HYDRAULIC REPORT

Highland Road Culvert Replacement
Boxford, Massachusetts

November 17, 2016

Prepared for:

Town of Boxford
Department of Public Works
7B Spofford Road
Boxford, MA 01921

Prepared by:

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TABLE OF CONTENTS

1. PROJECT DESCRIPTION

A. Introduction

The following is a detailed report of the proposed culvert replacement project located on Highland Road in Boxford, MA. The purpose of the report is to 1) provide a description of the proposed project and its design alternatives, and 2) analyze the hydraulic impacts on the local drainage condition.

This report has been prepared to accompany the Massachusetts Department of Environmental Protection (MASS DEP) Notice of Intent (NOI) in accordance with the requirements of the Massachusetts Wetlands Protection Act and the Town of Boxford Wetland Protection By-Laws/Regulations.

B. Existing Condition

The project site is an existing 12" CMP culvert located on Highland Road in Boxford, MA approximately 1,000 feet northeast of the Ipswich Road/Highland Road intersection. Highway Road is an approximately 4,000 linear foot roadway that is located within a rural, residential neighborhood. An intermittent stream flows in a southerly direction towards Highland Road, through the existing culvert, and then into a large, wetland system to the southeast. The existing culvert is located on two private properties along with the Highland Road right-of-way. The upstream portion of the culvert is located on the 20 Highland Road property (Tax Map 14, Block 1, Lot 17). The downstream portion of the culvert is located on the 17 Highland Road property (Tax Map 14, Block 2, Lot 19).

The drainage area to this culvert is located north of Highland Road and measures approximately 28.5 acres (see Figure 3). The majority of this area is undeveloped land but also includes a portion of Highland Road and a few single-family residences. The drainage area generally slopes in a south-southwest direction from Shaven Crown Hill towards Highland Road. The topography is relatively steep down from Shaven Crown Hill to the Highland Road culvert with about 140 feet of elevation change.

According to the Natural Resources Conservation Service (NRCS) Soil Map, on-site soils consist of a range of excessively well-drained soils (253-Hinckley, 254-Merrimac, 406-Charlton, 710-Canton/Charlton), moderately-drained soils (260-Sudbury), and poorly-drained soils (311-Woodbridge). The intermittent stream and associated wetlands were delineated by the project wetland scientist (Wetland Consulting Services of Merrimac, MA) and are shown on the construction plans prepared by this office.

C. Culvert Replacement Standards

Per 310 CMR 10.54(8) of the Massachusetts Wetlands Protection Act Regulation:

At a minimum, in evaluating the potential to comply with the standards to the maximum extent practicable, the applicant shall consider site constraints in meeting the standard, undesirable effects of risk in meeting the standard and the environmental benefit of meeting the standard compared to the cost by evaluating the following:

- *The potential for downstream flooding;*
- *Upstream and downstream habitat (in-stream habitat, wetlands);*
- *Potential for erosion and head-cutting;*
- *Stream stability;*
- *Habitat fragmentation caused by the crossing;*
- *The amount of stream mileage made accessible by the improvements;*
- *Storm flow conveyance;*
- *Engineering design constraints specific to the crossing;*
- *Hydrologic constraints specific to the crossing;*
- *Impacts to wetlands that would occur by improving the crossing;*
- *Potential to affect property and infrastructure; and*
- *Cost of replacement.*

D. Proposed Culvert Replacement

The Town of Boxford has been making a continued effort to replace undersized and/or deficient roadway culverts in order to avoid more serious roadway damage and flooding during large storm events. The proposed project involves removing the existing 12" CMP culvert and replacing it with a new 5'x3' pipe arch and headwalls. A portion of

Highland Road will be removed and reconstructed along with re-grading the adjacent side slopes to comply with AASHTO roadside standards. The project will impact approximately 645 square feet of wetland area. In order to mitigate this impact, it is proposed to create approximately 971 square feet of new wetland on the upstream side of the project.

E. Design Alternatives

The following design alternatives were evaluated as part of this project:

1. Replace existing 12" culvert with 18" CMP culvert
2. Replace existing 12" culvert with 5'x3' pipe arch (with stream embedment)
3. Replace existing 12" culvert with 8'x8' box culvert (with stream embedment)

This evaluation included the following site-specific criterion:

- Existing site conditions
- Hydraulic capacity of culvert
- Downstream flooding impacts
- Maximum culvert openness factor
- Wetland/wetland buffer impacts
- Construction costs (See Appendix E)

Based on the above criterion, it is our opinion that the most practicable option is to replace the existing culvert with a 5'x3' pipe arch (Option #2). This option will improve the stability and public safety aspects of the culvert and roadway, while decreasing the possibility of the flooding upstream residences during large storm events. This option provides the Town of Boxford a good balance between increasing wildlife connectively, mitigating impacts to wetland areas and working within the financial limitations of the associated construction costs.

2. HYDRAULIC ANALYSIS

A. Methodology

In accordance with the Town of Boxford and MassDEP requirements, the 2-year, 10-year, 25-year and 100-year 24-hour storm frequencies were evaluated. Evaluation of the quantitative runoff impacts of the proposed culvert replacement project were determined by comparing the post-construction flows with the existing flows for the site.

The drainage area to the existing culvert was determined using USGS topographic maps for this area. Total drainage area calculations for existing conditions and post-construction conditions were evaluated and designed using the HydroCAD® version 10.0 stormwater modeling program for the Soil Conservation Service (SCS) type III storm distribution. Values for time of concentration used in the analysis were calculated using the methodology contained within U.S.D.A-S.C.S. publication Urban Hydrology for Small Watersheds Technical Release No. 55 (TR55).

