

It can be expected that the track corridor stormwater runoff suspended solids concentration will be relatively low, compared to that of a typical highway corridor.

As the local topography permits, stormwater runoff from trackside ditches that discharge upgrade of resource areas will be treated via sediment forebays with check dams for suspended solids removal.

Track corridor stormwater runoff that cannot be collected and conveyed by a ditch or swale will be intercepted and conveyed by a buried pipe underdrain system. This runoff will have received suspended solids removal treatment due to the geotextile filter fabric the flow must pass through prior to being intercepted by the underdrain.

Unless protected by a sediment forebay and check dam, stone protection measures will be constructed at all pipe and ditch outlets to mitigate erosion.

### 5.2 Standard 2 - Stormwater Discharge Rates

"Stormwater management systems shall be designed so that post-development peak discharge rates do not exceed pre-development peak discharge rates. This standard may be waived for discharges to land subject to coastal storm flowage as defined in 310 CMR 10.04"

The proposed improvements within this existing railroad corridor do not include the construction of any new impervious surfaces. As a result, post-construction peak runoff rates will be the same as the pre-construction runoff rates.

### 5.3 Standard 3 - Groundwater Recharge

"Loss of annual recharge to groundwater shall be eliminated or minimized through the use of infiltration measures including environmentally sensitive site design, low impact development techniques, stormwater best management practices, and good operation and maintenance. At a minimum, the annual recharge from the post-development site shall approximate the annual recharge from the pre-development conditions based on soil type. This standard is met when the stormwater management system is designed to infiltrate the required recharge volume as determined in accordance with the Massachusetts Stormwater Handbook"

The proposed improvements within this existing railroad corridor do not include the construction of any new impervious surfaces. As a result, the post-construction annual groundwater recharge will approximate the annual recharge for the pre-construction conditions.

### 5.4 Standard 4 - 80% Total Suspended Solids Removal

"Stormwater management systems shall be designed to remove 80% of the average annual post-construction load of Total Suspended Soilds (TSS)"

Rail operations typically generate smaller concentrations of TSS than that of a comparably sized highway corridor. The surface of trackbed structure itself is predominantly ballast, a non-erodible substance, protecting the more erodible surface beneath. For discharges to resource areas, to the extent practicable, TSS will be removed from stormwater runoff by use of sediment forebays and underdrain filter fabric. Sediment forebays proposed as a post-construction practice slow incoming stormwater runoff and facilitate the gravity separation of suspended solids before entering the adjacent wetlands. Due to the limited available land on the project site, the volume of the sediment forebay is sized at a minimum to hold 0.1-inch per impervious acre. The impervious area was conservatively computed assuming the width of the typical subballast track foundation is impervious.

### 5.5 Standard 5 - Discharge from Areas with Higher Pollutant Loads

"For land uses with higher pollutant loads, source control and pollution prevention shall be implemented in accordance with the Massachusetts Stormwater Handbook to eliminate or reduce the discharge of stormwater runoff from such land uses to the maximum extent practicable. If through source control and/or pollution prevention all land uses with higher potential pollutant loads cannot be completely protected from exposure to rain, snow, snow melt, and stormwater runoff, the proponent shall use the specific structural stormwater BMP's determined by the Department to but suitable for such uses as provided in the Massachusetts Stormwater Handbook."

This project site is not considered a land uses with higher potential pollutant loads as defined in 310 CMR 10.04.

### 5.6 Standard 6 - Discharge to Critical Areas

"Stormwater discharges within the Zone II or Interim Wellhead Protection Area of a public water supply and stormwater discharge near or to any other critical area, require the use of specific source control and pollution prevention measures and the specific structural stormwater best management practices determined by the Department to be suitable for managing discharges to such areas, as provided in the Massachusetts Stormwater Handbook."

This standard is not applicable since stormwater from the track corridor does not discharge to Wellhead Protection Zones or Areas of Critical Environmental Critical Areas as defined in the SMP.

In one area the existing corridor passes through a buffer zone of a vernal pool. Presently the storm runoff from the trackbed along this length is via overland / sheet flow with no point discharges. The limit of proposed grading and temporary impact will not encroach into the vernal pool limit. The existing drainage patterns in this area are proposed to be maintained with no new point discharges. This will result in no impact to the vernal pool resource.

### 5.7 Standard 7 - Redevelopment Sites

"A redevelopment project is required to meet the following Stormwater Management Standards only to the maximum extent practicable: Standard 2, Standard 3, and the pretreatment and structural best management practice requirements of Standard 4, 5 and 6. Existing stormwater discharges shall comply with Standard 1 only to the maximum extent practicable. A redevelopment project shall also comply with all other requirements of the Stormwater Management Standards and improve existing conditions."

Standard 2 and Standard 3 need not be met because there are no new impervious surfaces being constructed.

To address Standard 1 and to the extent practicable for Standard 4, all stormwater runoff discharges to resources areas will be treated by use of sediment forebays or geotextile filter fabric. Pipe and ditch outlets not requiring treatment will discharge to stone end protection pads.

### 5.8 Standard 8 - Erosion and Sedimentation Control

"A plan to control construction-related impacts including erosion, sedimentation and other pollutant sources during construction and land disturbance activities (construction period erosion, sedimentation, and pollution prevention plan) shall be developed and implemented."

The Project will be required to obtain coverage under the Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Construction General Permit (CGP). As required under that permit, a Stormwater Pollution Prevention Plan (SWPPP) will be prepared. Construction period pollution prevention and erosion and sedimentation controls will be prepared and implemented by the contractor and MassDOT (MBTA) during construction in accordance with the final design and NPDES SWPPP.

An erosion and sedimentation control plan will be developed and implemented prior to any land disturbance.

### 5.9 Standard 9 - Operation & Maintenance Plan

"A long term operation and maintenance plan shall be developed and implemented to ensure that stormwater management systems function as designed."

A Long Term Stormwater Operation and Maintenance Plan will be developed during the final design phase of the project.

### 5.10 Standard 10 – Prohibition of Illicit Discharges

"All illicit discharges to the stormwater management system are prohibited."

Illicit discharges to open or closed drainage system within the project limits will not be allowed. A compliance statement will be submitted prior to the discharge of any stormwater to post-construction BMPs.

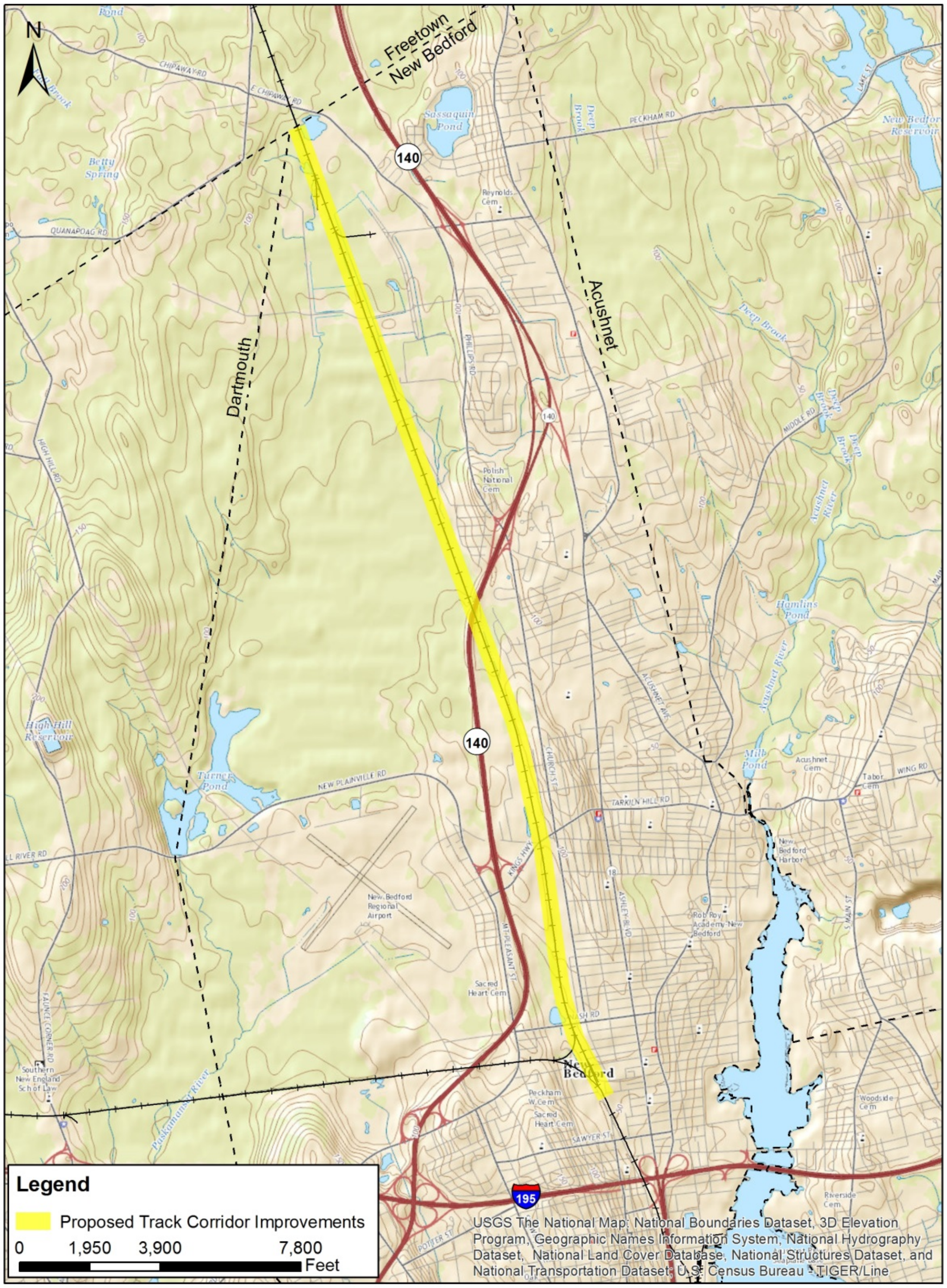



**Figure 1 - Site Locus Plan**

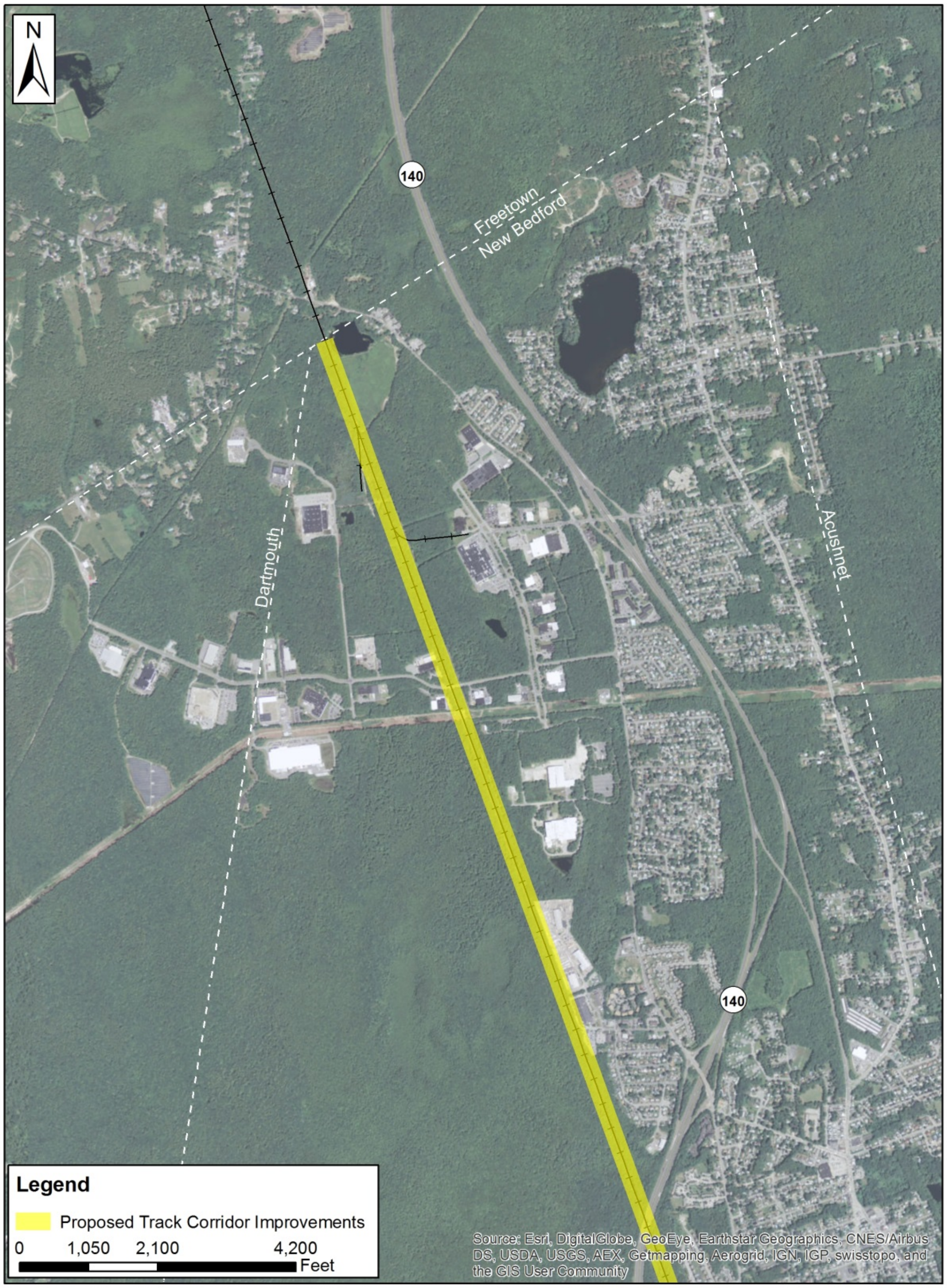



Figure 2 - Project Location Plan, North

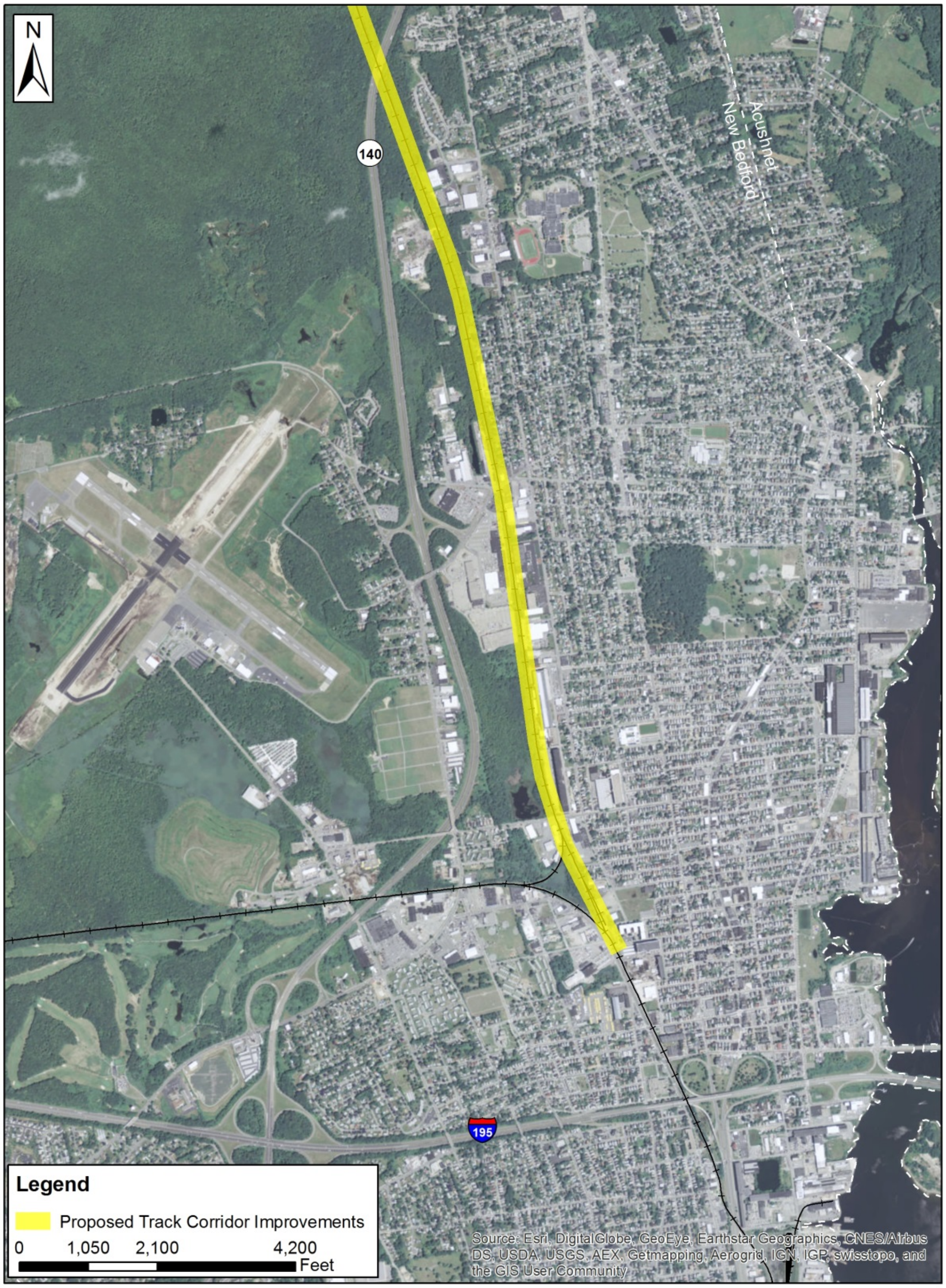



**Figure 3 - Project Location Plan, South**

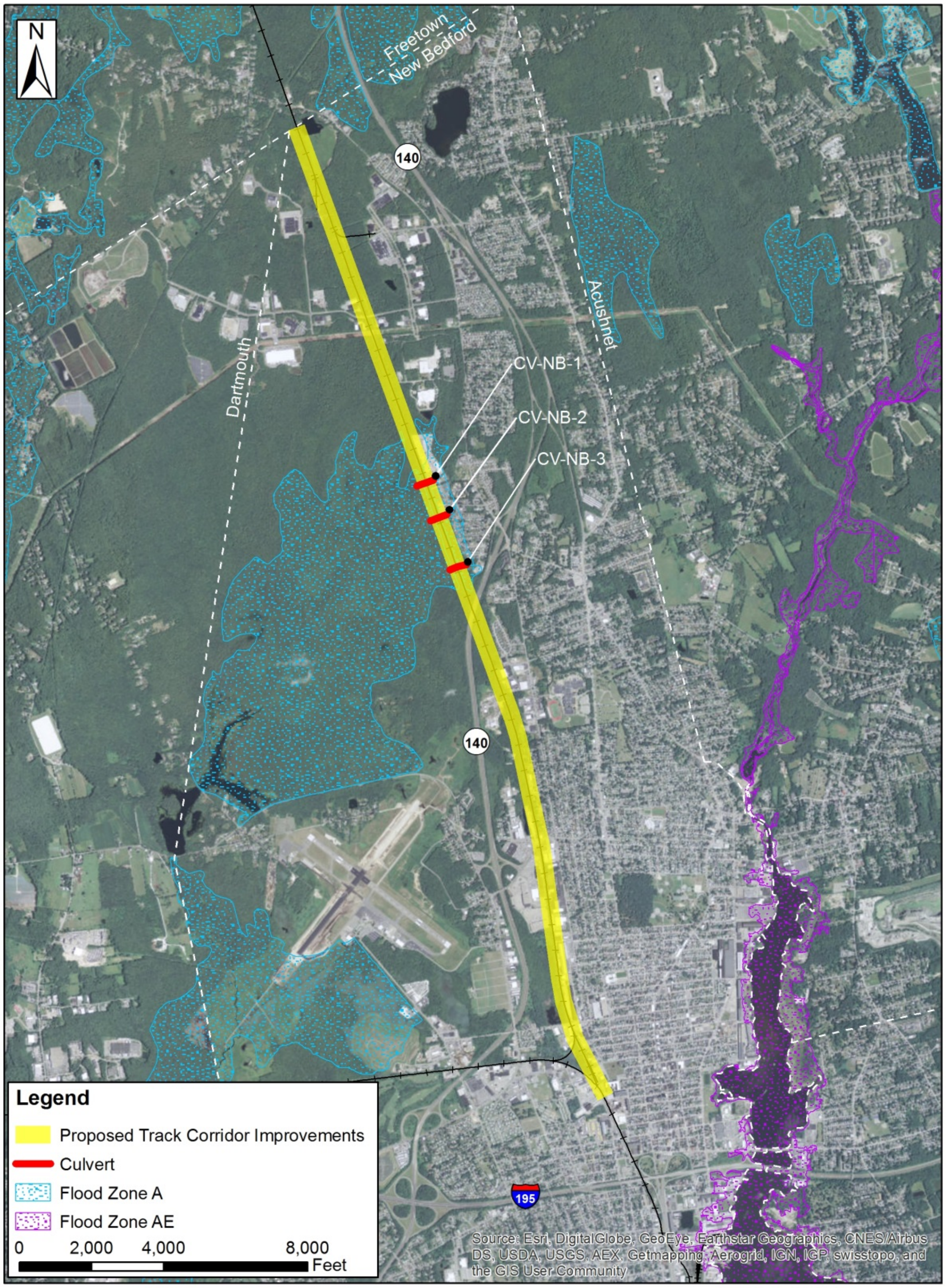
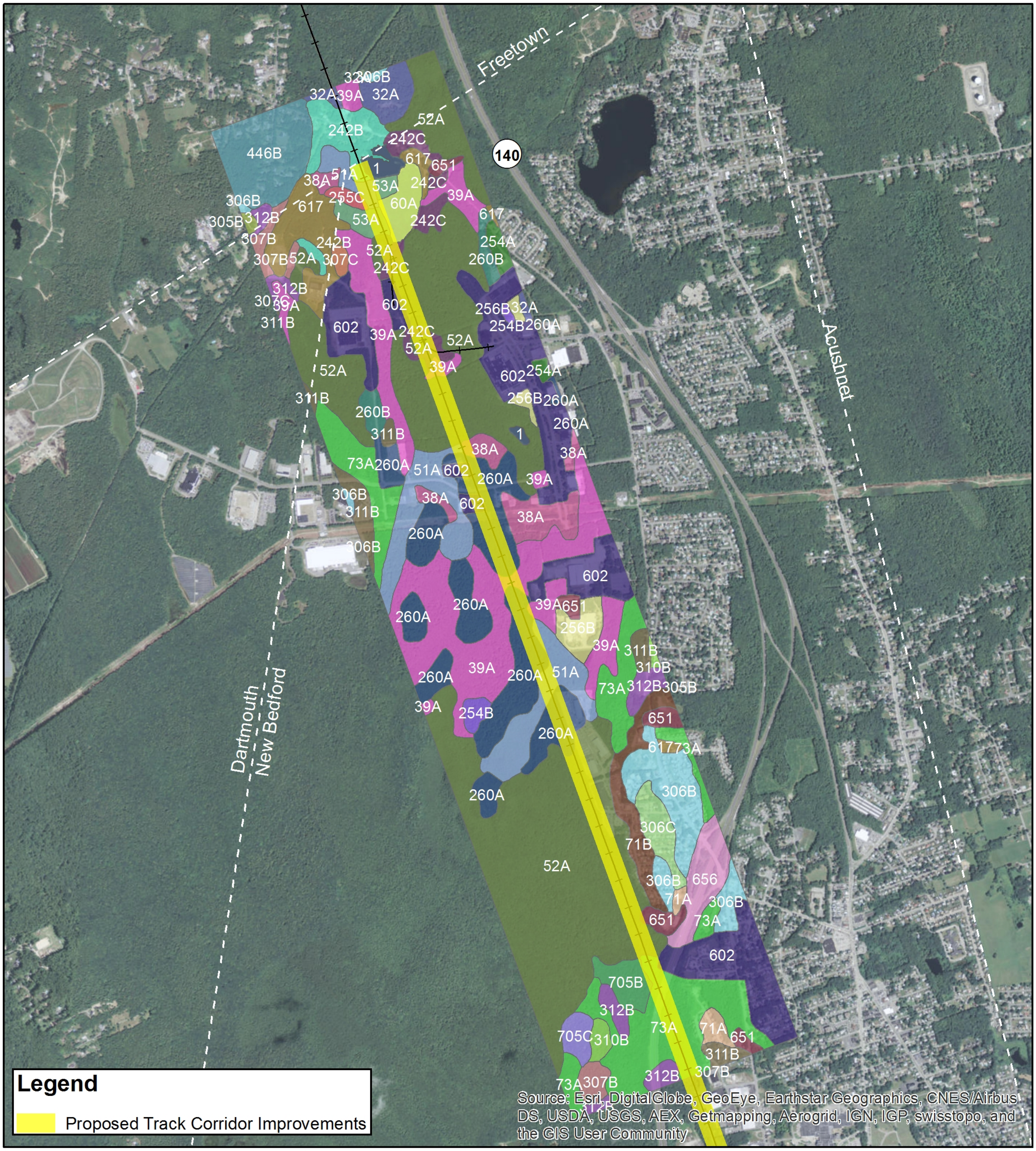



**Figure 4 - FEMA Base Flood Delineations**

**APPENDIX A - Surficial Geology and Soils**




SCR SOUTH COAST RAIL

Massachusetts Bay Transportation Authority

N

0 700 1,400 2,800 4,200 5,600 Feet

Surficial Geology and Soils, Municipal Line to Route 140

Source: NRCS Web Soil Survey

# Hydrologic Soil Group

| Hydrologic Soil Group— Summary by Map Unit — Bristol County, Massachusetts, Southern Part (MA603) | | | | |
|---|---|---|---|---|
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI |
| 1 | Water | | 6.5 | 0.4% |
| 32A | Wareham loamy sand, 0 to 3 percent slopes | A/D | 17.1 | 1.1% |
| 38A | Pipestone loamy sand, 0 to 3 percent slopes | A/D | 30.4 | 2.0% |
| 39A | Scarboro mucky fine sandy loam, 0 to 3 percent slopes | A/D | 157.5 | 10.5% |
| 51A | Swansea muck, 0 to 1 percent slopes | B/D | 70.2 | 4.7% |
| 52A | Freetown muck, 0 to 1 percent slopes | B/D | 411.8 | 27.3% |
| 53A | Freetown muck, ponded, 0 to 1 percent slopes | B/D | 10.0 | 0.7% |
| 60A | Swansea coarse sand, 0 to 2 percent slopes | B/D | 12.5 | 0.8% |
| 71A | Ridgebury fine sandy loam, 0 to 3 percent slopes, extremely stony | B/D | 6.6 | 0.4% |
| 71B | Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony | B/D | 21.8 | 1.4% |
| 73A | Whitman fine sandy loam, 0 to 3 percent slopes, extremely stony | D | 132.5 | 8.8% |
| 242B | Hinckley loamy sand, 3 to 8 percent slopes | A | 25.8 | 1.7% |
| 242C | Hinckley loamy sand, 8 to 15 percent slopes | A | 20.9 | 1.4% |
| 254A | Merrimac fine sandy loam, 0 to 3 percent slopes | A | 6.6 | 0.4% |
| 254B | Merrimac fine sandy loam, 3 to 8 percent slopes | A | 5.4 | 0.4% |
| 255C | Windsor loamy sand, 8 to 15 percent slopes | A | 3.2 | 0.2% |
| 256B | Deerfield loamy sand, 0 to 5 percent slopes | A | 16.0 | 1.1% |
| 260A | Sudbury fine sandy loam, 0 to 3 percent slopes | B | 121.3 | 8.1% |

| Hydrologic Soil Group— Summary by Map Unit — Bristol County, Massachusetts, Southern Part (MA603) | | | | |
|---|---|---|---|---|
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI |
| 260B | Sudbury fine sandy loam, 3 to 8 percent slopes | B | 10.3 | 0.7% |
| 305B | Paxton fine sandy loam, 3 to 8 percent slopes | C | 1.5 | 0.1% |
| 306B | Paxton fine sandy loam, 0 to 8 percent slopes, very stony | C | 46.7 | 3.1% |
| 306C | Paxton fine sandy loam, 8 to 15 percent slopes, very stony | C | 13.2 | 0.9% |
| 307B | Paxton fine sandy loam, 0 to 8 percent slopes, extremely stony | C | 12.9 | 0.9% |
| 307C | Paxton fine sandy loam, 8 to 15 percent slopes, extremely stony | C | 2.6 | 0.2% |
| 310B | Woodbridge fine sandy loam, 3 to 8 percent slopes | C/D | 5.6 | 0.4% |
| 311B | Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony | C/D | 20.3 | 1.3% |
| 312B | Woodbridge fine sandy loam, 0 to 8 percent slopes, extremely stony | C/D | 22.7 | 1.5% |
| 446B | Gloucester - Hinckley complex, undulating, very stony | A | 45.3 | 3.0% |
| 602 | Urban land | | 153.9 | 10.2% |
| 617 | Pits - Udorthents complex, gravelly | | 37.3 | 2.5% |
| 651 | Udorthents, smoothed | A | 16.6 | 1.1% |
| 656 | Udorthents - Urban land complex | | 21.3 | 1.4% |
| 705B | Charlton - Paxton fine sandy loams, 3 to 8 percent slopes, rocky | A | 12.2 | 0.8% |
| 705C | Charlton - Paxton fine sandy loams, 8 to 15 percent slopes, rocky | A | 7.6 | 0.5% |
| **Totals for Area of Interest** | | | **1,505.9** | **100.0%** |

## Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

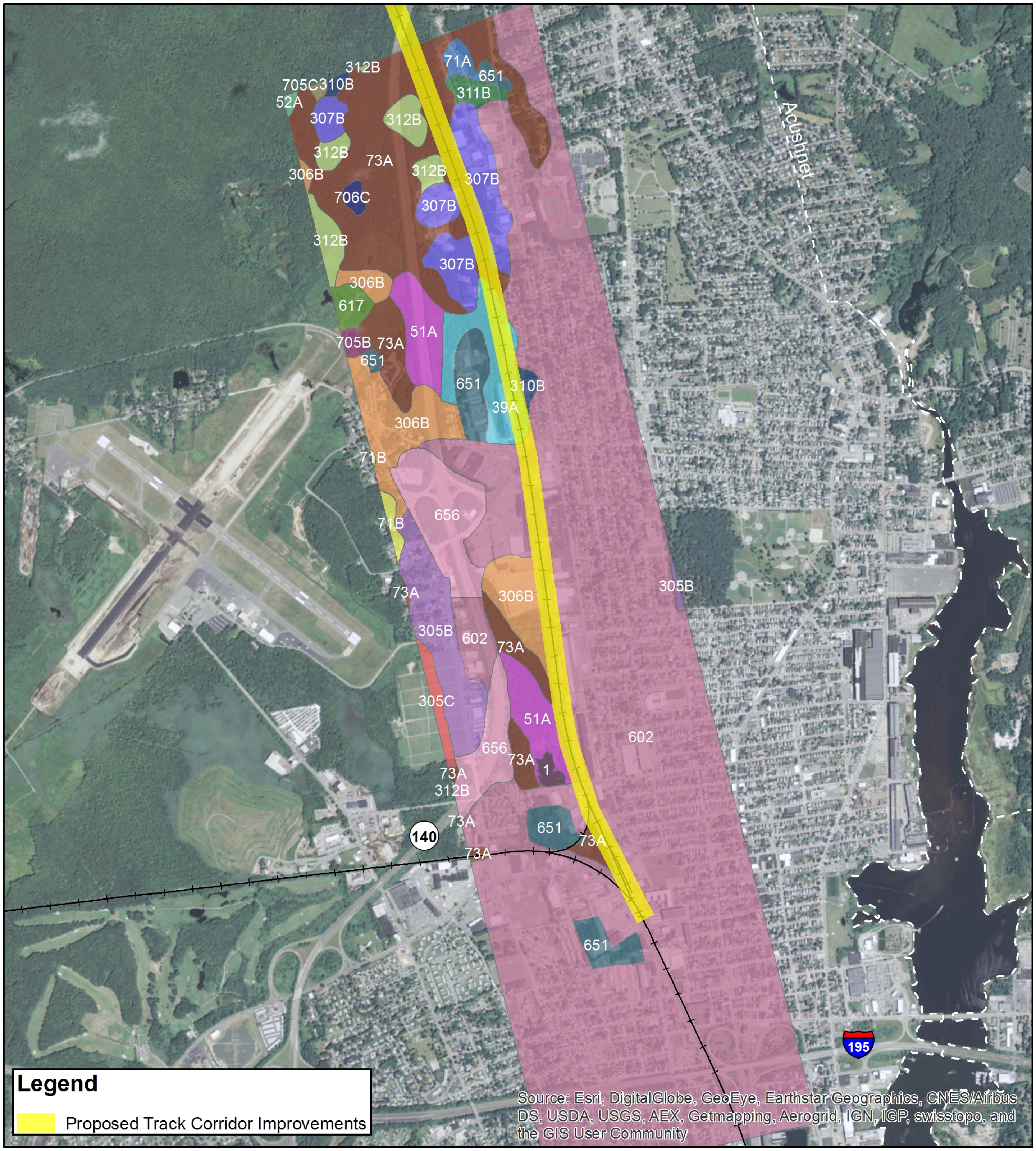
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

## Rating Options

*Aggregation Method:* Dominant Condition

*Component Percent Cutoff:* *None Specified*

*Tie-break Rule:* Higher




SCR SOUTH COAST RAIL

Massachusetts Bay Transportation Authority

N

0 650 1,300 2,600 3,900 5,200 Feet

Surficial Geology and Soils, Route 140 to Interstate 195

Source: NRCS Web Soil Survey

# Hydrologic Soil Group

| Hydrologic Soil Group— Summary by Map Unit — Bristol County, Massachusetts, Southern Part (MA603) | | | | |
|---|---|---|---|---|
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI |
| 1 | Water | | 3.2 | 0.2% |
| 39A | Scarboro mucky fine sandy loam, 0 to 3 percent slopes | A/D | 35.9 | 2.2% |
| 51A | Swansea muck, 0 to 1 percent slopes | B/D | 42.0 | 2.6% |
| 52A | Freetown muck, 0 to 1 percent slopes | B/D | 1.2 | 0.1% |
| 71A | Ridgebury fine sandy loam, 0 to 3 percent slopes, extremely stony | B/D | 5.0 | 0.3% |
| 71B | Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony | B/D | 3.8 | 0.2% |
| 73A | Whitman fine sandy loam, 0 to 3 percent slopes, extremely stony | D | 190.7 | 11.9% |
| 305B | Paxton fine sandy loam, 3 to 8 percent slopes | C | 45.7 | 2.9% |
| 305C | Paxton fine sandy loam, 8 to 15 percent slopes | C | 7.1 | 0.4% |
| 306B | Paxton fine sandy loam, 0 to 8 percent slopes, very stony | C | 64.9 | 4.1% |
| 307B | Paxton fine sandy loam, 0 to 8 percent slopes, extremely stony | C | 53.2 | 3.3% |
| 310B | Woodbridge fine sandy loam, 3 to 8 percent slopes | C/D | 4.9 | 0.3% |
| 311B | Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony | C/D | 6.4 | 0.4% |
| 312B | Woodbridge fine sandy loam, 0 to 8 percent slopes, extremely stony | C/D | 24.9 | 1.6% |
| 602 | Urban land | | 987.3 | 61.9% |
| 617 | Pits - Udorthents complex, gravelly | | 7.1 | 0.4% |
| 651 | Udorthents, smoothed | A | 40.6 | 2.5% |

| Hydrologic Soil Group— Summary by Map Unit — Bristol County, Massachusetts, Southern Part (MA603) | | | | |
|---|---|---|---|---|
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI |
| 656 | Udorthents - Urban land complex | | 65.2 | 4.1% |
| 705B | Charlton - Paxton fine sandy loams, 3 to 8 percent slopes, rocky | A | 3.0 | 0.2% |
| 705C | Charlton - Paxton fine sandy loams, 8 to 15 percent slopes, rocky | A | 1.3 | 0.1% |
| 706C | Charlton - Rock outcrop - Paxton complex, 3 to 15 percent slopes | | 3.0 | 0.2% |
| **Totals for Area of Interest** | | | **1,596.1** | **100.0%** |

## Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

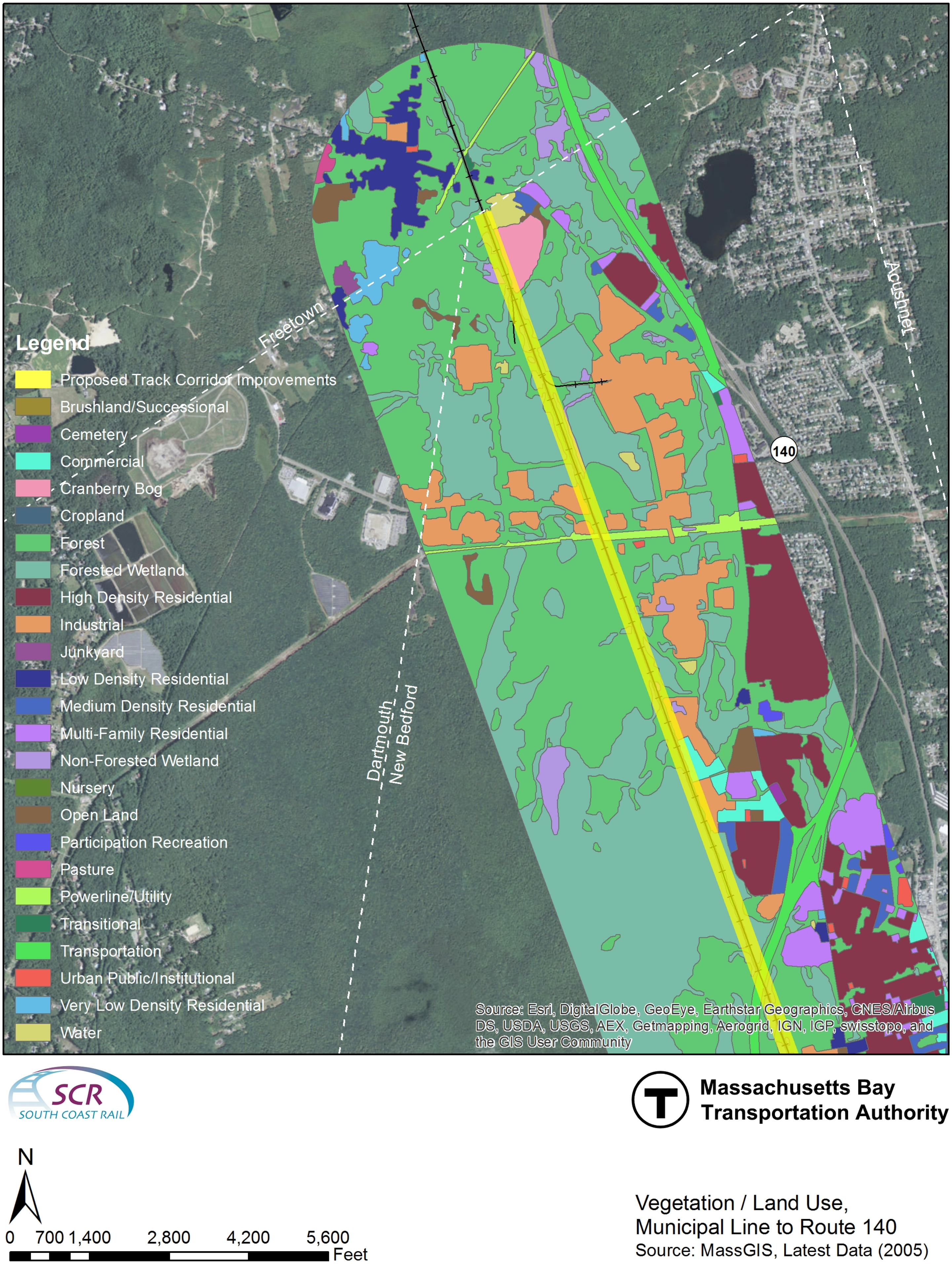
## Rating Options

*Aggregation Method:* Dominant Condition

*Component Percent Cutoff: None Specified*

*Tie-break Rule:* Higher

**APPENDIX B - Vegetation / Land Use**

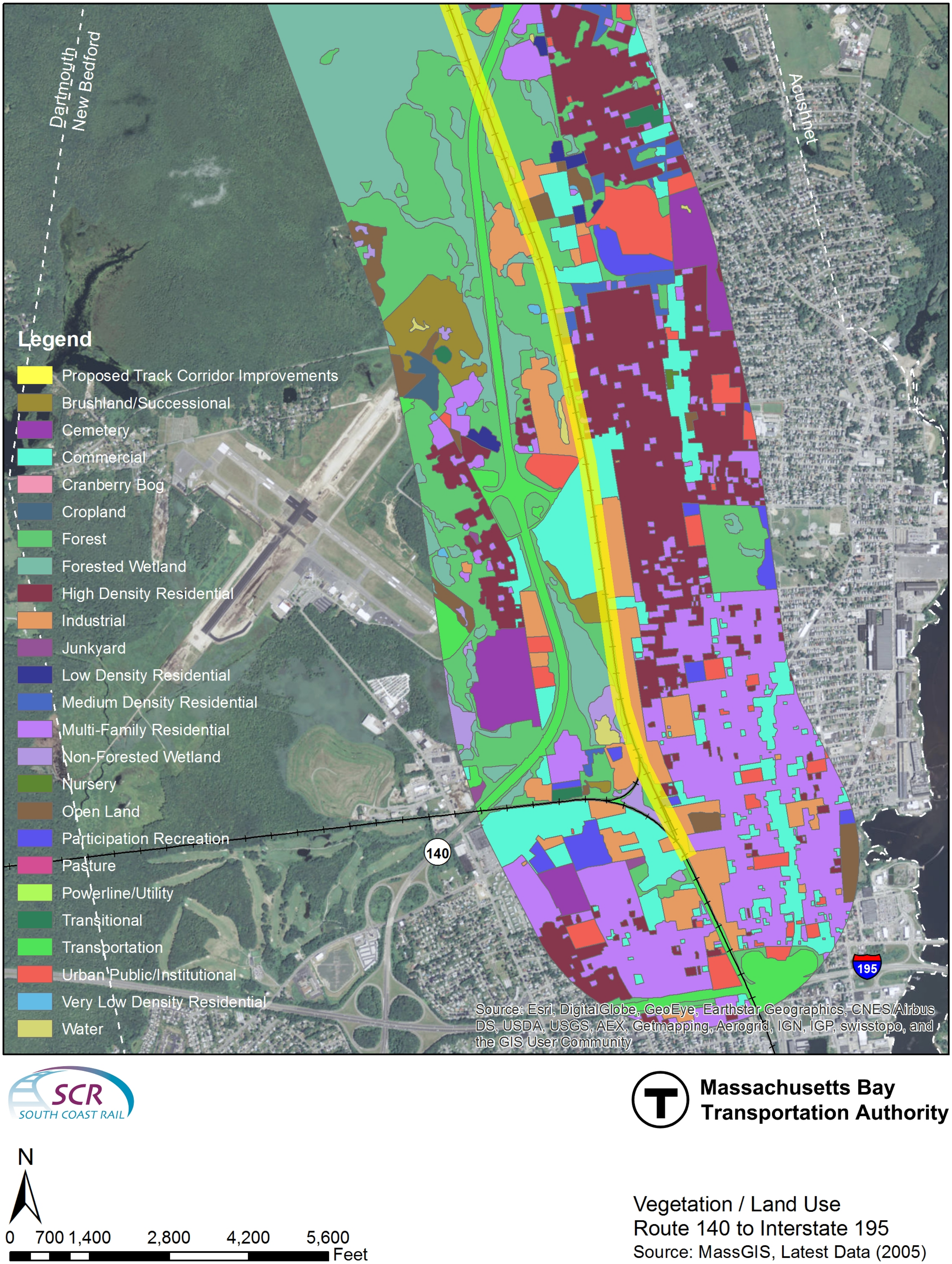



SCR SOUTH COAST RAIL

Massachusetts Bay Transportation Authority

Vegetation / Land Use, Municipal Line to Route 140

Source: MassGIS, Latest Data (2005)




SCR SOUTH COAST RAIL

Massachusetts Bay Transportation Authority

Vegetation / Land Use
Route 140 to Interstate 195
Source: MassGIS, Latest Data (2005)

# APPENDIX C - Culvert Analyses

Appendix C - Organization of Calculations / Supporting Materials

The culvert numbering convention used in this NOI submission is CV-NB-X, where CV indicates a culvert structure, NB indicates New Bedford and X represents the unique sequential number assigned to each culvert.

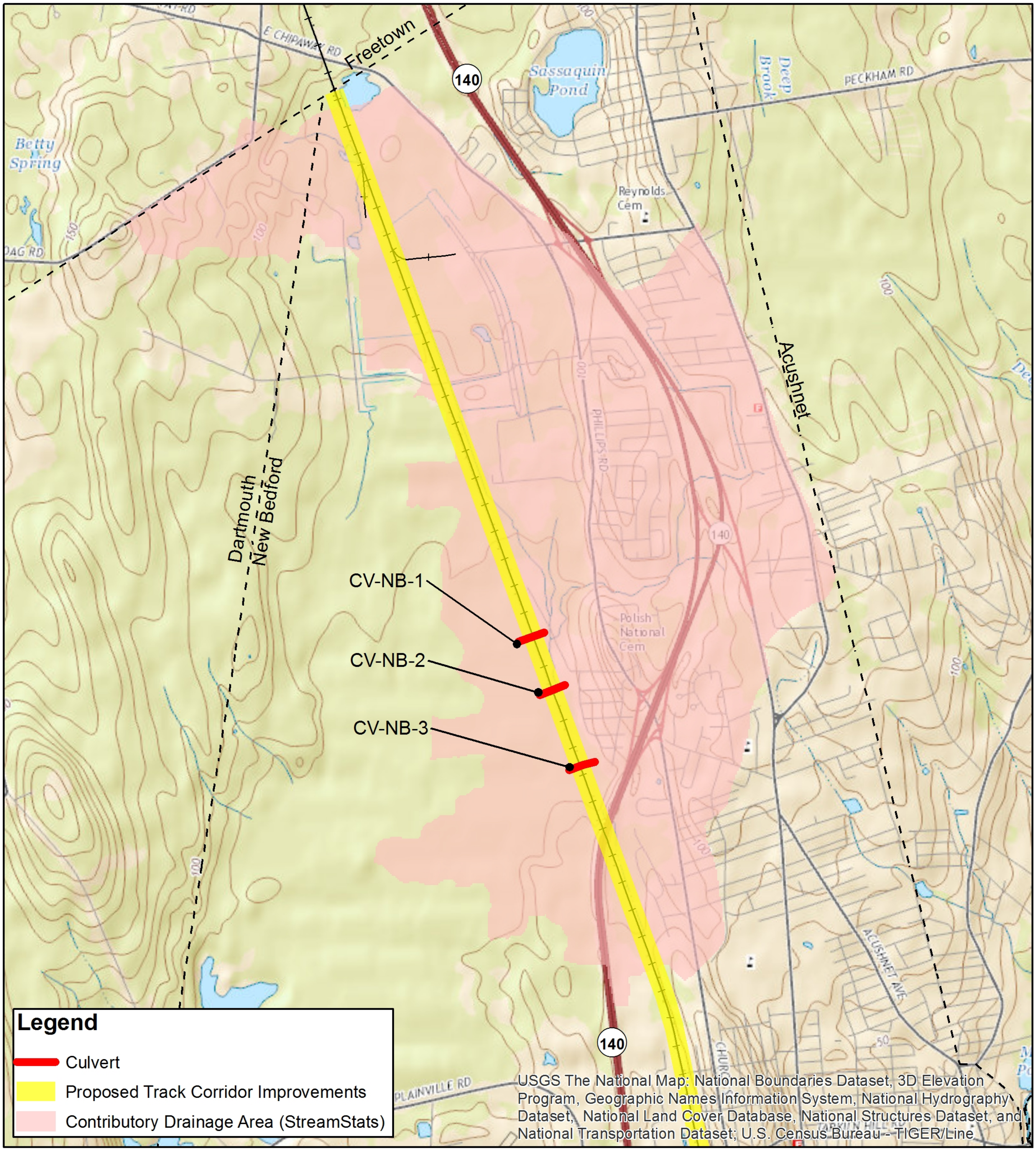
The tabulation immediately following this page, entitled Engineering Methods Used for Culvert Analysis, lists all cross-culverts within New Bedford and the engineering methods used in their hydrologic / hydraulic analysis, either:

1. National Streamflow Statistics (NSS) / FHWA HY-8 (herein referred to as the NSS/HY-8 method)
2. HydroCAD

Immediately following that tabulation is a Culvert Location Plan showing the location of each culvert and its tributary watershed. Following that Plan are calculations and supporting materials for each individual culvert.

**Engineering Methods Used for Culvert Analyses**
**New Bedford**

| Culvert Name | Hydrologic / Hydraulic Methods Used | |
|---|---|---|
| | National Streamflow Statistics (NSS) / FHWA HY-8 | HydroCAD |
| CV-NB-1 | X | |
| CV-NB-2 | X | |
| CV-NB-3 | X | |




SCR SOUTH COAST RAIL

Massachusetts Bay Transportation Authority

N

0 750 1,500 3,000 4,500 6,000 Feet

Culvert Location Plan

# StreamStats Version 3.0

## Basin Characteristics Ungaged Site Report

**Date: Wed Dec 16, 2015 11:24:28 AM GMT-5**
**Study Area: Massachusetts**
**NAD 1983 Latitude: 41.7003 ( 41 42 01)**
**NAD 1983 Longitude: -70.9548 (-70 57 18)**

| Label | Value | Units | Definition |
|---|---|---|---|
| DRNAREA | 3.18 | square miles | Area that drains to a point on a stream |
| STRMTOT | 7.88 | miles | Total length of mapped streams in basin |
| DRFTPERSTR | 0.2 | square mile per mile | Area of stratified drift per unit of stream length |
| MAREGION | 0 | dimensionless | Region of Massachusetts 0 for Eastern 1 for Western |
| FOREST | 23.04 | percent | Percentage of area covered by forest |
| CRSDFT | 45.12 | percent | Percentage of area of coarse-grained stratified drift |
| BSLDEM10M | 2.79 | percent | Mean basin slope computed from 10 m DEM |
| BSLDEM250 | 0.883 | percent | Mean basin slope computed from 1:250K DEM |
| ACRSDFT | 1.57 | square miles | Area underlain by stratified drift |
| LC11IMP | 24 | percent | Percentage of impervious area determined from NLCD 2011 impervious dataset |
| LC11DEV | 57.4 | percent | Percentage of land-use from NLCD 2011 classes 21-24 |
| ELEV | 99.7 | feet | Mean Basin Elevation |
| PRECPRIS00 | 49.8 | inches | Basin average mean annual precipitation for 1971 to 2000 from PRISM |
| LAKEAREA | 0.14 | percent | Percentage of Lakes and Ponds |
| OUTLETX | 245375 | State plane coordinates | Basin outlet horizontal (x) location in state plane coordinates |
| OUTLETY | 827925 | State plane coordinates | Basin outlet vertical (y) location in state plane coordinates |
| MAXTEMPC | 15 | degrees | Mean annual maximum air temperature over basin area, in degrees Centigrade |
| WETLAND | 26.34 | percent | Percentage of Wetlands |
| CENTROIDX | 245764.1 | State plane coordinates | Basin centroid horizontal (x) location in state plane coordinates |
| CENTROIDY | 829327.9 | State plane coordinates | Basin centroid vertical (y) location in state plane units |

National Streamflow Statistics Program
Version 5
Based on Techniques and Methods Book 4-A6
Equations from database C:\NSS\data\NSS_v6_2013-08-28.mdb
Updated by tkoenig 8/28/2013 at 04:10:29 PM Add 2 new params for AR 2008-5065

Site: CV-NB-1+CV-NB-2+CV-NB-3, Massachusetts
User:
Date: Friday, March 04, 2016 10:00 AM

Equations for Massachusetts developed using English units

Rural Estimate: Rural 1
   Basin Drainage Area: 3.18 square miles
   1 Region
   Region: Peak_Flow_Eastern_Mass
      Drainage_Area = 3.18 square miles
   Crippen & Bue Region 2

Results for: Rural 1

Equations used:
PK2 = 36.3* (DRNAREA)^(0.682)
PK5 = 55.38* (DRNAREA)^(0.67)
PK10 = 72.12* (DRNAREA)^(0.66)
PK25 = 96.71* (DRNAREA)^(0.651)
PK50 = 118.1* (DRNAREA)^(0.645)
PK100 = 143.1* (DRNAREA)^(0.638)
PK500 = 0

| Statistic | Value, cfs | Standard Error, % | Equivalent Years |
|---|---|---|---|
| PK2 | 79.9 | 49 | |
| PK5 | 120 | 45 | |
| PK10 | 155 | 44 | |
| PK25 | 205 | 46 | 5 |
| PK50 | 249 | 48 | 6 |
| PK100 | 299 | 52 | 7 |
| PK500 | 448 * | | |

*Extrapolated value
maximum: 12300 (for C&B region 2)

Urban Estimate: Urban 1
   Basin Drainage Area: 3.18 square miles
   1 Region
   Region: National Urban
      Drainage_Area = 3.18 square miles
      Channel_Slope = 13.5 feet per mi
      2_hour_2_year_Rainfall_Intensity = 1.54 inches
      Basin_Storage = 10 percent
      Basin_Development_Factor = 5 dimensionless
      Impervious_Surfaces = 24 percent
      Rural Scenario = Rural 1
   Crippen & Bue Region 2

Results for: Urban 1

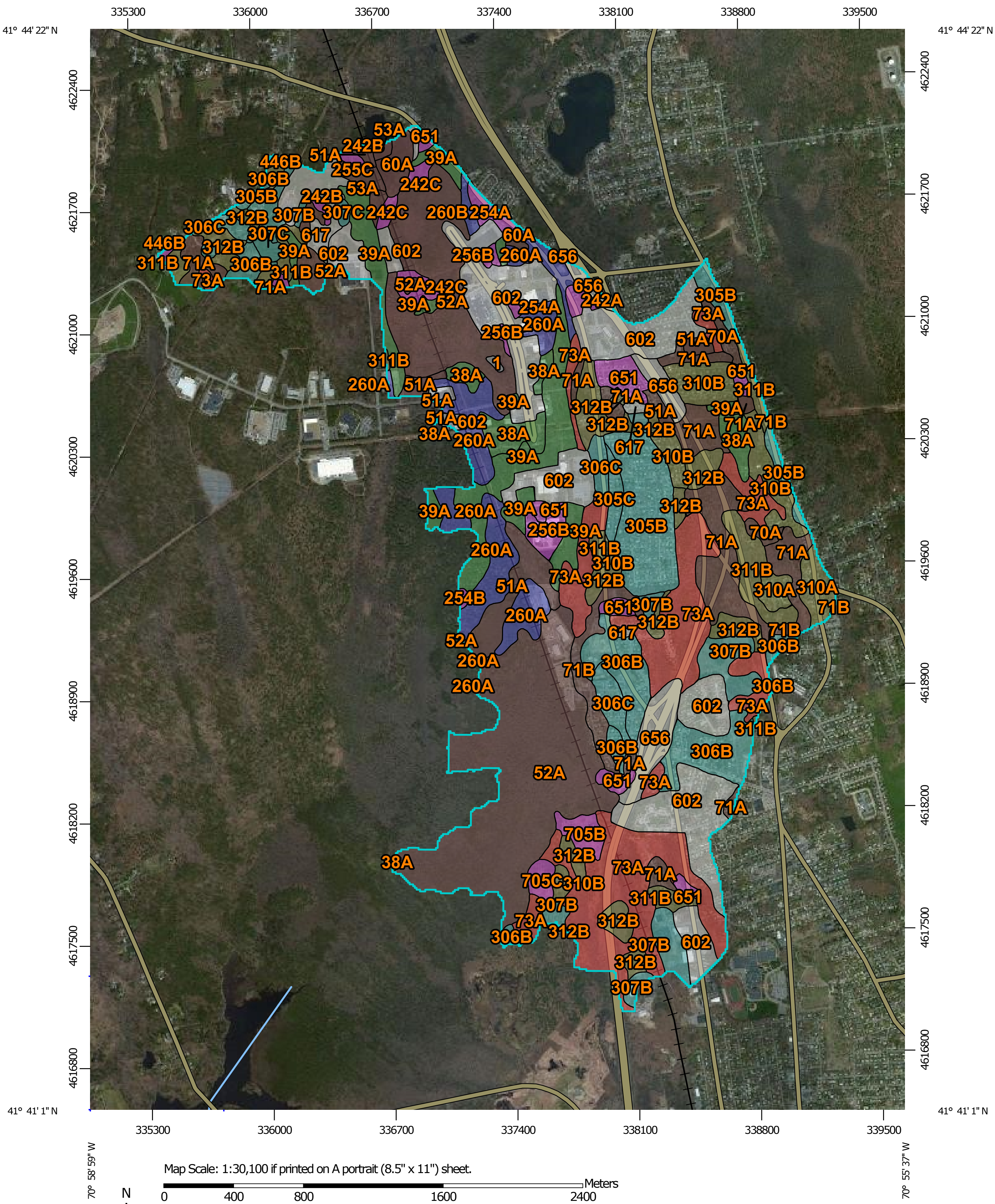
Equations used:

PK2 = 2.35 * (Rural_Dis)^0.47 * (Rural_DA)^0.41 * (CSL10_85)^0.17 * (I2H2Y+3)^2.04 * (STORAGE+8)^(-0.65) * (-1*(BDF-13))^(-0.32) * (IMPERV)^0.15
PK5 = 2.7 * (Rural_Dis)^0.54 * (Rural_DA)^0.35 * (CSL10_85)^0.16 * (I2H2Y+3)^1.86 * (STORAGE+8)^(-0.59) * (-1*(BDF-13))^(-0.31) * (IMPERV)^0.11
PK10 = 2.99 * (Rural_Dis)^0.58 * (Rural_DA)^0.32 * (CSL10_85)^0.15 * (I2H2Y+3)^1.75 * (STORAGE+8)^(-0.57) * (-1*(BDF-13))^(-0.3) * (IMPERV)^0.09
PK25 = 2.78 * (Rural_Dis)^0.6 * (Rural_DA)^0.31 * (CSL10_85)^0.15 * (I2H2Y+3)^1.76 * (STORAGE+8)^(-0.55) * (-1*(BDF-13))^(-0.29) * (IMPERV)^0.07
PK50 = 2.67 * (Rural_Dis)^0.62 * (Rural_DA)^0.29 * (CSL10_85)^0.15 * (I2H2Y+3)^1.74 * (STORAGE+8)^(-0.53) * (-1*(BDF-13))^(-0.28) * (IMPERV)^0.06
PK100 = 2.5 * (Rural_Dis)^0.63 * (Rural_DA)^0.29 * (CSL10_85)^0.15 * (I2H2Y+3)^1.76 * (STORAGE+8)^(-0.52) * (-1*(BDF-13))^(-0.28) * (IMPERV)^0.06
PK500 = 2.27 * (Rural_Dis)^0.63 * (Rural_DA)^0.29 * (CSL10_85)^0.16 * (I2H2Y+3)^1.86 * (STORAGE+8)^(-0.54) * (-1*(BDF-13))^(-0.27) * (IMPERV)^0.05

| Statistic | Value, cfs | Standard Error, % |
|---|---|---|
| PK2 | 128 | 38 |
| PK5 | 184 | 37 |
| PK10 | 231 | 38 |
| PK25 | 287 | 40 |
| PK50 | 343 | 42 |
| PK100 | 404 | 44 |
| PK500 | 528 | 49 |

maximum: 12300 (for C&B region 2)

Hydrologic Soil Group—Bristol County, Massachusetts, Southern Part
(GlobalWatershed)




Map Scale: 1:30,100 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 400, 800, 1600, 2400

Feet: 0, 1000, 2000, 4000, 6000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

## MAP LEGEND

**Area of Interest (AOI)**
- Area of Interest (AOI)

**Soils**

**Soil Rating Polygons**
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

**Soil Rating Lines**
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

**Soil Rating Points**
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

**Water Features**
- Streams and Canals

**Transportation**
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

**Background**
- Aerial Photography

## MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Bristol County, Massachusetts, Southern Part
Survey Area Data: Version 9, Sep 28, 2015