B. Existing Drainage Conditions

As can be seen on the Drainage Area Map (Figure 3), the drainage area to the existing 12" culvert is approximately 28.5 acres located north of Highland Road. Runoff drains in a south-southwest direction where it enters an intermittent stream. The stream flows through the existing culvert and continues in a southeasterly direction where it eventually enters into a large wetland system associated with Spofford Pond. The analysis includes the upstream storage capacity to accurately model the detention volumes and flooding limits during large storm events. The summation of peak flows and volumes exiting the culvert and flowing to the downstream wetland will be analyzed as the **Point of Analysis (POA).**

Table 1 below illustrates the characteristics of the existing 12" culvert and adjacent storage areas during the existing drainage condition. The existing drainage calculations estimating peak rates of runoff and volumes to the points of analysis are shown in Appendix A of this study and summarized in Table 2 below.

TABLE 1:

CHARACTERISTICS OF 12" CULVERT AND ADJACENT STORAGE AREAS FOR EXISTING DRAINAGE CONDITION

Location	Storm Frequency	Inflow (cfs)	Outflow (cfs)	Upstream Pipe Invert	Highland Road Elev.	Max. Water Surface Elev.
Existing 12" Culvert	2-year	0.47	0.47	91.80	98.5 +/-	92.43
	10-year	6.03	3.19			94.36
	25-year	14.59	4.49			95.88
	100-year	38.96	6.00			98.30

TABLE 1:

SUMMARY OF EXISTING PEAK FLOWS & VOLUMES

Location	Storm Event	Peak Flow Rates (cfs)	Volumes (ac-ft)
Point of Analysis (POA)	2-year	0.47	0.281
	10-year	3.19	1.490
	25-year	4.49	2.922
	100-year	6.00	6.774

C. Post-Construction Drainage Conditions

Similar to the existing condition, the drainage area to the proposed 5'x3' pipe arch is approximately 28.5 acres located north of Highland Road. Runoff drains in a south-southwest direction where it enters an intermittent stream. The stream flows through the existing culvert and continues in a southeasterly direction where it eventually enters into a large wetland system associated with Spofford Pond. The analysis includes the upstream storage capacity to accurately model the detention volumes and flooding limits during large storm events. Due to the wetland mitigation, there is slightly more upstream, storage capacity in the post-construction condition. The summation of peak flows and volumes exiting the culvert and flowing to the downstream wetland will be analyzed as the **Point of Analysis (POA).**

Table 3 below illustrates the characteristics of the proposed 5'x3' pipe arch and adjacent storage areas during the post-construction drainage condition. The post-construction runoff computations are detailed in Appendix B and summarized with comparison to the existing conditions in Table 4 below.

TABLE 3:

CHARACTERISTICS OF 5'X3' PIPE ARCH AND ADJACENT STORAGE AREAS FOR POST-CONSTRUCTION DRAINAGE CONDITION

Location	Storm Frequency	Inflow (cfs)	Outflow (cfs)	Upstream Pipe Invert	Highland Road Elev.	Max. Water Surface Elev.
Proposed 18" Culvert	2-year	0.47	0.47	92.00	98.5 +/-	92.12
	10-year	6.03	6.00			92.65
	25-year	14.59	14.38			93.23
	100-year	38.59	33.11			94.89

TABLE 4:

COMPARISON OF EXISTING AND POST-CONSTRUCTION PEAK FLOWS & VOLUMES

Location	Storm Event	Peak Flow Rates (cfs)		Volumes (ac-ft)	
		'PRE'	'POST'	'PRE'	'POST'
Point of Analysis (POA)	2-year	0.47	0.47	0.281	0.281
	10-year	3.19	6.00	1.490	1.490
	25-year	4.49	14.38	2.922	2.922
	100-year	6.00	33.11	6.774	6.774

Table 5 below shows the hydraulic condition of the design alternatives in comparison to the existing and proposed conditions.

TABLE 5:

COMPARISON OF HYDRAULIC CONDITION UNDER DESIGN ALTERNATIVES

OPTION	CULVERT DESCRIPTION	HYDRAULIC CONDITION							
		2-YR		10-YR		25-YR		100-YR	
		PEAK FLOW	ELEV.	PEAK FLOW	ELEV.	PEAK FLOW	ELEV.	PEAK FLOW	ELEV.
	EXISTING 12" CMP CULVERT	0.47	92.43	3.19	94.36	4.49	95.88	6.00	98.30
1	PROPOSED 18" CMP CULVERT	0.47	92.38	5.35	93.48	9.06	94.86	13.62	97.19
2	PROPOSED 5'X3' PIPE ARCH (W/ STREAM EMBEDMENT)	0.47	92.12	6.00	92.65	14.38	93.23	33.11	94.89
3	PROPOSED 8'X8' BOX CULVERT (W/ STREAM EMBEDMENT)	0.47	92.09	6.02	92.43	14.57	92.77	38.82	93.48

D. Results

1. The analysis shows that the existing 12" culvert can only pass up to and including the 2-year storm event. Larger storm events will cause localized flooding upstream of the culvert.
2. The existing 20 Highland Road single-family residence is located adjacent to the culvert and has a basement grade of EL=95.0 +/-. According to discussions with the home owner, the basement has come close to flooding on numerous occasions during large storm events. The existing conditions analysis agreed with this statement as it shows that this basement would be flooded during a 25-year storm event or greater.
3. The proposed 5'x3' pipe arch has significantly more capacity than the existing 12" culvert; therefore, post-construction peak flows are greater than the existing condition. Due to the size of the existing downstream wetland system associated with Spofford Pond, it is our opinion that this increase will not adversely affect the downstream drainage condition.
4. Replacing the existing 12" culvert with a proposed 5'x3' pipe arch will increase the culvert's carrying capacity and decrease localized flooding upstream. The analysis shows over a 1-foot decrease in the post-construction water elevations compared with the existing condition for the 10, 25 & 100-year storm events.