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 30, 2011—Oct 8, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

# Hydrologic Soil Group

| Hydrologic Soil Group— Summary by Map Unit — Bristol County, Massachusetts, Southern Part (MA603) | | | | |
|---|---|---|---|---|
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI |
| 1 | Water | | 1.3 | 0.1% |
| 32A | Wareham loamy sand, 0 to 3 percent slopes | A/D | 2.2 | 0.1% |
| 38A | Pipestone loamy sand, 0 to 3 percent slopes | A/D | 37.6 | 1.9% |
| 39A | Scarboro mucky fine sandy loam, 0 to 3 percent slopes | A/D | 118.6 | 5.8% |
| 51A | Swansea muck, 0 to 1 percent slopes | B/D | 46.4 | 2.3% |
| 52A | Freetown muck, 0 to 1 percent slopes | B/D | 375.1 | 18.5% |
| 53A | Freetown muck, ponded, 0 to 1 percent slopes | B/D | 9.7 | 0.5% |
| 60A | Swansea coarse sand, 0 to 2 percent slopes | B/D | 13.7 | 0.7% |
| 70A | Ridgebury fine sandy loam, 0 to 3 percent slopes | B/D | 10.1 | 0.5% |
| 71A | Ridgebury fine sandy loam, 0 to 3 percent slopes, extremely stony | B/D | 112.1 | 5.5% |
| 71B | Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony | B/D | 26.5 | 1.3% |
| 73A | Whitman fine sandy loam, 0 to 3 percent slopes, extremely stony | D | 240.7 | 11.8% |
| 242A | Hinckley loamy sand, 0 to 3 percent slopes | A | 5.0 | 0.2% |
| 242B | Hinckley loamy sand, 3 to 8 percent slopes | A | 3.9 | 0.2% |
| 242C | Hinckley loamy sand, 8 to 15 percent slopes | A | 14.9 | 0.7% |
| 254A | Merrimac fine sandy loam, 0 to 3 percent slopes | A | 9.9 | 0.5% |
| 254B | Merrimac fine sandy loam, 3 to 8 percent slopes | A | 2.3 | 0.1% |
| 255C | Windsor loamy sand, 8 to 15 percent slopes | A | 2.7 | 0.1% |

| Hydrologic Soil Group— Summary by Map Unit — Bristol County, Massachusetts, Southern Part (MA603) | | | | |
|---|---|---|---|---|
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI |
| 256B | Deerfield loamy sand, 0 to 5 percent slopes | A | 16.0 | 0.8% |
| 260A | Sudbury fine sandy loam, 0 to 3 percent slopes | B | 103.0 | 5.1% |
| 260B | Sudbury fine sandy loam, 3 to 8 percent slopes | B | 4.5 | 0.2% |
| 305B | Paxton fine sandy loam, 3 to 8 percent slopes | C | 87.5 | 4.3% |
| 305C | Paxton fine sandy loam, 8 to 15 percent slopes | C | 9.0 | 0.4% |
| 306B | Paxton fine sandy loam, 0 to 8 percent slopes, very stony | C | 87.2 | 4.3% |
| 306C | Paxton fine sandy loam, 8 to 15 percent slopes, very stony | C | 26.5 | 1.3% |
| 307B | Paxton fine sandy loam, 0 to 8 percent slopes, extremely stony | C | 59.8 | 2.9% |
| 307C | Paxton fine sandy loam, 8 to 15 percent slopes, extremely stony | C | 7.7 | 0.4% |
| 310A | Woodbridge fine sandy loam, 0 to 3 percent slopes | C/D | 24.1 | 1.2% |
| 310B | Woodbridge fine sandy loam, 3 to 8 percent slopes | C/D | 55.9 | 2.7% |
| 311B | Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony | C/D | 48.6 | 2.4% |
| 312B | Woodbridge fine sandy loam, 0 to 8 percent slopes, extremely stony | C/D | 86.9 | 4.3% |
| 446B | Gloucester - Hinckley complex, undulating, very stony | A | 2.6 | 0.1% |
| 602 | Urban land | | 254.6 | 12.5% |
| 617 | Pits - Udorthents complex, gravelly | | 31.6 | 1.6% |
| 651 | Udorthents, smoothed | A | 32.2 | 1.6% |
| 656 | Udorthents - Urban land complex | | 42.3 | 2.1% |
| 705B | Charlton - Paxton fine sandy loams, 3 to 8 percent slopes, rocky | A | 12.2 | 0.6% |

| Hydrologic Soil Group— Summary by Map Unit — Bristol County, Massachusetts, Southern Part (MA603) | | | | |
|---|---|---|---|---|
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI |
| 705C | Charlton - Paxton fine sandy loams, 8 to 15 percent slopes, rocky | A | 7.6 | 0.4% |
| **Totals for Area of Interest** | | | **2,032.4** | **100.0%** |

## Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

## Rating Options

*Aggregation Method:* Dominant Condition

*Component Percent Cutoff:* *None Specified*

*Tie-break Rule:* Higher

# HY-8 Culvert Analysis Report

## EXISTING HYDRAULIC OPERATION

## Culverts

## CV-NB-1

**Station 2638+10**

## CV-NB-2

**Station 2649+00**

## and

## CV-NB-3

**Station 2663+62**

## Crossing Discharge Data

Discharge Selection Method: Recurrence

## Analysis Methodology:

During the more extreme and infrequent storm events for which these three culvert crossings have to be analyzed, they all share a common water surface / headwater, based upon the FEMA base flood elevation delineations. Given this situation, the culverts can be analyzed as a single multiple barrel crossing, however accounting for differing culvert sizes and invert elevations.

### Table 1 - Summary of Culvert Flows at Crossing:

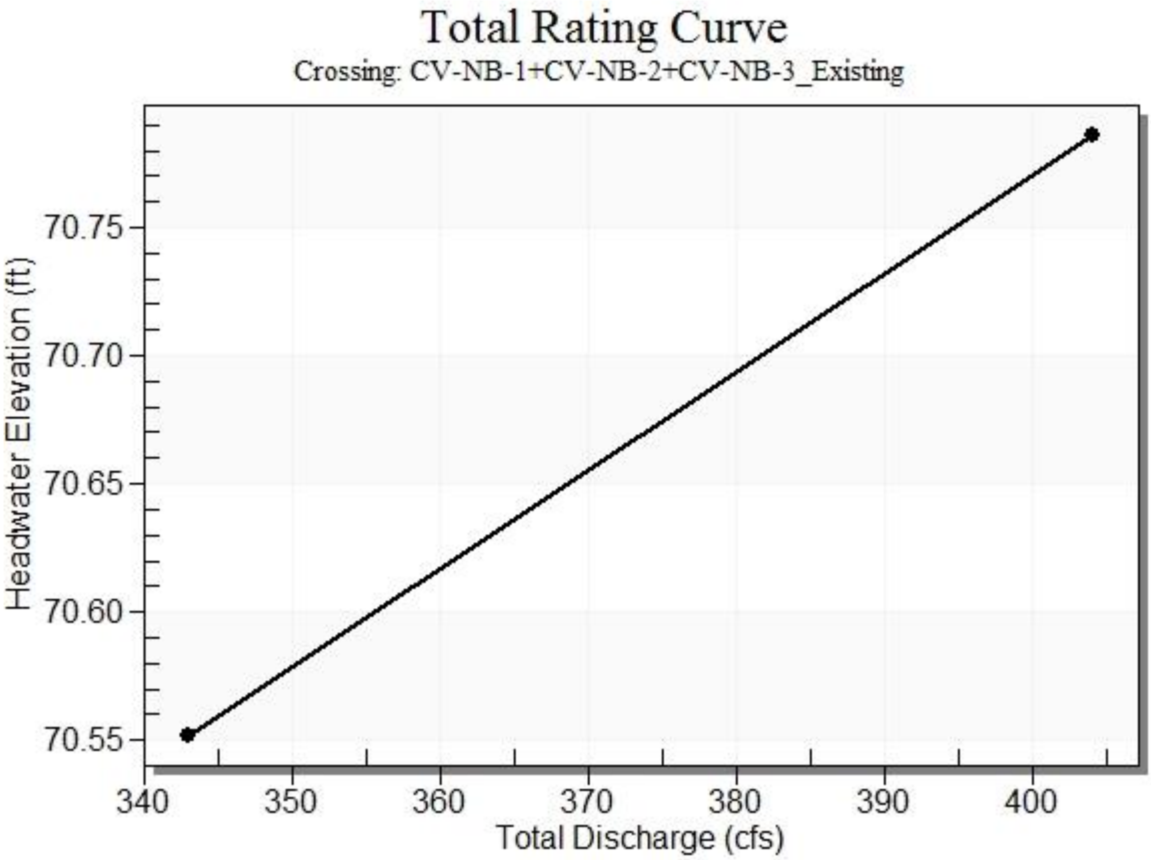
| Headwater Elevation (ft) | Discharge Names | Total Discharge (cfs) | Culvert 1 Discharge (cfs) | Culvert 2 Discharge (cfs) | Culvert 3 Discharge (cfs) | Roadway Discharge (cfs) | Iterations |
|---|---|---|---|---|---|---|---|
| 70.55 | 50 year | 343.00 | 157.91 | 59.78 | 125.81 | 0.00 | 9 |
| 70.79 | 100 year | 404.00 | 181.14 | 74.14 | 150.31 | 0.00 | 12 |
| 70.80 | Overtopping | 408.62 | 182.40 | 74.59 | 151.63 | 0.00 | Overtopping |

**CV-NB-1+CV-NB-2+CV-NB-3_Existing**

Conclusions:

This computed Headwater Elevation, 70.79, is essentially the same as the interpreted current FEMA Base Flood Elevation (100-yr return storm event) of Elevation 71 at the upstream ends of these culverts.

**Rating Curve Plot for Crossing: CV-NB-1+CV-NB-2+CV-NB-3_Existing**



## Table 2 - Culvert Summary Table: Culvert 1

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 year | 343.00 | 157.91 | 70.55 | 4.299 | 4.741 | 9-A2t | -1.000 | 2.509 | 3.920 | 5.000 | 5.755 | 0.000 |
| 100 year | 404.00 | 181.14 | 70.79 | 4.768 | 4.976 | 9-A2t | -1.000 | 2.750 | 3.920 | 5.000 | 6.601 | 0.000 |

*******************************************************************************

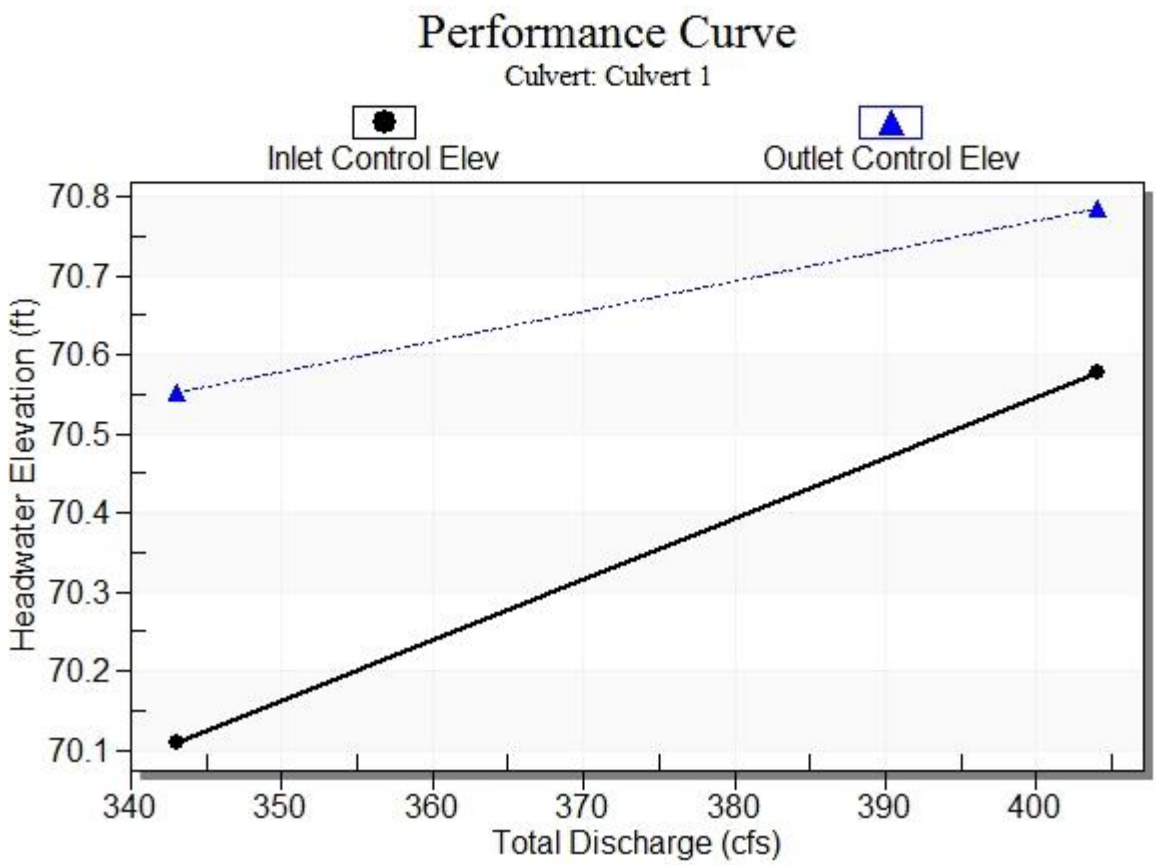
Straight Culvert

Inlet Elevation (invert): 65.81 ft, Outlet Elevation (invert): 66.08 ft

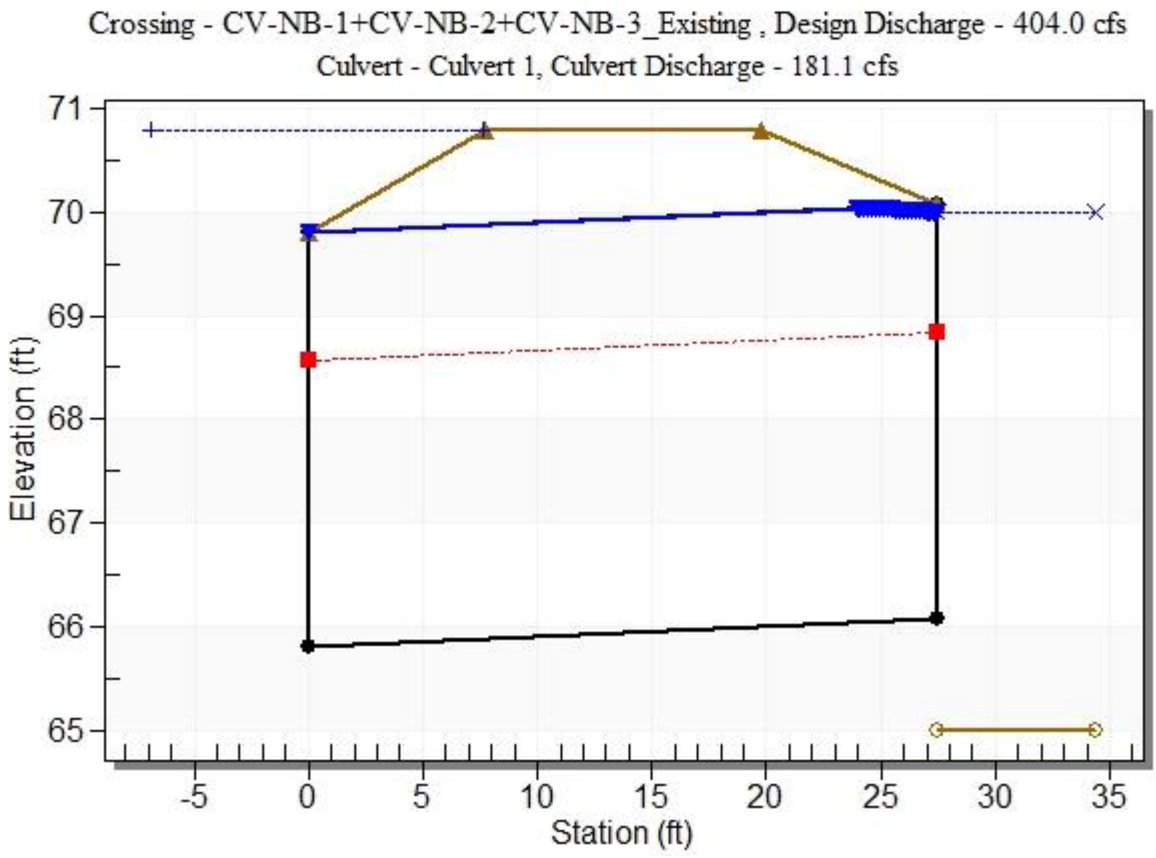
Culvert Length: 27.50 ft, Culvert Slope: -0.0098

*******************************************************************************

**Culvert Performance Curve Plot: Culvert 1**



## Water Surface Profile Plot for Culvert: Culvert 1




## Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 65.81 ft

Outlet Station: 27.50 ft

Outlet Elevation: 66.08 ft

Number of Barrels: 1

## Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 7.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0250

Culvert Type: Straight

Inlet Configuration: Square Edge (90º) Headwall

Inlet Depression: NONE

## Table 3 - Culvert Summary Table: Culvert 2

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 year | 343.00 | 59.78 | 70.55 | 2.831 | 3.051 | 1-S1f | 1.004 | 1.763 | 4.000 | 5.000 | 3.321 | 0.000 |
| 100 year | 404.00 | 74.14 | 70.79 | 3.285 | 3.008 | 1-JS1f | 1.165 | 2.035 | 4.000 | 5.000 | 4.119 | 0.000 |

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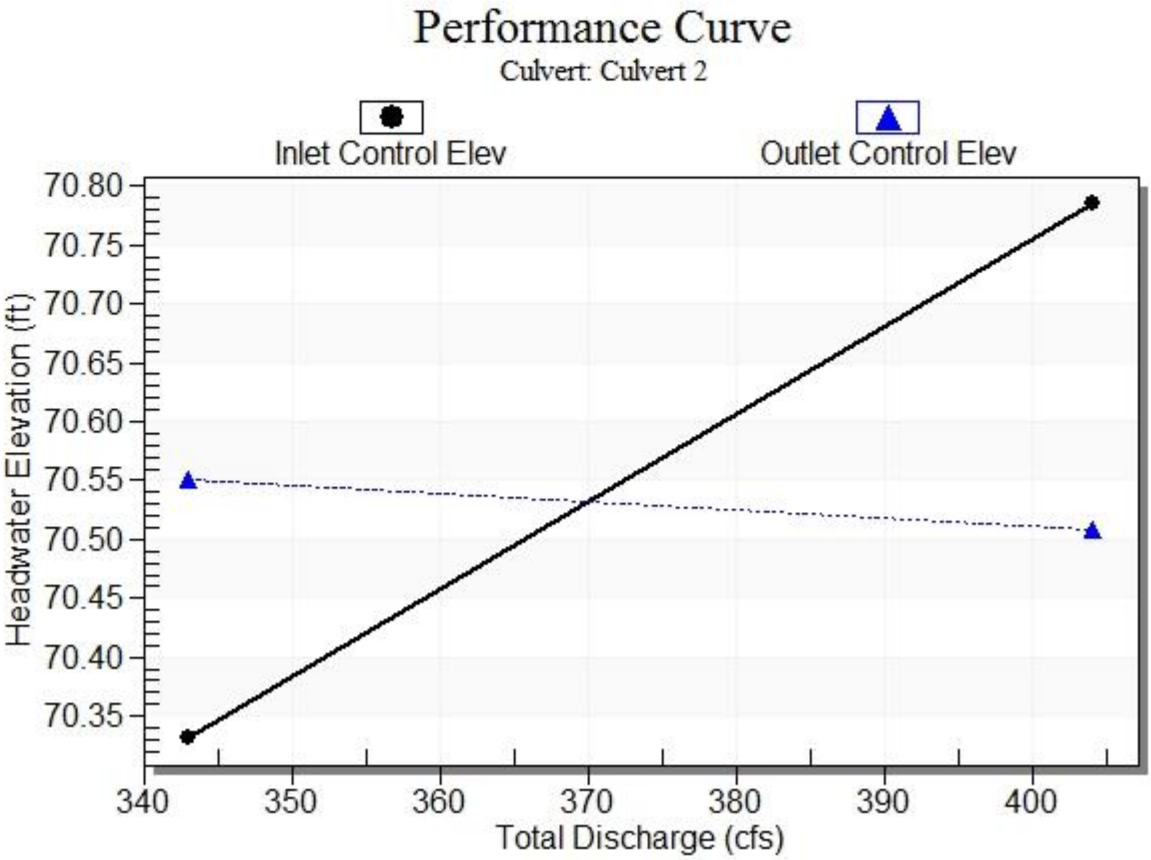
Straight Culvert