3. MASS DEP STORMWATER MANAGEMENT STANDARDS

This project is considered a "redevelopment project" Standard 7 of the Massachusetts Department of Environmental Protection's Stormwater Handbook states the following:

"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 stormwater best management practice requirements of Standards 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 #1: Untreated Stormwater

The proposed re-development project does not include any 'new' stormwater conveyances. The project has been designed to do not discharge untreated stormwater to, or cause erosion to, wetlands or waters of the Commonwealth.

Standard #2: Post-Development Peak Discharge Rate

The existing ground cover and overall drainage areas to the subject culvert will not change as a result of this project. The proposed project will not adversely affect the downstream drainage condition. The attached analysis has been provided to compare post-construction peak flows and volumes with the existing condition.

Standard #3: Recharge to Groundwater

The annual groundwater recharge for the post-construction site approximates annual recharge from existing site conditions.

Standard #4: 80% TSS Removal

A long term pollution plan has been provided as part of the Notice of Intent filing. The project will lessen steep slopes on both sides of Highland Road, therefore, reducing the likelihood of erosion and sedimentation within the intermittent stream.

Standard #5: Higher Potential Pollutant Loads

The Project is not considered a Higher Potential Pollutant Load use.

Standard #6: Protection of Critical Areas

This project is not located within a critical area.

Standard #7: Redevelopment Projects

The project is considered a "Redevelopment Project".

Standard #8: Erosion/Sedimentation Control

Erosion and sediment controls are incorporated into the project design plans to prevent erosion, control sediment movement, and stabilize exposed soils.

Standard #9: Operation/Maintenance Plan

An Operation and Maintenance plan for both construction and post-development stormwater controls has been developed.

Standard #10: Prohibition of Illicit Discharges

No illicit discharges are proposed as part of this development.

4. EROSION AND SEDIMENTATION CONTROL PROVISIONS

Erosion control measures are proposed throughout the project, to ensure that the adjacent off-site areas and downstream water resources are protected from erosion/siltation and debris during construction of this project. Said measures include silt fence, straw bale barriers, a dewatering bag and stabilization matting. These devices are shown in greater detail on the complete set of construction plans submitted to the Town of Boxford and MassDEP.

A. Temporary Erosion Control Measures

During the construction phase of the project, specific erosion and sedimentation controls have been developed into the design of the project and details of these items are included in the project plans. The erosion control notes and construction sequence were developed to limit soil loss due to erosion and are therefore directed at minimizing the degradation of water quality on and off the site.

B. Permanent Erosion Control Measures

Permanent erosion control measures have been included in the design of the project to limit long-term erosion conditions. Loam and seed requirements have been specified to establish conditions that minimize erodible conditions. This is complemented by the minimization of stormwater flow lengths to keep runoff quantities and velocities as low as possible. When completed and in place, these permanent measure provide

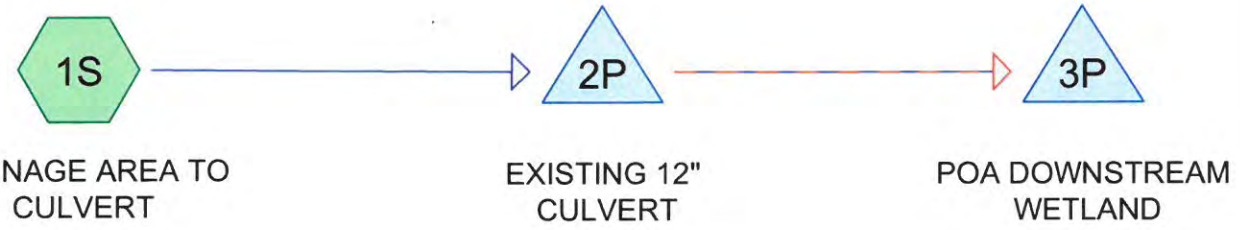
treatment methods that help maintain, long-term water quality in downstream water resources.

C. Control of Water

The work shall be scheduled to occur in the dry season during periods of minimal or no flow in the stream bed. The work shall take into consideration predicted weather conditions during the construction period and shall have a contingency plans for unexpected storm events. The contractor shall be responsible for the control of ground water and stormwater at all times during construction, including maintaining all erosion control devices as needed to prevent sediment from leaving the site and entering wetland resource areas.