Inlet Elevation (invert): 67.50 ft, Outlet Elevation (invert): 65.37 ft

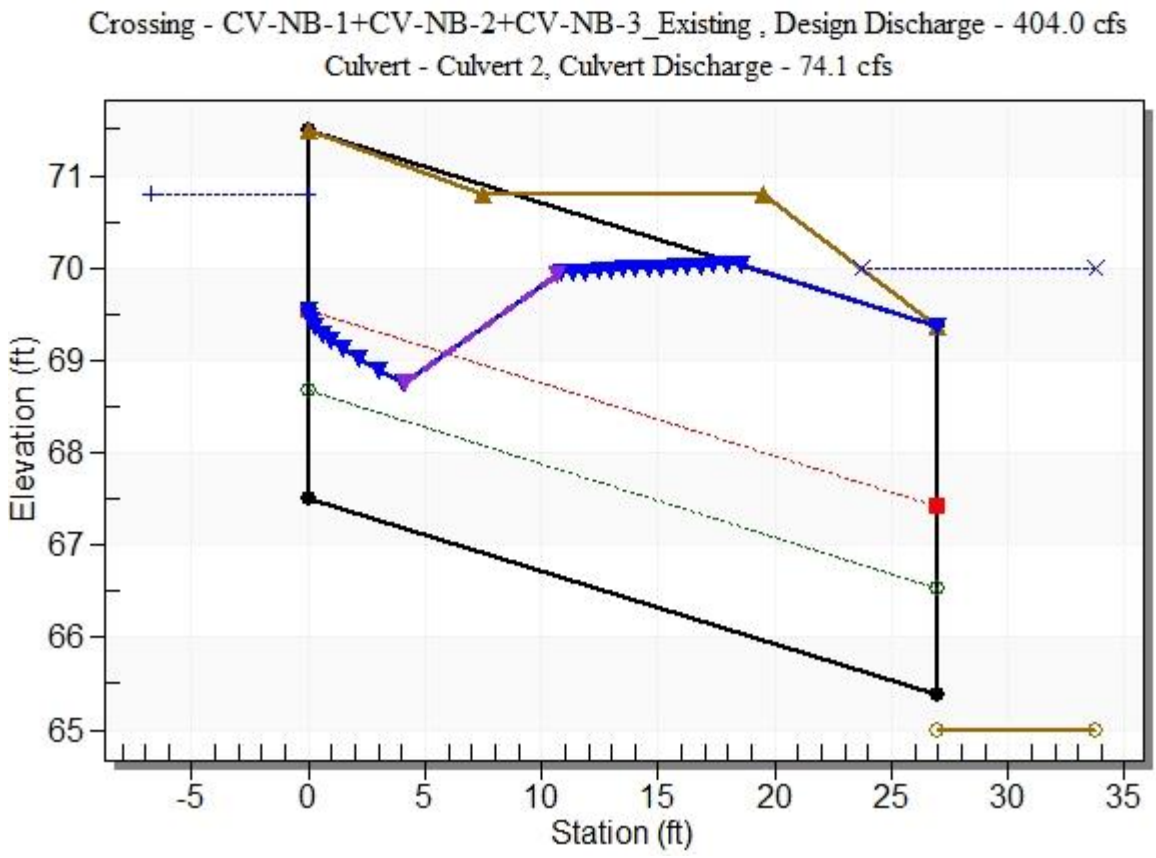
Culvert Length: 27.08 ft, Culvert Slope: 0.0789

******************************************************************************

**Culvert Performance Curve Plot: Culvert 2**



**Water Surface Profile Plot for Culvert: Culvert 2**




**Site Data - Culvert 2**

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 67.50 ft

Outlet Station: 27.00 ft

Outlet Elevation: 65.37 ft

Number of Barrels: 1

**Culvert Data Summary - Culvert 2**

Barrel Shape: Concrete Box

Barrel Span: 4.50 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0250

Culvert Type: Straight

Inlet Configuration: Square Edge (90º) Headwall

Inlet Depression: NONE

## Table 4 - Culvert Summary Table: Culvert 3

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 year | 343.00 | 125.81 | 70.55 | 4.005 | 4.951 | 1-S1f | 2.299 | 2.390 | 5.000 | 5.000 | 4.194 | 0.000 |
| 100 year | 404.00 | 150.31 | 70.79 | 4.513 | 5.185 | 1-S1f | 2.618 | 2.691 | 5.000 | 5.000 | 5.010 | 0.000 |

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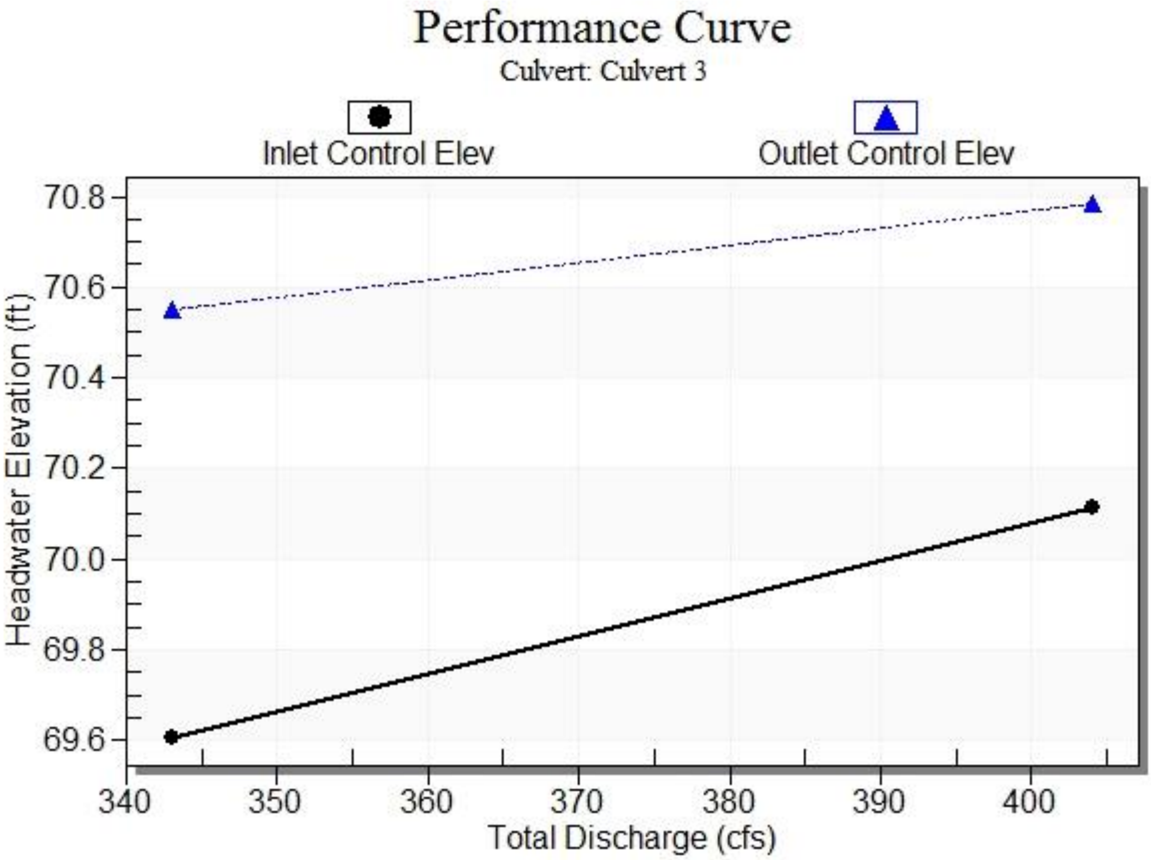
Straight Culvert

Inlet Elevation (invert): 65.60 ft, Outlet Elevation (invert): 64.95 ft

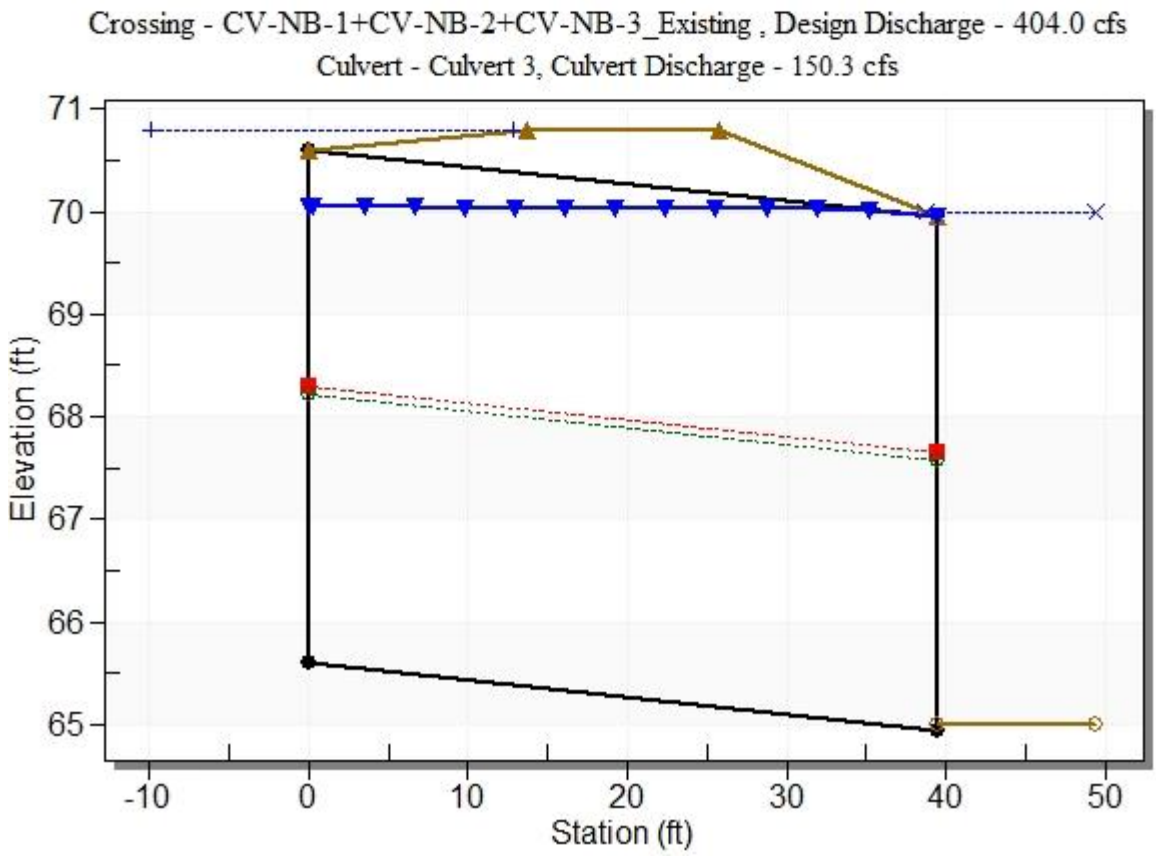
Culvert Length: 39.51 ft, Culvert Slope: 0.0165

******************************************************************************

**Culvert Performance Curve Plot: Culvert 3**



**Water Surface Profile Plot for Culvert: Culvert 3**




**Site Data - Culvert 3**

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 65.60 ft

Outlet Station: 39.50 ft

Outlet Elevation: 64.95 ft

Number of Barrels: 1

**Culvert Data Summary - Culvert 3**

Barrel Shape: Concrete Box

Barrel Span: 6.00 ft

Barrel Rise: 5.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0250

Culvert Type: Straight

Inlet Configuration: Square Edge (90º) Headwall

Inlet Depression: NONE

**Table 5 - Downstream Channel Rating Curve (Crossing: CV-NB-1+CV-NB-2+CV-NB-3_Existing )**

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) |
|---|---|---|
| 343.00 | 70.00 | 5.00 |
| 404.00 | 70.00 | 5.00 |

## Tailwater Channel Data - CV-NB-1+CV-NB-2+CV-NB-3_Existing

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 70.00 ft

## Roadway Data for Crossing: CV-NB-1+CV-NB-2+CV-NB-3_Existing

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 500.00 ft

Crest Elevation: 70.80 ft

Roadway Surface: Gravel

Roadway Top Width: 12.00 ft

# HY-8 Culvert Analysis Report

## PROPOSED HYDRAULIC OPERATION

## Culverts

## CV-NB-1

**Station 2638+10**

## CV-NB-2

**Station 2649+00**

## and

## CV-NB-3

**Station 2663+62**

## Crossing Discharge Data

Discharge Selection Method: Recurrence

## Analysis Methodology:

During the more extreme and infrequent storm events for which these three culvert crossings have to be analyzed, they all share a common water surface / headwater, based upon the FEMA base flood elevation delineations. Given this situation, the culverts can be analyzed as a single multiple barrel crossing, however accounting for differing culvert sizes and invert elevation

## Table 1 - Summary of Culvert Flows at Crossing:

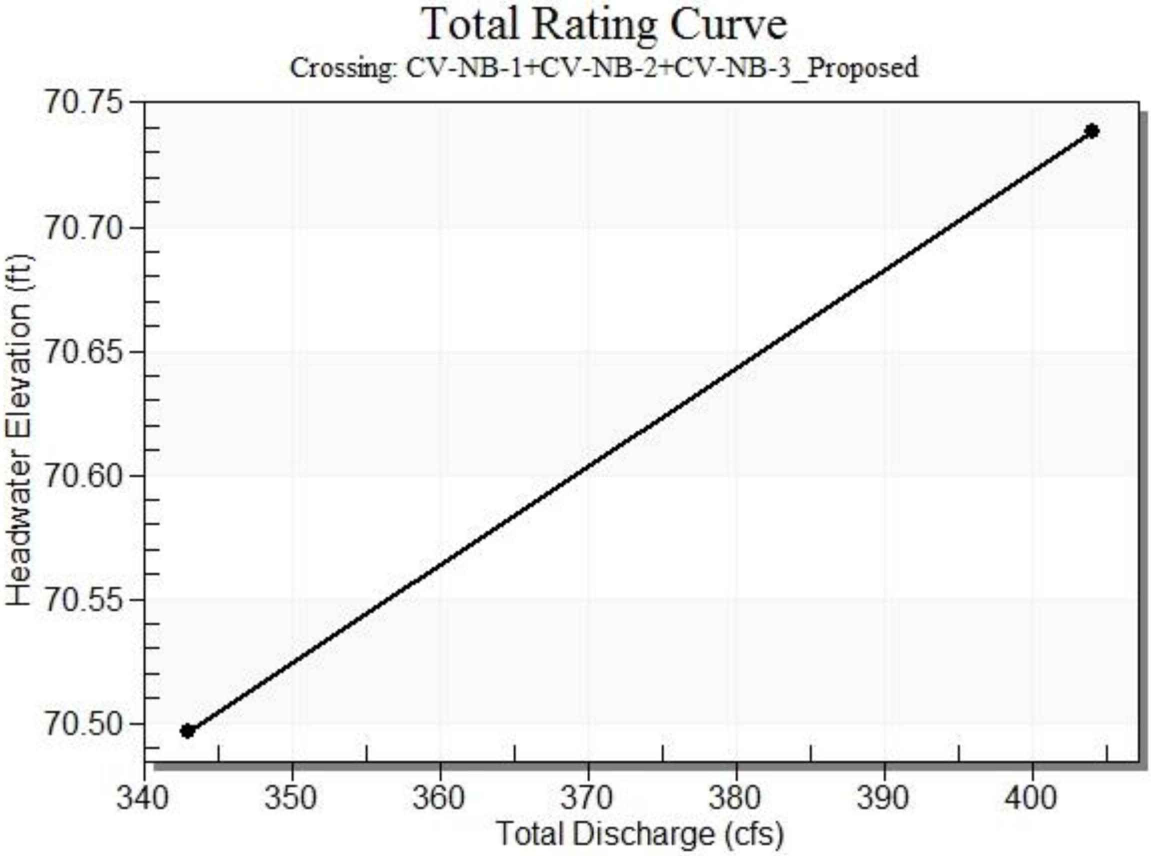
| Headwater Elevation (ft) | Discharge Names | Total Discharge (cfs) | Culvert 1 Discharge (cfs) | Culvert 2 Discharge (cfs) | Culvert 3 Discharge (cfs) | Roadway Discharge (cfs) | Iterations |
|---|---|---|---|---|---|---|---|
| 70.50 | 50 year | 343.00 | 151.90 | 64.08 | 127.46 | 0.00 | 12 |
| 70.74 | 100 year | 404.00 | 176.66 | 72.29 | 154.86 | 0.00 | 6 |
| 73.75 | Overtopping | 782.32 | 305.72 | 166.83 | 309.77 | 0.00 | Overtopping |

**CV-NB-1+CV-NB-2+CV-NB-3_Proposed**

Conclusions:

1. This computed Headwater Elevation, 70.74, is essentially the same as the existing computed Headwater Elevation 70.79 and the interpreted current FEMA Base Flood Elevation (100-yr return storm event) of Elevation 71 at the upstream ends of these culverts.
2. The proposed culverts match as close as possible to the existing culverts dimensions.
3. Based upon the lowest Top of Rail elevation at these three culverts, 73.85, the minimum distance between top of tie and the 100-yr water surface is about 2.5-ft. Per Design Criteria, this clearance should be minimum 18-inches.
4. The proposed culverts meet the design criteria.

**Rating Curve Plot for Crossing: CV-NB-1+CV-NB-2+CV-NB-3_Proposed**



## Table 2 - Culvert Summary Table: Culvert 1

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 year | 343.00 | 151.90 | 70.50 | 4.180 | 4.686 | 9-A2t | -1.000 | 2.445 | 3.920 | 5.000 | 5.536 | 0.000 |
| 100 year | 404.00 | 176.66 | 70.74 | 4.676 | 4.928 | 9-A2t | -1.000 | 2.704 | 3.920 | 5.000 | 6.438 | 0.000 |

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Straight Culvert

Inlet Elevation (invert): 65.81 ft, Outlet Elevation (invert): 66.08 ft

Culvert Length: 27.50 ft, Culvert Slope: -0.0098

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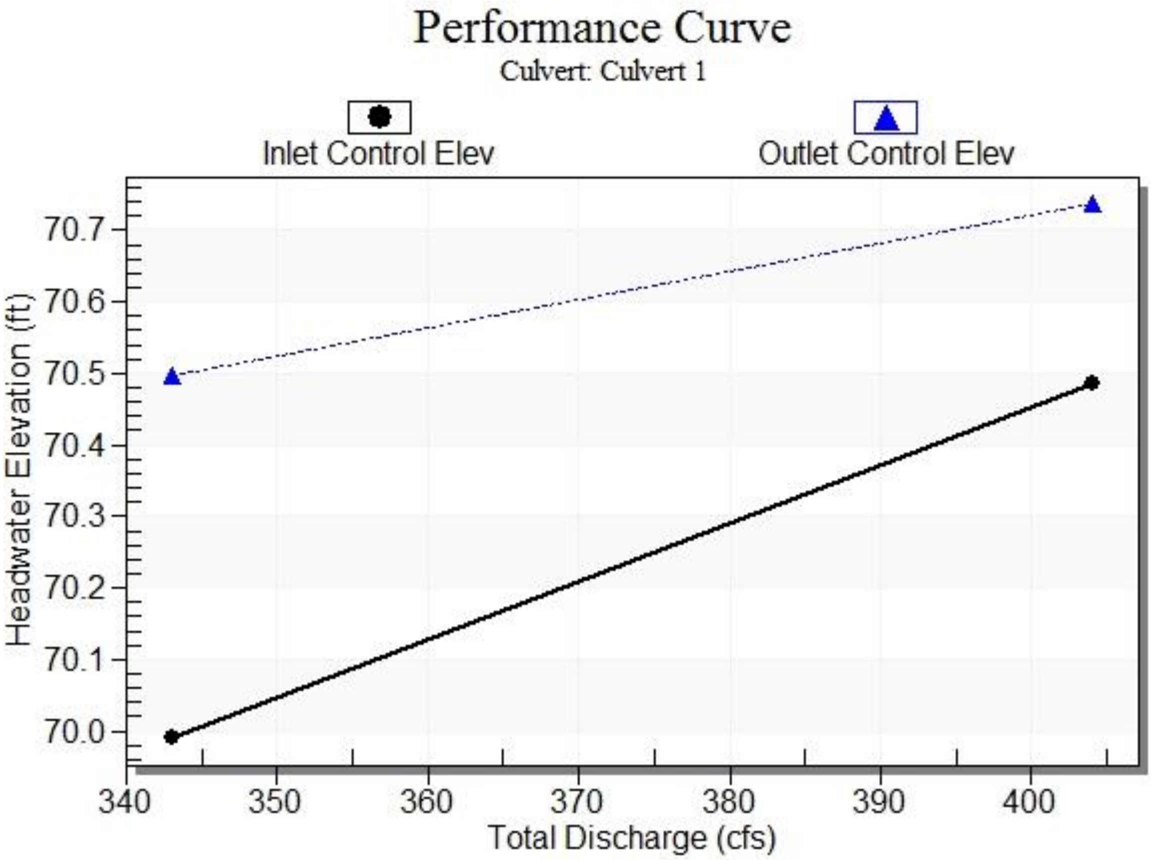
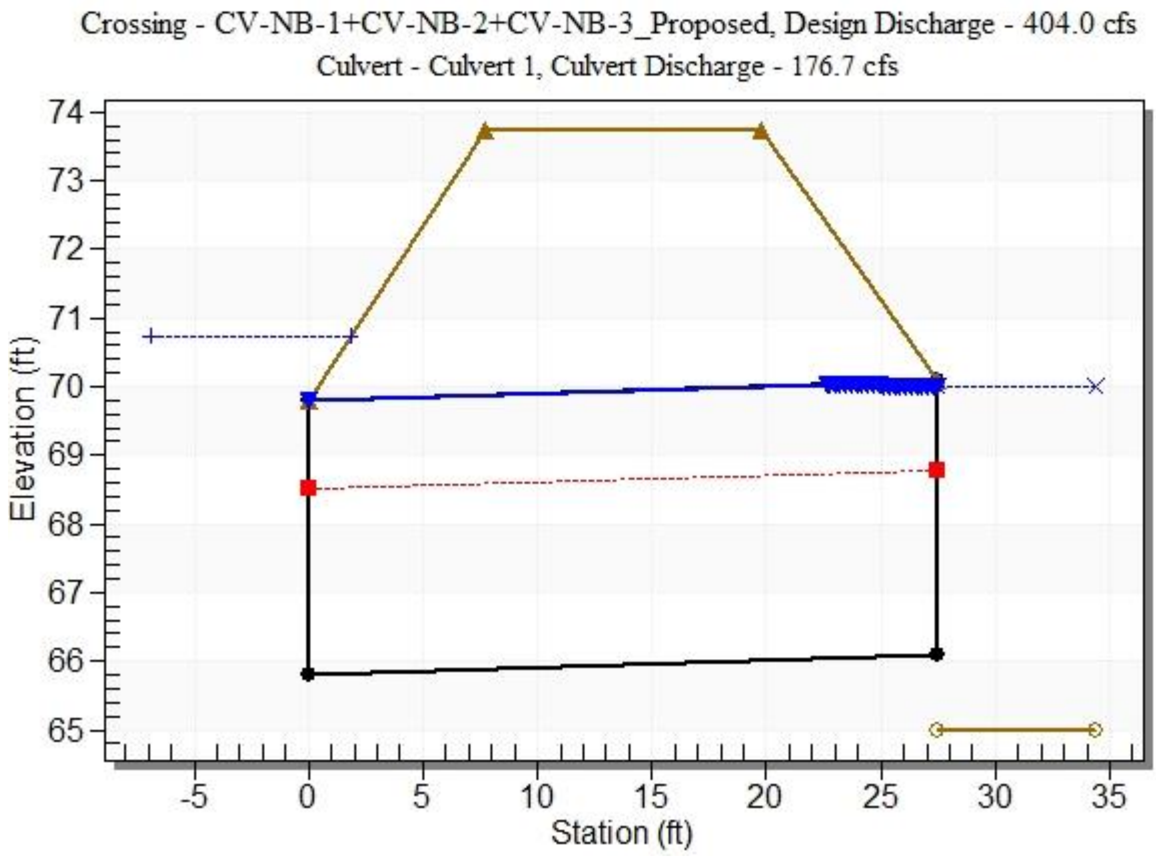
**Culvert Performance Curve Plot: Culvert 1**



## Water Surface Profile Plot for Culvert: Culvert 1




## Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 65.81 ft

Outlet Station: 27.50 ft

Outlet Elevation: 66.08 ft

Number of Barrels: 1

## Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 7.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Culvert Type: Straight

Inlet Configuration: Square Edge (90º) Headwall

Inlet Depression: NONE

## Table 3 - Culvert Summary Table: Culvert 2

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 year | 343.00 | 64.08 | 70.50 | 2.775 | 2.996 | 1-S1f | 0.615 | 1.721 | 3.500 | 5.000 | 3.662 | 0.000 |
| 100 year | 404.00 | 72.29 | 70.74 | 3.018 | 3.239 | 1-S1f | 0.670 | 1.865 | 3.500 | 5.000 | 4.131 | 0.000 |

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Straight Culvert

Inlet Elevation (invert): 67.50 ft, Outlet Elevation (invert): 65.37 ft

Culvert Length: 27.08 ft, Culvert Slope: 0.0789

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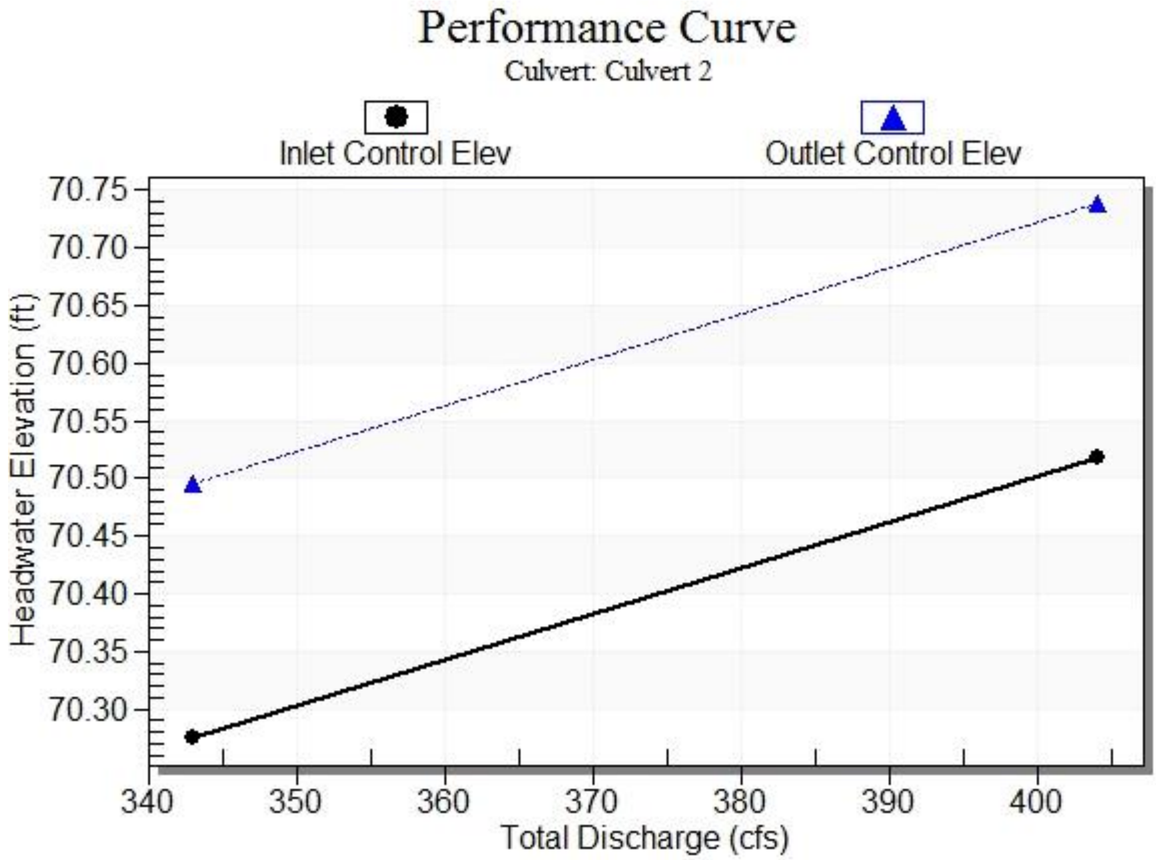
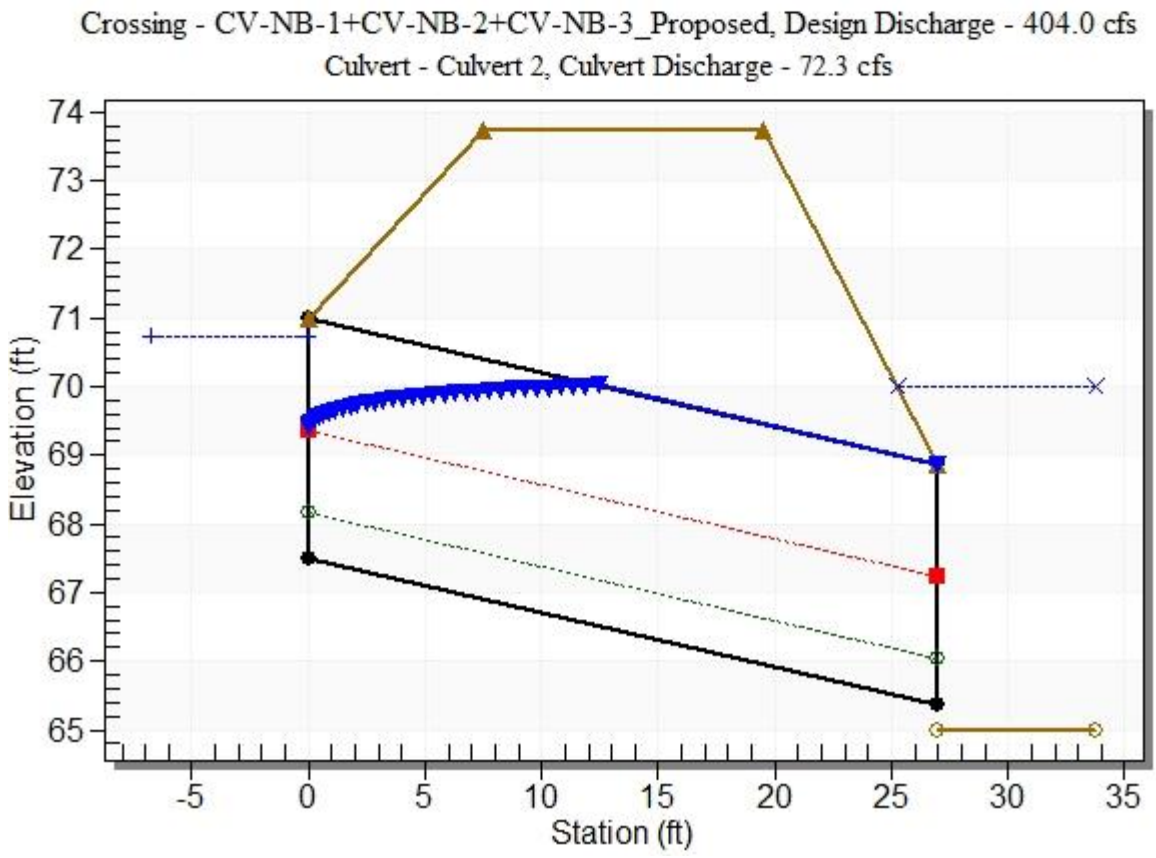
**Culvert Performance Curve Plot: Culvert 2**



## Water Surface Profile Plot for Culvert: Culvert 2




## Site Data - Culvert 2

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 67.50 ft

Outlet Station: 27.00 ft

Outlet Elevation: 65.37 ft

Number of Barrels: 1

## Culvert Data Summary - Culvert 2

Barrel Shape: Concrete Box

Barrel Span: 5.00 ft

Barrel Rise: 3.50 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Culvert Type: Straight

Inlet Configuration: Square Edge (90º) Headwall

Inlet Depression: NONE

## Table 4 - Culvert Summary Table: Culvert 3

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 year | 343.00 | 127.46 | 70.50 | 4.039 | 4.896 | 1-S1f | 1.453 | 2.411 | 5.000 | 5.000 | 4.249 | 0.000 |
| 100 year | 404.00 | 154.86 | 70.74 | 4.606 | 5.138 | 1-S1f | 1.674 | 2.745 | 5.000 | 5.000 | 5.162 | 0.000 |

***************************************************************************************

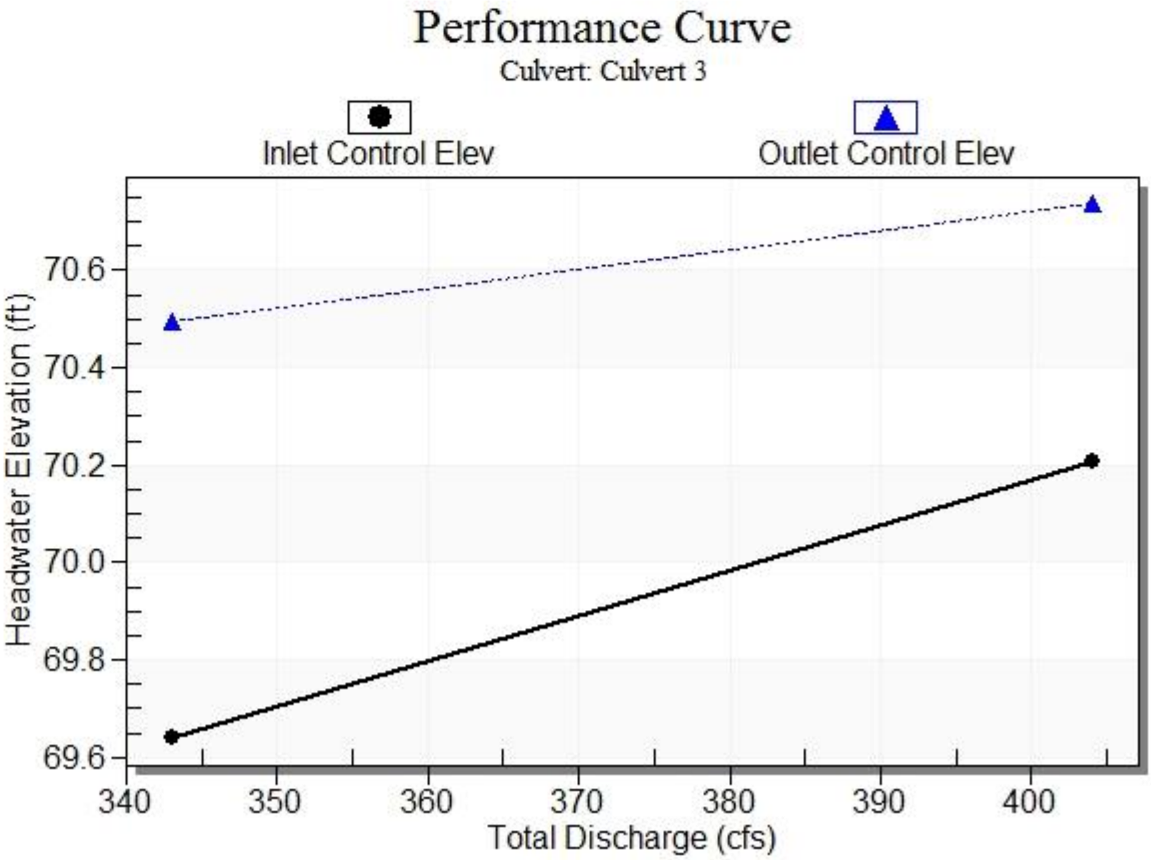
Straight Culvert

Inlet Elevation (invert): 65.60 ft,       Outlet Elevation (invert): 64.95 ft

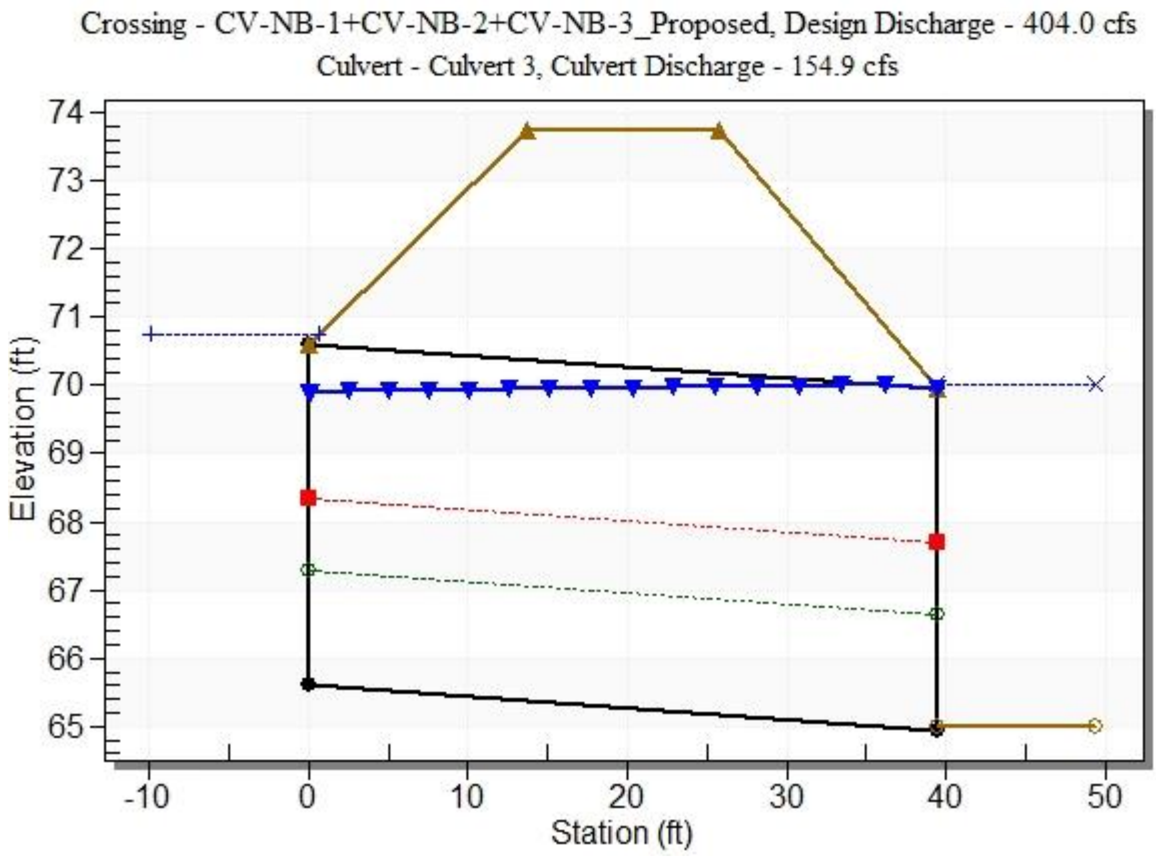
Culvert Length: 39.51 ft,       Culvert Slope: 0.0165

***************************************************************************************

**Culvert Performance Curve Plot: Culvert 3**



### Water Surface Profile Plot for Culvert: Culvert 3




### Site Data - Culvert 3

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 65.60 ft

Outlet Station: 39.50 ft

Outlet Elevation: 64.95 ft

Number of Barrels: 1

### Culvert Data Summary - Culvert 3

Barrel Shape: Concrete Box

Barrel Span: 6.00 ft

Barrel Rise: 5.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Culvert Type: Straight

Inlet Configuration: Square Edge (90º) Headwall

Inlet Depression: NONE

**Table 5 - Downstream Channel Rating Curve (Crossing: CV-NB-1+CV-NB-2+CV-NB-3_Proposed)**

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) |
|---|---|---|
| 343.00 | 70.00 | 5.00 |
| 404.00 | 70.00 | 5.00 |