APPENDIX A

EXISTING CONDITION DRAINAGE CALCULATIONS



Subcat Reach Pond Link

Routing Diagram for EXISTING CONDITION
Prepared by Hayner/Swanson, Inc., Printed 11/17/16

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
23.410	46	2 acre lots, 12% imp, HSG A (1S)
3.500	65	2 acre lots, 12% imp, HSG B (1S)
1.550	77	2 acre lots, 12% imp, HSG C (1S)
28.460	**50**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
23.410	HSG A	1S
3.500	HSG B	1S
1.550	HSG C	1S
0.000	HSG D	
0.000	Other	
28.460		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
23.410	3.500	1.550	0.000	0.000	28.460	2 acre lots, 12% imp	1S
23.410	**3.500**	**1.550**	**0.000**	**0.000**	**28.460**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	2P	91.80	91.90	36.0	-0.0028	0.025	12.0	0.0	0.0

Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: DRAINAGE AREA TO Runoff Area=28.460 ac 12.00% Impervious Runoff Depth=1.23"
Flow Length=2,115' Slope=0.0660 '/' Tc=50.2 min CN=50 Runoff=14.59 cfs 2.922 af

Pond 2P: EXISTING 12" CULVERT Peak Elev=95.88' Storage=36,171 cf Inflow=14.59 cfs 2.922 af
Primary=4.49 cfs 2.922 af Secondary=0.00 cfs 0.000 af Outflow=4.49 cfs 2.922 af

Pond 3P: POA DOWNSTREAM WETLAND Inflow=4.49 cfs 2.922 af
Primary=4.49 cfs 2.922 af

Total Runoff Area = 28.460 ac Runoff Volume = 2.922 af Average Runoff Depth = 1.23"
88.00% Pervious = 25.045 ac 12.00% Impervious = 3.415 ac

Summary for Subcatchment 1S: DRAINAGE AREA TO CULVERT

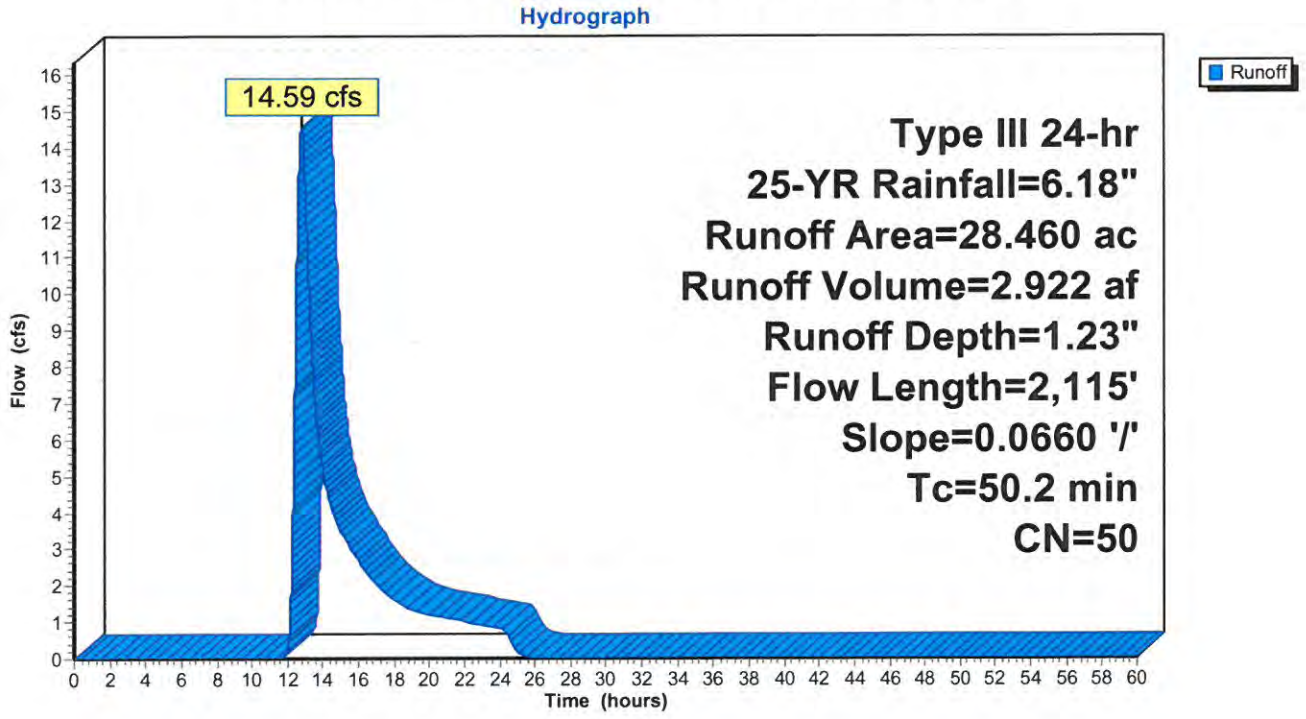
Runoff = 14.59 cfs @ 12.78 hrs, Volume= 2.922 af, Depth= 1.23"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-YR Rainfall=6.18"

Area (ac)	CN	Description
23.410	46	2 acre lots, 12% imp, HSG A
3.500	65	2 acre lots, 12% imp, HSG B
1.550	77	2 acre lots, 12% imp, HSG C
28.460	50	Weighted Average
25.045		88.00% Pervious Area
3.415		12.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
50.2	2,115	0.0660	0.70		**Lag/CN Method,**

Subcatchment 1S: DRAINAGE AREA TO CULVERT



Summary for Pond 2P: EXISTING 12" CULVERT

Inflow Area = 28.460 ac, 12.00% Impervious, Inflow Depth = 1.23" for 25-YR event
Inflow = 14.59 cfs @ 12.78 hrs, Volume= 2.922 af
Outflow = 4.49 cfs @ 14.27 hrs, Volume= 2.922 af, Atten= 69%, Lag= 89.4 min
Primary = 4.49 cfs @ 14.27 hrs, Volume= 2.922 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Peak Elev= 95.88' @ 14.27 hrs Surf.Area= 26,488 sf Storage= 36,171 cf
Flood Elev= 98.50' Surf.Area= 59,265 sf Storage= 148,264 cf

Plug-Flow detention time= 83.5 min calculated for 2.922 af (100% of inflow)
Center-of-Mass det. time= 83.5 min (1,016.0 - 932.6)

Volume	Invert	Avail.Storage	Storage Description
#1	92.00'	179,365 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

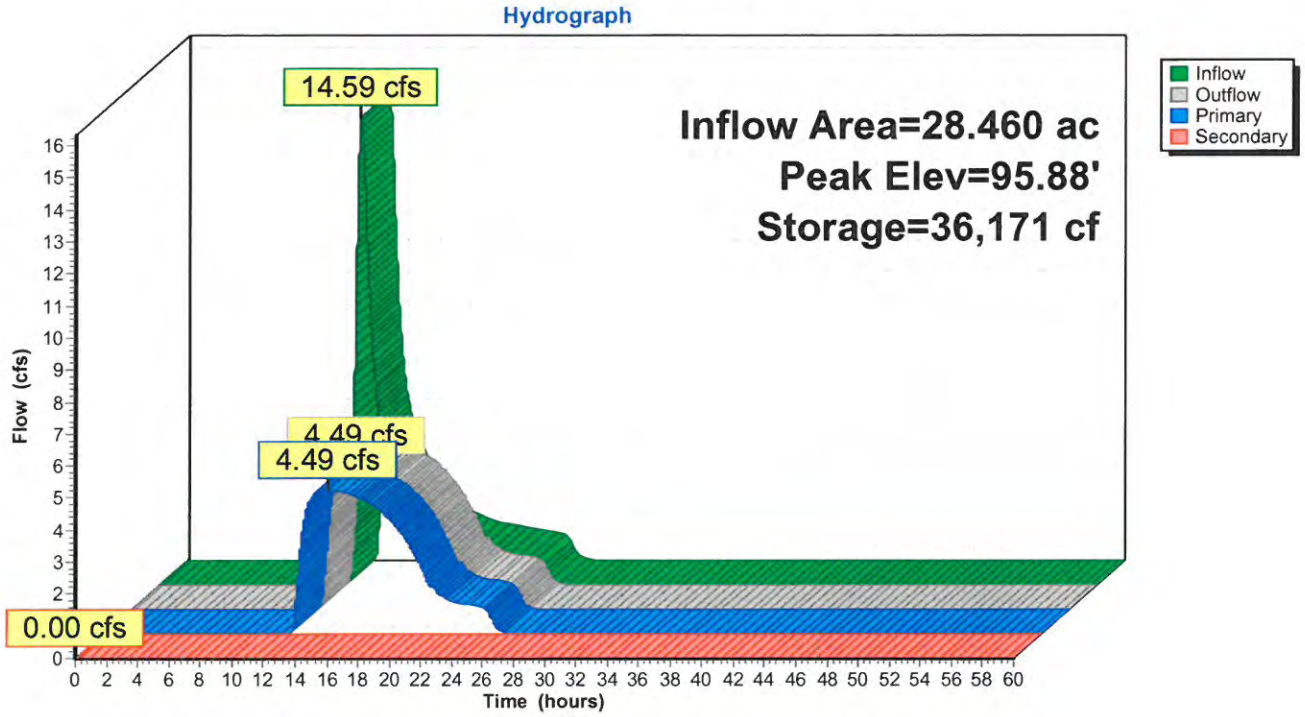
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
92.00	10	0	0
93.00	2,410	1,210	1,210
94.00	7,940	5,175	6,385
95.00	14,960	11,450	17,835
96.00	27,990	21,475	39,310
97.00	40,100	34,045	73,355
98.00	53,390	46,745	120,100
99.00	65,140	59,265	179,365

Device	Routing	Invert	Outlet Devices
#1	Primary	91.90'	**12.0" Round Culvert** L= 36.0' CMP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 91.80' / 91.90' S= -0.0028 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 0.79 sf
#2	Secondary	98.50'	**60.0' long x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=4.49 cfs @ 14.27 hrs HW=95.88' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 4.49 cfs @ 5.72 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=92.00' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 2P: EXISTING 12" CULVERT