### Tailwater Channel Data - CV-NB-1+CV-NB-2+CV-NB-3_Proposed

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 70.00 ft

### Roadway Data for Crossing: CV-NB-1+CV-NB-2+CV-NB-3_Proposed

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 500.00 ft

Crest Elevation: 73.75 ft

Roadway Surface: Gravel

Roadway Top Width: 12.00 ft

## APPENDIX D - Track Drainage Design

- **Stormwater Drains and Underdrains**
- **Pipe Outlet End Protection**
- **Vegetated Swale Discharge End Protection**

# STORM DRAINS

# AND

# UNDERDRAINS

| For: | Franklin | Sheet No. | 1 of 1 |
|---|---|---|---|
| Made by: | thl | Cked by: | anc |
| Date: | 3/18/16 | Date: | 3/18/16 |

**HNTB**

**MBTA, South Coast Rail in New Bedford, Masasachusetts**

Assumptions:
(1) Underdrain pipe material HDPE, n=0.011; RCP n = 0.013
(2) Rational Method for peak discharge
(3) C-factor for Sub-Ballast = 0.42 (Per MassDOT Chapter 8 Drainage and Erosion Control, Railroad Yard C value = 0.2 to 0.35. Using 0.35 for Sub-Ballast, multiply by a factor Ca = 1.2 for 50-yr storm, 3.5x1.2 = 4.2)
(4) Underdrain design storm: 50-year; use Rainfall Intensity-Duration-Frequency Curves for Boston, MA. Offsite existing pipe uses 10-year storm.
(5) Nominal Pipe Diameter based on calculated pipe diameter and commonly available pipe sizes

## 50-Year Storm Analysis

| From Sta. | To Sta. | Length (ft.) | Average Width (ft.) | Area (sf) | Drainage Area (ac) | C - factor | Tc (min.) | Intensity (in./hr.) | CA | Qpeak (cfs) | Qpeak Total (cfs) | Slope | n-factor | Diam. (ft.) | Diam. (in.) | Nominal Diam. (in.) | Qfull (cfs) | Q/Qfull |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2741+00 | 2742+40 | 140 | 13.5 | 1,890 | 0.043 | 0.42 | 5.00 | 5.40 | 0.02 | 0.10 | | 0.0110 | 0.011 | 0.24 | 2.87 | 12 | 4.43 | 0.02 |
| 2736+00 | 2742+40 | 640 | 13.5 | 8,640 | 0.198 | 0.42 | 5.00 | 5.40 | 0.08 | 0.45 | | 0.0090 | 0.011 | 0.44 | 5.27 | 12 | 4.00 | 0.11 |
| DMH 64 | DMH 63 | | | | | | | | | | 0.55 | 0.0200 | 0.011 | 0.41 | 4.89 | 12 | 5.97 | 0.09 |
| South of Tarkiln Hill Rd | | | | | | | | | | | | | | | | | | |
| East side: Existing 24" RCP, computed by Mannings formula; flowing full | | | | | | | | | | 7.15 | | 0.0010 | 0.013 | 1.99 | 23.91 | 24 | 7.17 | 1.00 |
| DMH 63 | DMH 138 | | | | | | | | | | 7.70 | | | | | | | |
| DMH 138 | DMH 149 | 52 | | | | | | | | 7.70 | | 0.0020 | 0.013 | 1.80 | 21.59 | 24 | 10.14 | 0.76 |
| DMH 149 | DMH 150 | 39 | | | | | | | | 7.70 | | 0.0020 | 0.013 | 1.80 | 21.59 | 24 | 10.14 | 0.76 |
| 2743+55 | 2746+45 | 286 | | | | | | | | 7.70 | | 0.0010 | 0.013 | 2.05 | 24.58 | 30 | 13.00 | 0.59 |
| 2746+45 | 2749+50 | 299 | | | | | | | | 7.70 | | 0.0010 | 0.013 | 2.05 | 24.58 | 30 | 13.00 | 0.59 |
| off site, west, 12" SD | 2749+50 | | | | | | | | | 5.00 | | | | | | | | |
| 2749+50 | 2752+05 | 253 | | | | | | | | | 12.70 | 0.0010 | 0.013 | 2.47 | 29.66 | 30 | 13.00 | 0.98 |
| off site,east, 12" SD | 2752+05 | | | | | | | | | 2.50 | | | | | | | | |
| 2752+05 | 2754+50 | 240 | | | | | | | | | 15.20 | 0.0010 | 0.013 | 2.64 | 31.73 | 36 | 21.14 | 0.72 |
| 2754+50 | 2756+05 | 152 | | | | | | | | 17.70 | | 0.0010 | 0.013 | 2.80 | 33.59 | 36 | 21.14 | 0.84 |
| 2756+05 | 2759+05 | 300 | | | | | | | | 17.70 | | 0.0010 | 0.013 | 2.80 | 33.59 | 36 | 21.14 | 0.84 |
| off site, west, 24" SD | 2759+05 | | | | | | | | | 15.00 | | | | | | | | |
| 2759+05 | 2761+85 | 269 | | | | | | | | | 32.70 | 0.0010 | 0.013 | 3.52 | 42.29 | 48 | 45.52 | 0.72 |
| 2761+80 | 2764+60 | 272 | | | | | | | | 32.70 | | 0.0010 | 0.013 | 3.52 | 42.29 | 48 | 45.52 | 0.72 |
| 2702+75 | 2707+81 | 295 | 13.5 | 3,983 | 0.091 | 0.42 | 5.00 | 6.60 | 0.04 | 0.25 | | 0.0020 | 0.011 | 0.47 | 5.64 | 12 | 1.89 | 0.13 |
| offsite 2702+00 to 2707+00 RT | | | | 43,325 | 0.995 | 0.25 | 15.00 | 4.80 | 0.25 | 1.19 | | 0.0020 | 0.013 | 0.89 | 10.73 | 12 | 1.60 | 0.75 |
| 2702+00 | 2707+00 | 295 | 13.5 | 3,983 | 0.091 | 0.42 | 5.00 | 6.60 | 0.04 | 0.25 | 1.45 | 0.0020 | 0.011 | 0.90 | 10.83 | 12 | 1.89 | 0.77 |
| **UD LEFT** | | | | | | | | | | | | | | | | | | |
| 2743+50 | 2745+00 | 146 | 10 | 1,460 | 0.034 | 0.42 | 5.00 | 6.60 | 0.01 | 0.09 | | 0.0050 | 0.011 | 0.27 | 3.26 | 12 | 2.98 | 0.03 |
| 2745+00 | 2747+71 | 267 | 10 | 2,670 | 0.061 | 0.42 | 5.00 | 6.60 | 0.03 | 0.17 | 0.26 | 0.0020 | 0.011 | 0.48 | 5.71 | 12 | 1.89 | 0.14 |
| 2747+71 | 2749+67 | 192 | 10 | 1,920 | 0.044 | 0.42 | 5.00 | 6.60 | 0.02 | 0.12 | 0.39 | 0.0080 | 0.011 | 0.42 | 5.08 | 12 | 3.77 | 0.10 |
| 2749+67 | 2752+63 | 294 | 20 | 5,880 | 0.135 | 0.42 | 5.00 | 6.60 | 0.06 | 0.37 | 0.76 | 0.0010 | 0.011 | 0.81 | 9.69 | 12 | 1.33 | 0.57 |
| 2752+63 | 2755+62 | 295 | 20 | 5,900 | 0.135 | 0.42 | 5.00 | 6.60 | 0.06 | 0.38 | 1.13 | 0.0030 | 0.011 | 0.76 | 9.17 | 12 | 2.31 | 0.49 |
| 2755+62 | 2758+55 | 287 | 20 | 5,740 | 0.132 | 0.42 | 5.00 | 6.60 | 0.06 | 0.37 | 1.50 | 0.0040 | 0.011 | 0.80 | 9.64 | 12 | 2.67 | 0.56 |
| 2758+55 | 2761+30 | 271 | 20 | 5,420 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 1.84 | 0.0040 | 0.011 | 0.87 | 10.42 | 12 | 2.67 | 0.69 |
| 2761+30 | 2764+05 | 271 | 20 | 5,420 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 2.19 | 0.0040 | 0.011 | 0.93 | 11.11 | 12 | 2.67 | 0.82 |
| 2764+05 | 2766+78 | 271 | 20 | 5,420 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 2.53 | 0.0018 | 0.011 | 1.14 | 13.64 | 15 | 3.25 | 0.78 |
| 2766+78 | 2769+55 | 271 | 20 | 5,420 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 2.88 | 0.0044 | 0.011 | 1.01 | 12.10 | 15 | 5.07 | 0.57 |
| 2769+55 | 2772+30 | 271 | 20 | 5,420 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 3.22 | 0.0062 | 0.011 | 0.99 | 11.83 | 15 | 6.02 | 0.54 |
| 2772+30 | 2775+05 | 271 | 20 | 5,420 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 3.57 | 0.0060 | 0.011 | 1.03 | 12.37 | 15 | 5.93 | 0.60 |
| 2775+05 | 2777+78 | 271 | 20 | 5,420 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 3.91 | 0.0062 | 0.011 | 1.06 | 12.73 | 15 | 6.02 | 0.65 |
| 2777+78 | 2780+55 | 271 | 20 | 5,420 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 4.26 | 0.0062 | 0.011 | 1.09 | 13.14 | 15 | 6.02 | 0.71 |
| 2780+55 | under track | 35 | | 473 | 0.011 | | | | | 4.26 | | 0.0039 | 0.011 | 1.19 | 14.33 | 18 | 7.77 | 0.55 |
| 2780+58 | 2784+38 | 380 | 28 | 10,640 | 0.244 | 0.49 | 5.00 | 6.60 | 0.12 | 0.79 | | 0.0077 | 0.011 | 0.56 | 6.71 | 12 | 3.70 | 0.21 |
| 2784+38 | 2787+34 | 296 | 26 | 7,696 | 0.177 | 0.42 | 5.00 | 6.60 | 0.07 | 0.49 | 1.28 | 0.0081 | 0.011 | 0.66 | 7.96 | 12 | 3.80 | 0.34 |
| 2787+34 | 2790+32 | 298 | 26 | 7,748 | 0.178 | 0.42 | 5.00 | 6.60 | 0.07 | 0.49 | 1.77 | 0.0077 | 0.011 | 0.76 | 9.08 | 12 | 3.70 | 0.48 |
| 2790+32 | 2793+32 | 300 | 26 | 7,800 | 0.179 | 0.42 | 5.00 | 6.60 | 0.08 | 0.50 | 2.27 | 0.0054 | 0.011 | 0.89 | 10.65 | 12 | 3.10 | 0.73 |
| 2793+32 | 2796+28 | 296 | 36 | 10,656 | 0.245 | 0.50 | 5.00 | 6.60 | 0.12 | 0.81 | 3.08 | 0.0027 | 0.011 | 1.13 | 13.59 | 18 | 6.46 | 0.48 |
| 2796+28 | 2799+26 | 298 | 100 | 29,800 | 0.684 | 0.59 | 5.00 | 6.60 | 0.40 | 2.66 | 5.74 | 0.0024 | 0.011 | 1.46 | 17.55 | 18 | 6.09 | 0.94 |
| 2799+26 | 2802+22 | 296 | 100 | 29,600 | 0.680 | 0.59 | 5.00 | 6.60 | 0.40 | 2.65 | 8.39 | 0.0025 | 0.011 | 1.67 | 20.08 | 24 | 13.40 | 0.63 |
| 2802+22 | 2805+30 | 308 | 50 | 15,400 | 0.354 | 0.54 | 5.00 | 6.60 | 0.19 | 1.26 | 9.65 | 0.0027 | 0.011 | 1.74 | 20.86 | 24 | 13.92 | 0.69 |
| 2813+73 | 2811+06 | 267 | 45 | 12,015 | 0.276 | 0.42 | 5.00 | 6.60 | 0.12 | 0.76 | | 0.0020 | 0.011 | 0.71 | 8.53 | 12 | 1.89 | 0.41 |
| 2811+06 | 2808+05 | 301 | 30 | 9,030 | 0.207 | 0.42 | 5.00 | 6.60 | 0.09 | 0.57 | 1.34 | 0.0020 | 0.011 | 0.88 | 10.52 | 12 | 1.89 | 0.71 |
| 2808+05 | 2805+30 | 275 | 30 | 8,250 | 0.189 | 0.42 | 5.00 | 6.60 | 0.08 | 0.53 | 1.86 | 0.0070 | 0.011 | 0.78 | 9.42 | 12 | 3.53 | 0.53 |
| **UD RIGHT** | | | | | | | | | | | | | | | | | | |
| 2743+60 | 2745+50 | 185 | 19 | 3,423 | 0.079 | 0.42 | 5.00 | 6.60 | 0.03 | 0.22 | | 0.0026 | 0.011 | 0.42 | 5.07 | 12 | 2.15 | 0.10 |
| 2745+50 | 2747+71 | 217 | 25 | 5,425 | 0.125 | 0.42 | 5.00 | 6.60 | 0.05 | 0.35 | 0.56 | 0.0045 | 0.011 | 0.45 | 5.44 | 12 | 2.83 | 0.20 |
| 2747+71 | 2749+67 | 192 | 25 | 4,800 | 0.110 | 0.42 | 5.00 | 6.60 | 0.05 | 0.31 | 0.87 | 0.0024 | 0.011 | 0.72 | 8.65 | 12 | 2.07 | 0.42 |
| 2749+67 | 2751+45 | 175 | 25 | 4,375 | 0.100 | 0.42 | 5.00 | 6.60 | 0.04 | 0.28 | 1.15 | 0.0004 | 0.011 | 1.12 | 13.43 | 15 | 1.53 | 0.75 |
| 2751+45 | 2753+20 | 171 | 36 | 6,156 | 0.141 | 0.42 | 5.00 | 6.60 | 0.06 | 0.39 | 1.54 | 0.0021 | 0.011 | 0.92 | 10.99 | 15 | 3.51 | 0.44 |
| 2753+20 | 2755+90 | 266 | 10 | 2,660 | 0.061 | 0.42 | 5.00 | 6.60 | 0.03 | 0.17 | 1.71 | 0.0017 | 0.011 | 0.99 | 11.89 | 15 | 3.15 | 0.54 |
| 2755+90 | 2758+60 | 266 | 8 | 2,128 | 0.049 | 0.42 | 5.00 | 6.60 | 0.02 | 0.14 | 1.84 | 0.0014 | 0.011 | 1.06 | 12.68 | 15 | 2.86 | 0.64 |
| 2758+60 | 2761+30 | 266 | 8 | 2,128 | 0.049 | 0.42 | 5.00 | 6.60 | 0.02 | 0.14 | 1.98 | 0.0010 | 0.011 | 1.16 | 13.87 | 15 | 2.42 | 0.82 |
| 2761+30 | 2764+65 | 330 | 8 | 2,640 | 0.061 | 0.42 | 5.00 | 6.60 | 0.03 | 0.17 | 2.15 | 0.0010 | 0.011 | 1.19 | 14.30 | 15 | 2.42 | 0.89 |
| 2764+65 | DMH 190 | 17 | | | | | | | | 2.15 | | 0.0050 | 0.011 | 0.88 | 10.58 | 18 | 8.80 | 0.24 |
| | | | | | | | | | | | | | | | | 18" under track | | |
| 2755+00 | 2756+00 | 100 | 18.5 | 1,850 | 0.042 | 0.42 | 5.00 | 6.60 | 0.02 | 0.12 | | 0.0040 | 0.011 | 0.31 | 3.71 | 12 | 2.67 | 0.04 |
| 2756+00 | DMH 252 | | | | | | | | | 0.12 | | 0.0040 | 0.011 | 0.31 | 3.71 | 12 | 2.67 | 0.04 |
| DMH 252 | 2758+92 | 293 | 18.5 | 5,421 | 0.124 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 0.46 | 0.0030 | 0.011 | 0.55 | 6.55 | 12 | 2.31 | 0.20 |
| 2758+92 | 2761+82 | 290 | 18.5 | 5,365 | 0.123 | 0.42 | 5.00 | 6.60 | 0.05 | 0.34 | 0.80 | 0.0030 | 0.011 | 0.67 | 8.06 | 12 | 2.31 | 0.35 |
| 2761+82 | 2762+30 | 48 | 18.5 | 888 | 0.020 | 0.42 | 5.00 | 6.60 | 0.01 | 0.06 | 0.86 | 0.0020 | 0.011 | 0.74 | 8.92 | 12 | 1.89 | 0.46 |
| 2762+30 | 2763+71 | 137 | 18.5 | 2,535 | 0.058 | 0.42 | 5.00 | 6.60 | 0.02 | 0.16 | 1.02 | 0.0030 | 0.011 | 0.73 | 8.81 | 12 | 2.31 | 0.44 |
| 2763+71 | DMH 251 | 63 | | | | | | | | 1.02 | | 0.0030 | 0.011 | 0.73 | 8.81 | 12 | 2.31 | 0.44 |
| DMH 251 | DMH 190 | | | | | | | | | 1.02 | | 0.0070 | 0.011 | 0.63 | 7.52 | 12 | 3.53 | 0.29 |
| DMH 190 | ditch | | | | | | | | | | 35.87 | 0.0055 | 0.013 | 2.65 | 31.80 | 48 | 106.76 | 0.34 |

Note:
1. The Nominal Diameter represents the piping out of the drainage structure in the "To" column.