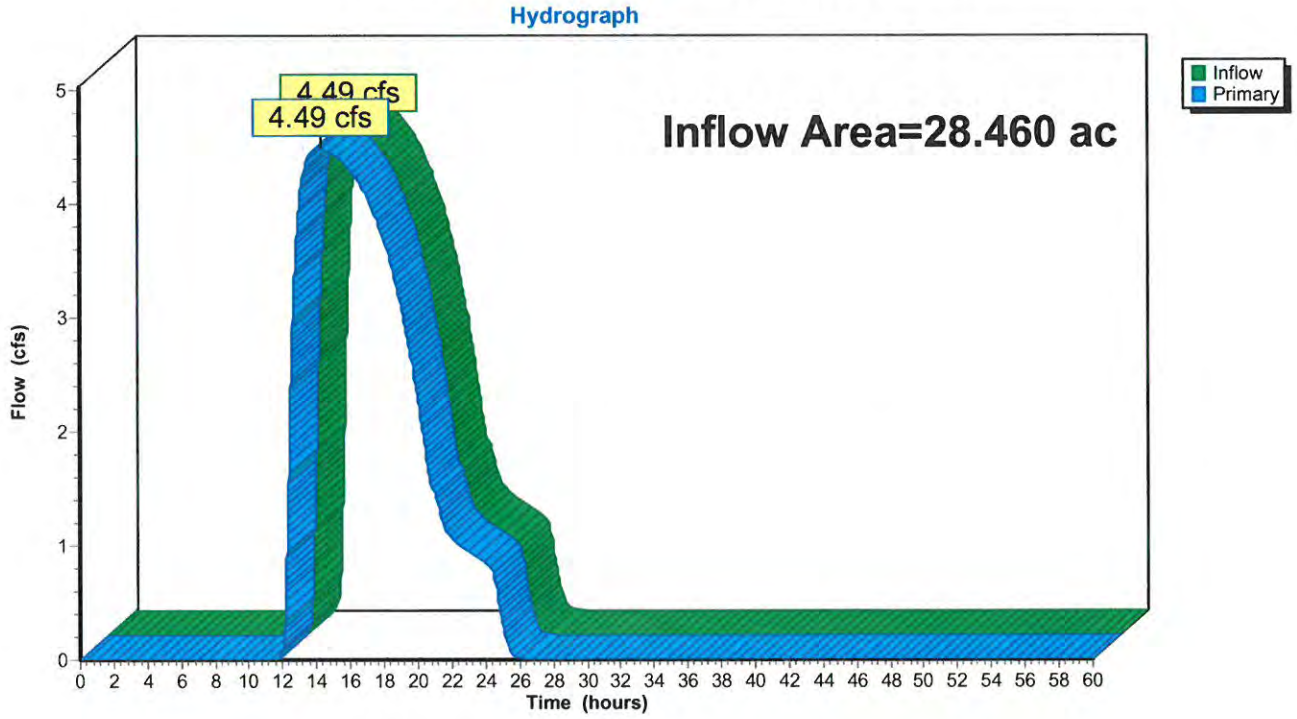


Summary for Pond 3P: POA DOWNSTREAM WETLAND

Inflow Area = 28.460 ac, 12.00% Impervious, Inflow Depth = 1.23" for 25-YR event
Inflow = 4.49 cfs @ 14.27 hrs, Volume= 2.922 af
Primary = 4.49 cfs @ 14.27 hrs, Volume= 2.922 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs

Pond 3P: POA DOWNSTREAM WETLAND



Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: DRAINAGE AREA TO Runoff Area=28.460 ac 12.00% Impervious Runoff Depth=0.12"
Flow Length=2,115' Slope=0.0660 '/' Tc=50.2 min CN=50 Runoff=0.47 cfs 0.281 af

Pond 2P: EXISTING 12" CULVERT Peak Elev=92.43' Storage=228 cf Inflow=0.47 cfs 0.281 af
Primary=0.47 cfs 0.281 af Secondary=0.00 cfs 0.000 af Outflow=0.47 cfs 0.281 af

Pond 3P: POA DOWNSTREAM WETLAND Inflow=0.47 cfs 0.281 af
Primary=0.47 cfs 0.281 af

Total Runoff Area = 28.460 ac Runoff Volume = 0.281 af Average Runoff Depth = 0.12"
88.00% Pervious = 25.045 ac 12.00% Impervious = 3.415 ac

Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: DRAINAGE AREA TO Runoff Area=28.460 ac 12.00% Impervious Runoff Depth=0.63"
Flow Length=2,115' Slope=0.0660 '/' Tc=50.2 min CN=50 Runoff=6.03 cfs 1.490 af

Pond 2P: EXISTING 12" CULVERT Peak Elev=94.36' Storage=9,703 cf Inflow=6.03 cfs 1.490 af
Primary=3.19 cfs 1.490 af Secondary=0.00 cfs 0.000 af Outflow=3.19 cfs 1.490 af

Pond 3P: POA DOWNSTREAM WETLAND Inflow=3.19 cfs 1.490 af
Primary=3.19 cfs 1.490 af

Total Runoff Area = 28.460 ac Runoff Volume = 1.490 af Average Runoff Depth = 0.63"
88.00% Pervious = 25.045 ac 12.00% Impervious = 3.415 ac

Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: DRAINAGE AREA TO Runoff Area=28.460 ac 12.00% Impervious Runoff Depth=2.86"
Flow Length=2,115' Slope=0.0660 '/' Tc=50.2 min CN=50 Runoff=38.96 cfs 6.774 af

Pond 2P: EXISTING 12" CULVERT Peak Elev=98.30' Storage=136,703 cf Inflow=38.96 cfs 6.774 af
Primary=6.00 cfs 6.774 af Secondary=0.00 cfs 0.000 af Outflow=6.00 cfs 6.774 af

Pond 3P: POA DOWNSTREAM WETLAND Inflow=6.00 cfs 6.774 af
Primary=6.00 cfs 6.774 af

Total Runoff Area = 28.460 ac Runoff Volume = 6.774 af Average Runoff Depth = 2.86"
88.00% Pervious = 25.045 ac 12.00% Impervious = 3.415 ac

Events for Pond 2P: EXISTING 12" CULVERT

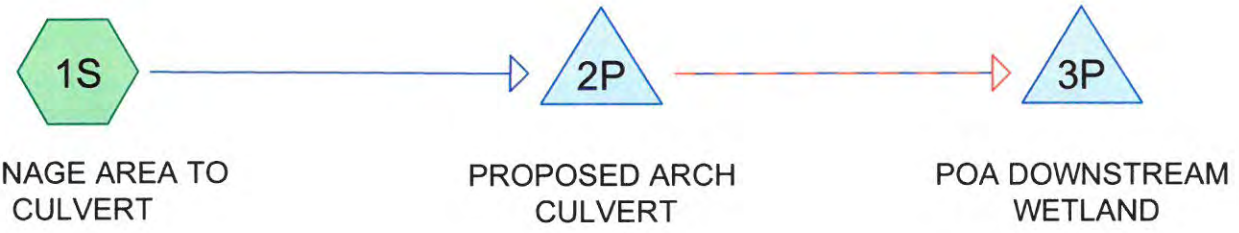
Event	Inflow (cfs)	Outflow (cfs)	Primary (cfs)	Secondary (cfs)	Volume (acre-feet)	Elevation (feet)	Storage (cubic-feet)
2-YR	0.47	0.47	0.47	**0.00**	0.281	92.43	229
10-YR	6.03	3.19	3.19	0.00	1.490	94.36	9,707
25-YR	14.59	4.49	4.49	0.00	2.922	95.88	36,179
100-YR	**38.96**	**6.00**	**6.00**	0.00	**6.774**	**98.30**	**136,703**

Events for Pond 3P: POA DOWNSTREAM WETLAND

Event	Inflow (cfs)	Primary (cfs)	Volume (acre-feet)	Elevation (feet)	Storage (cubic-feet)
2-YR	0.47	0.47	0.281	**0.00**	**0**
10-YR	3.19	3.19	1.490	0.00	0
25-YR	4.49	4.49	2.922	0.00	0
100-YR	**6.00**	**6.00**	**6.774**	0.00	0

APPENDIX B

PROPOSED CONDITION DRAINAGE CALCULATIONS



Subcat Reach Pond Link

Routing Diagram for PROPOSED CONDITION
Prepared by Hayner/Swanson, Inc., Printed 11/17/16

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
23.410	46	2 acre lots, 12% imp, HSG A (1S)
3.500	65	2 acre lots, 12% imp, HSG B (1S)
1.550	77	2 acre lots, 12% imp, HSG C (1S)
28.460	**50**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
23.410	HSG A	1S
3.500	HSG B	1S
1.550	HSG C	1S
0.000	HSG D	
0.000	Other	
28.460		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
23.410	3.500	1.550	0.000	0.000	28.460	2 acre lots, 12% imp	1S
23.410	**3.500**	**1.550**	**0.000**	**0.000**	**28.460**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	2P	91.00	90.50	45.0	0.0111	0.030	57.0	36.0	12.0

Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: DRAINAGE AREA TO Runoff Area=28.460 ac 12.00% Impervious Runoff Depth=1.23"
Flow Length=2,115' Slope=0.0660 '/' Tc=50.2 min CN=50 Runoff=14.59 cfs 2.922 af

Pond 2P: PROPOSED ARCH CULVERT Peak Elev=93.23' Storage=1,923 cf Inflow=14.59 cfs 2.922 af
Primary=14.38 cfs 2.922 af Secondary=0.00 cfs 0.000 af Outflow=14.38 cfs 2.922 af

Pond 3P: POA DOWNSTREAM WETLAND Inflow=14.38 cfs 2.922 af
Primary=14.38 cfs 2.922 af

Total Runoff Area = 28.460 ac Runoff Volume = 2.922 af Average Runoff Depth = 1.23"
88.00% Pervious = 25.045 ac 12.00% Impervious = 3.415 ac

Summary for Subcatchment 1S: DRAINAGE AREA TO CULVERT

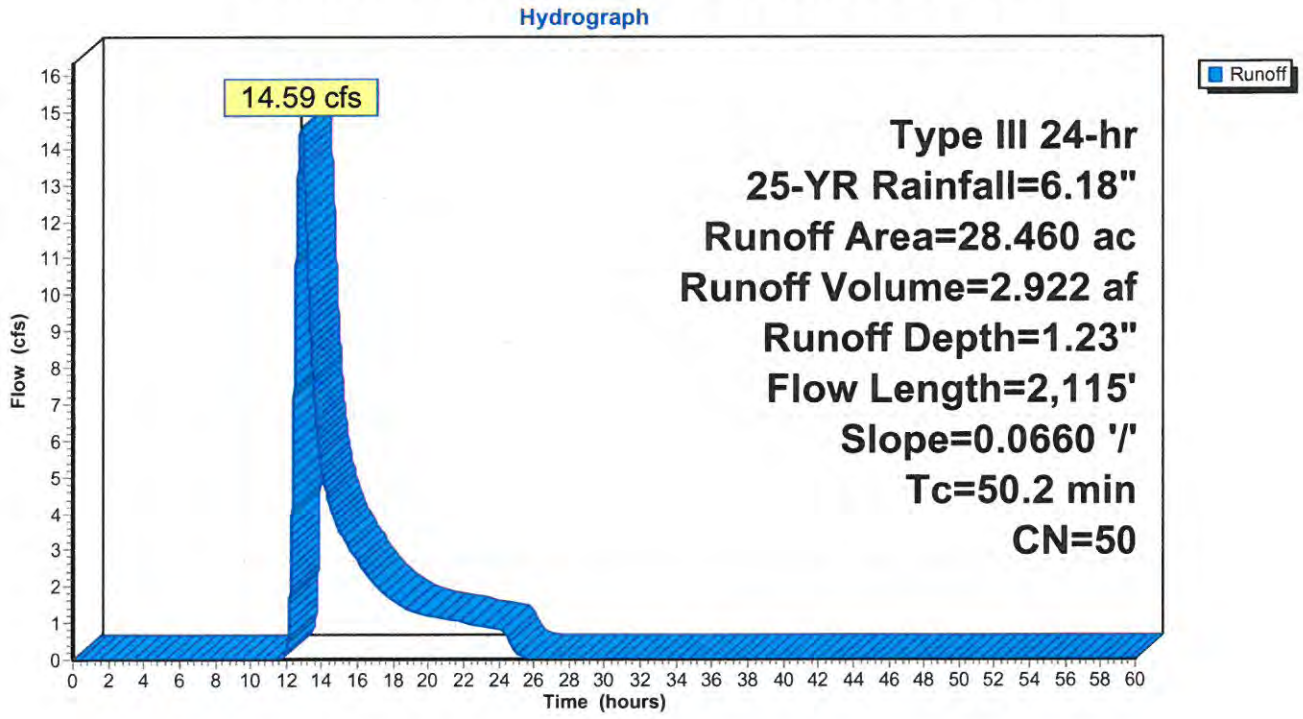
Runoff = 14.59 cfs @ 12.78 hrs, Volume= 2.922 af, Depth= 1.23"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-YR Rainfall=6.18"