# PIPE OUTLET END PROTECTION

| For: | SCR | Sheet No. | 1 of 1 |
|---|---|---|---|
| Made by: | thl | Cked by: | anc |
| Date: | 5/30/18 | Date: | 5/30/18 |

**PIPE OUTLET END PROTECTION**

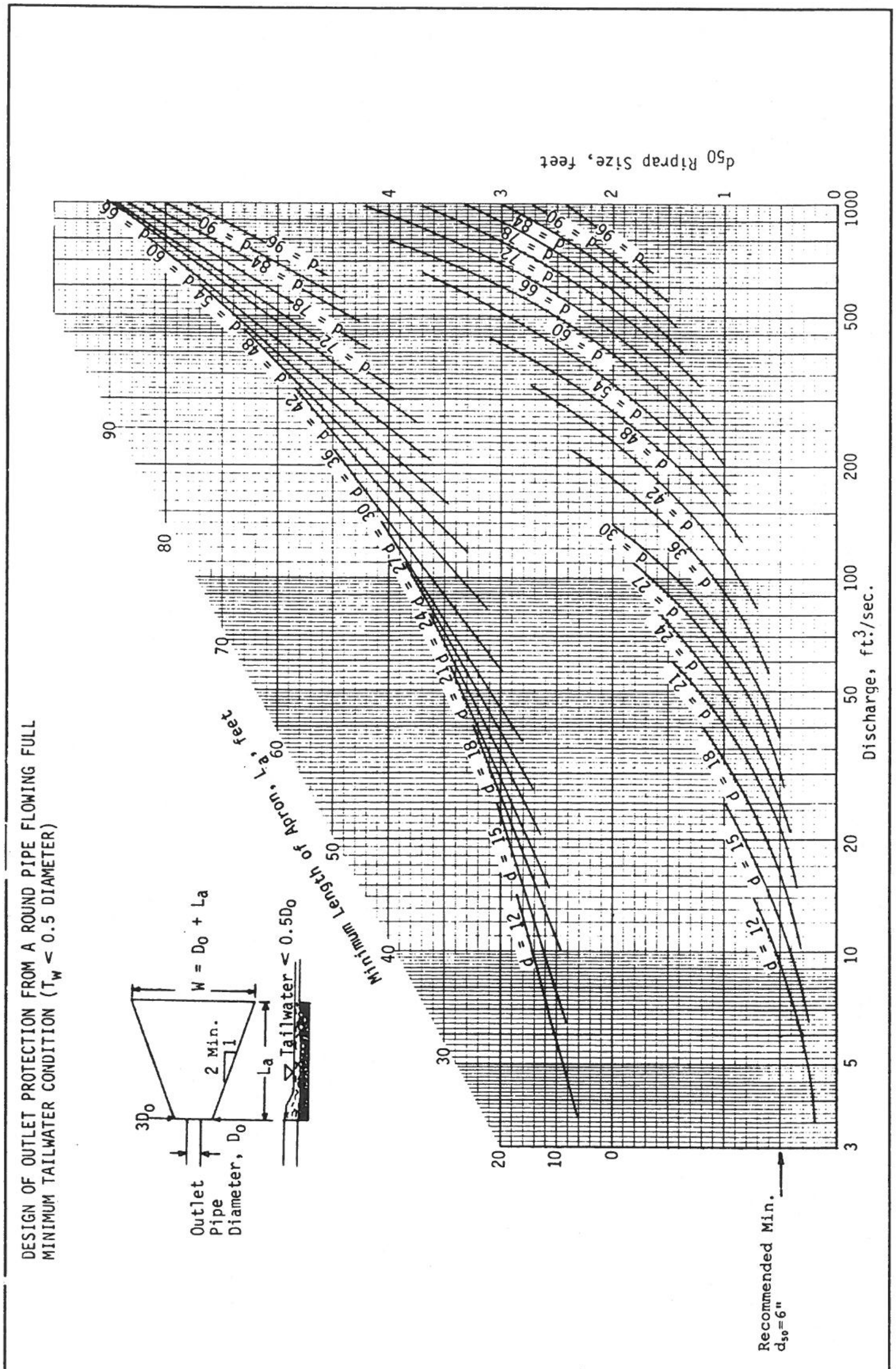
| | Pipe End Location | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2551+00 LT | 2568+85 LT | 2673+70 LT | 2693+30 LT | 2740+70 LT | 2702+00 RT | 2765+00 RT | 2780+55 RT |
| Pipe Diameter (D), in | 12 | 12 | 12 | 12 | 12 | 24 | 48 | 18 |
| Defined channel | no | no | no | no | no | yes | yes | no |
| Tail Water (Tw), ft | < 1/2 dia. | < 1/2 dia. | < 1/2 dia. | < 1/2 dia. | < 1/2 dia. | < 1/2 dia. | < 1/2 dia. | < 1/2 dia. |
| Flow (Q), cfs | 0.65 | 0.46 | 0.80 | 0.76 | 1.85 | 1.45 | 36 | 2.64 |
| Apron Width at Outlet | 3 | 3 | 3 | 3 | 3 | width of channel | width of channel | 4.5 |
| Apron Length, ft | 6 | 6 | 6 | 6 | 6 | 14 | 26 | 14 |
| Apron Width at End | 7 | 7 | 7 | 7 | 7 | width of channel | width of channel | 15.5 |
| Median Stone Dia., ft | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 | 0.5 |
| Median Stone Dia., in | 6 | 6 | 6 | 6 | 6 | 6 | 12 | 6 |
| Largest Stone Dia., ft | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 1.5 | 0.75 |
| Largest Stone Dia., in | 9 | 9 | 9 | 9 | 9 | 9 | 18 | 9 |
| Apron Depth, ft | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 2.25 | 1.13 |
| Apron Depth, in | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 27 | 13.5 |

Note: all dimensions in feet.

| | | | |
|---|---|---|---|
| Apron Width at Outlet | = | 3x pipe dia. or width of channel | |
| Apron Length | = | From Virginia DCR Handbook - Plate 3, 18-3 | if Tw depth is < 1/2 dia. |
| | = | From Virginia DCR Handbook - Plate 3, 18-4 | if Tw depth is >= 1/2 dia. |
| Apron Width at End | = | dia. + apron length | if Tw depth is < 1/2 dia. |
| | = | dia. + 0.4 x apron length | if Tw depth is >= 1/2 dia. |
| Rock Riprap | | | |
| Median Dia. (d50) | = | From Virginia DCR Handbook - Plate 3, 18-3 or 4 | |
| Largest stone dia | = | 6" or 1.5 x largest stone dia. | |
| Apron Depth, ft | = | 6" or 1.5 x largest stone dia. | |

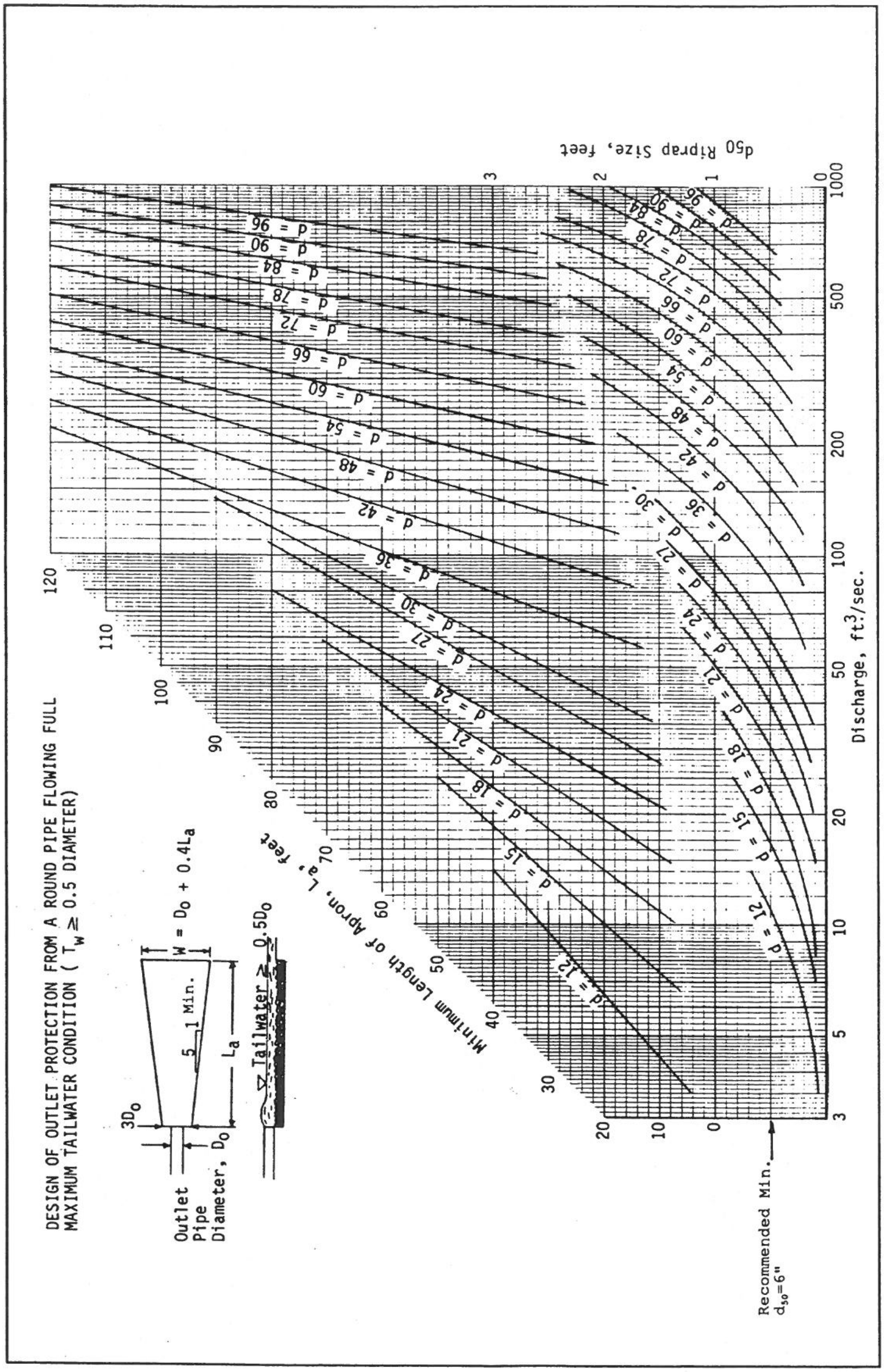
| Pipe End Protection | | | | |
|---|---|---|---|---|
| FES Station | X | Y | Z | Stone Diam. ($D_{50}$) |
| 2551+00 LT | 6 | 7 | 1.13 | 0.5 |
| 2568+85 LT | 6 | 7 | 1.13 | 0.5 |
| 2673+70 LT | 6 | 7 | 1.13 | 0.5 |
| 2693+30 LT | 6 | 7 | 1.13 | 0.5 |
| 2740+70 LT | 6 | 7 | 1.13 | 0.5 |
| 2702+00 RT | 14 | 6 (width of channel) | 1.13 | 0.5 |
| 2765+00 RT | 26 | 6 (width of channel) | 2.25 | 1.0 |
| 2780+55 RT | 14 | 15.5 | 1.13 | 0.5 |

Note: all dimensions in feet.




Source: USDA-SCS

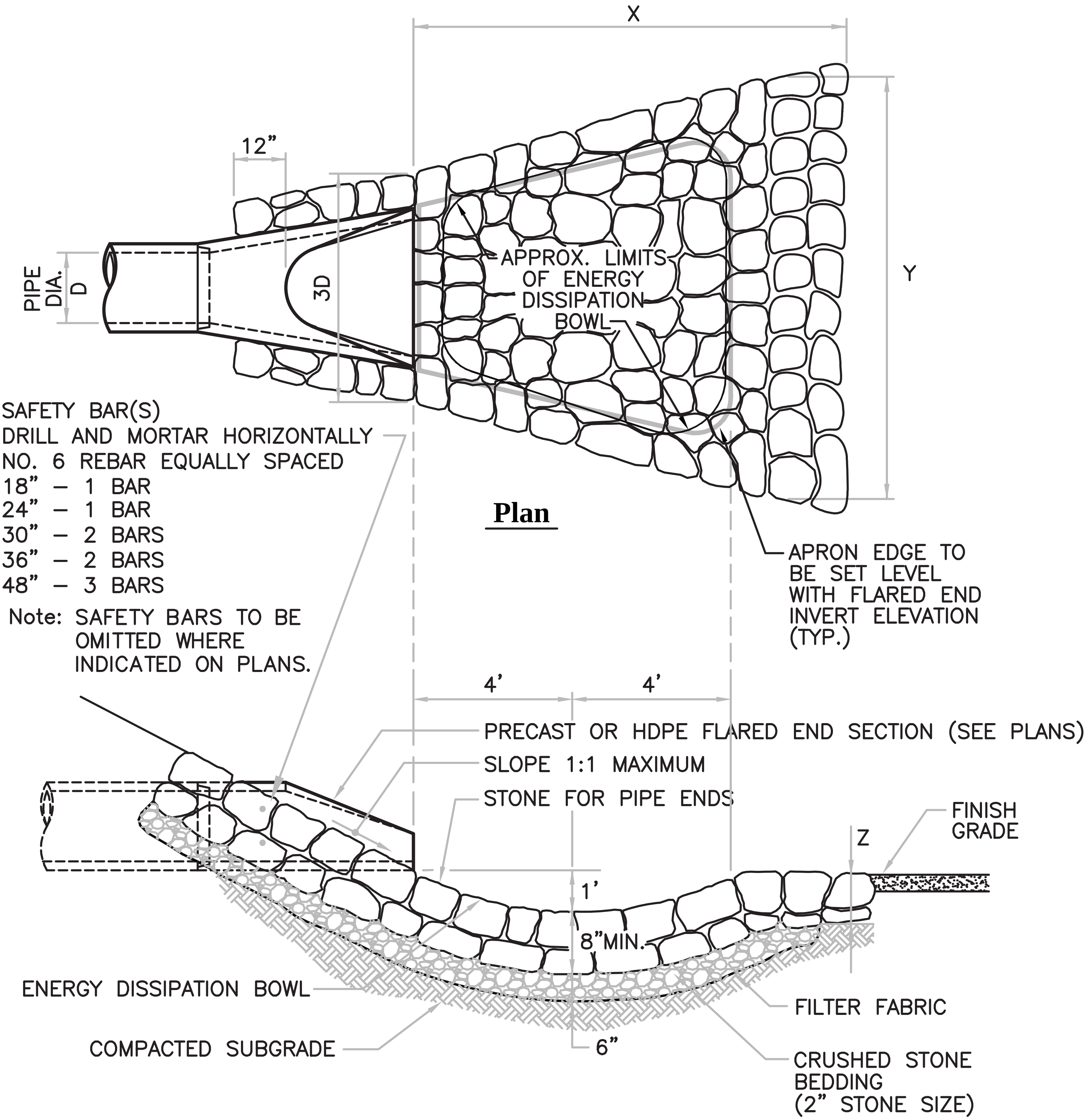
Plate 3.18-3




Source: USDA-SCS

Plate 3.18-4

| X | Y | Z | STONE DIA. ($D_{50}$) |
|---|---|---|---|
| 6' | 7' | 1.13' | 0.5' |




FLARED END SECTION WITH STONE PROTECTION

# VEGETATED SWALE DISCHARGE

# END PROTECTION

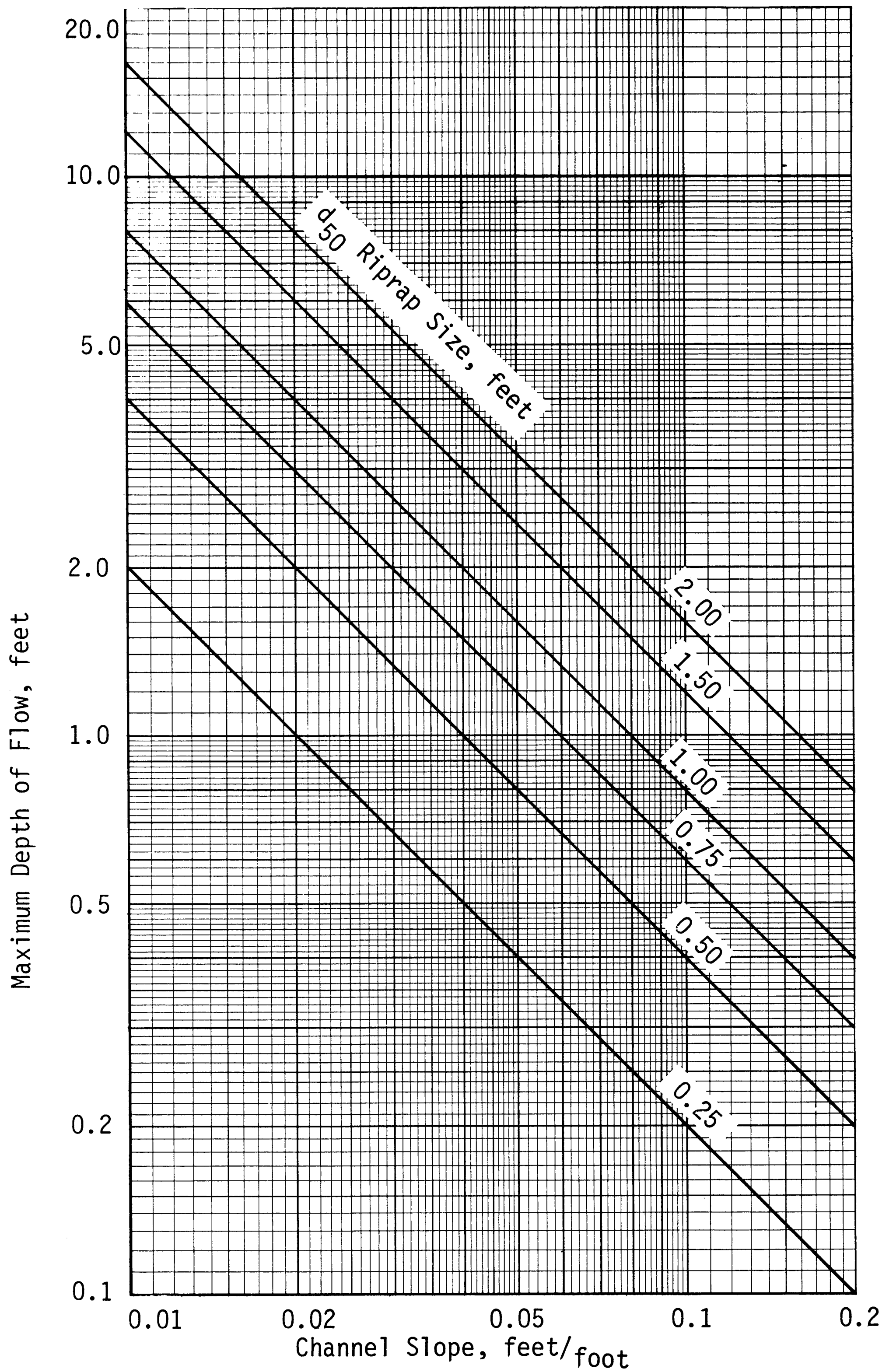
| For: | SCR | Sheet No. | 1 of 1 |
|---|---|---|---|
| Made by: | thl | Cked by: | anc |
| Date: | 5/30/18 | Date: | 5/30/18 |

**VEGETATED SWALE END PROTECTION**

| Vegetated Swale | | | | | |
|---|---|---|---|---|---|
| Begin | End | Length | Bottom Elev. | | Slope |
| 2589+90 | 2618+50 | 2,860 | 79.7 | 72.7 | 0.0025 |
| 2625+00 | 2635+50 | 1,050 | 70.9 | 70.1 | 0.0008 |
| 2589+85 | 2605+05 | 1,520 | 79.7 | 76.1 | 0.0024 |
| 2673+50 | 2669+85 | 365 | 74.2 | 72.2 | 0.0055 |

| Swale End Protection | | | | |
|---|---|---|---|---|
| Station | X | Y | Z | Stone Diam. ($D_{50}$) |
| 2618+50 LT | 8 | 10 | 1.13 | 0.5 |
| 2635+50 LT | 8 | 10 | 1.13 | 0.5 |
| 2605+05 RT | 8 | 10 | 1.13 | 0.5 |
| 2669+85 RT | 8 | 10 | 1.13 | 0.5 |

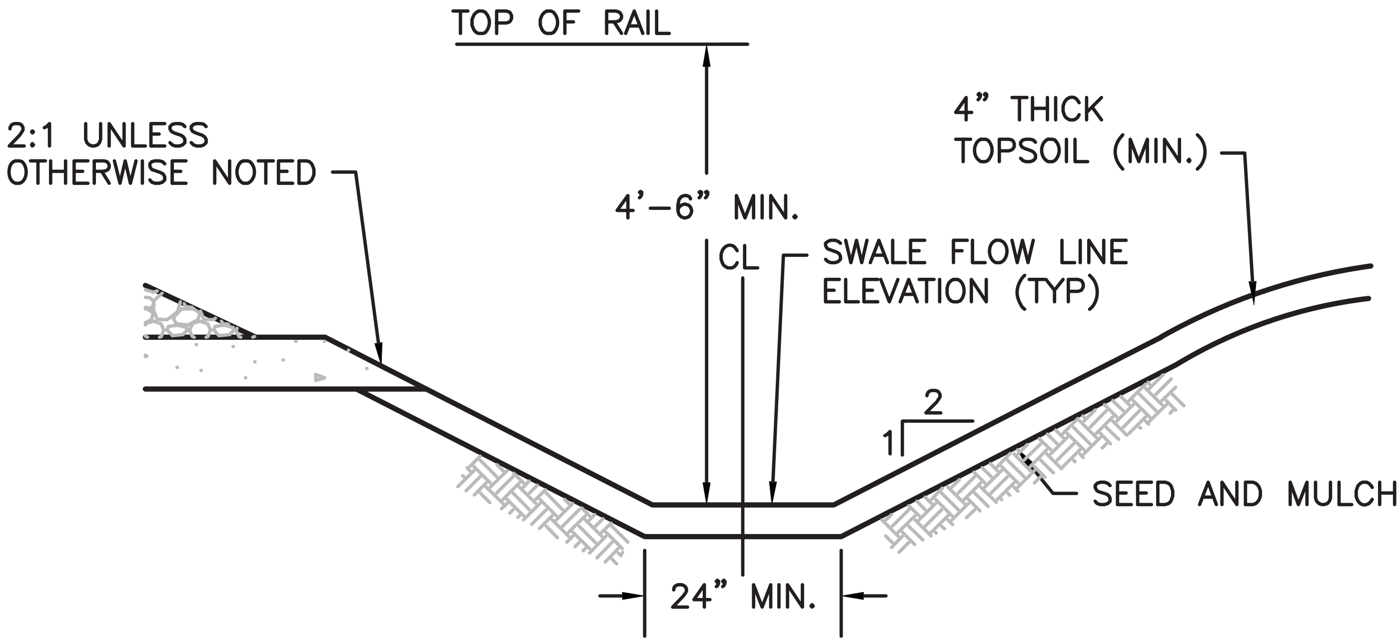
Note: all dimensions in feet.




MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

Source: VDOT Drainage Manual

Plate 3.19-3




Section - VEGETATED SWALE