Area (ac)	CN	Description
23.410	46	2 acre lots, 12% imp, HSG A
3.500	65	2 acre lots, 12% imp, HSG B
1.550	77	2 acre lots, 12% imp, HSG C
28.460	50	Weighted Average
25.045		88.00% Pervious Area
3.415		12.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
50.2	2,115	0.0660	0.70		**Lag/CN Method,**

Subcatchment 1S: DRAINAGE AREA TO CULVERT



Summary for Pond 2P: PROPOSED ARCH CULVERT

Inflow Area = 28.460 ac, 12.00% Impervious, Inflow Depth = 1.23" for 25-YR event
Inflow = 14.59 cfs @ 12.78 hrs, Volume= 2.922 af
Outflow = 14.38 cfs @ 12.87 hrs, Volume= 2.922 af, Atten= 1%, Lag= 5.1 min
Primary = 14.38 cfs @ 12.87 hrs, Volume= 2.922 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Peak Elev= 93.23' @ 12.87 hrs Surf.Area= 3,809 sf Storage= 1,923 cf
Flood Elev= 98.50' Surf.Area= 59,265 sf Storage= 149,134 cf

Plug-Flow detention time= 1.4 min calculated for 2.922 af (100% of inflow)
Center-of-Mass det. time= 1.4 min (934.0 - 932.6)

Volume	Invert	Avail.Storage	Storage Description
#1	92.00'	180,235 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

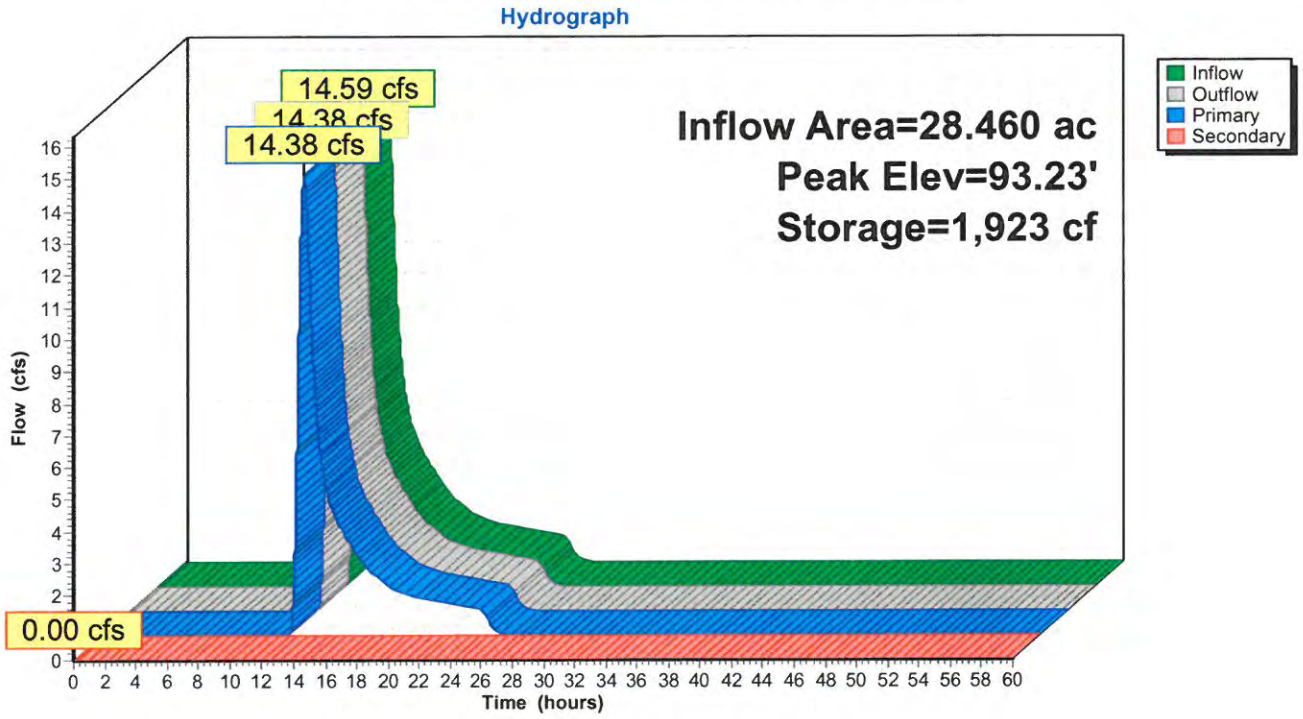
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
92.00	10	0	0
93.00	2,410	1,210	1,210
94.00	8,510	5,460	6,670
95.00	15,260	11,885	18,555
96.00	27,990	21,625	40,180
97.00	40,100	34,045	74,225
98.00	53,390	46,745	120,970
99.00	65,140	59,265	180,235

Device	Routing	Invert	Outlet Devices
#1	Primary	92.00'	**57.0" W x 36.0" H, R=28.7"/88.2" Pipe Arch Culvert w/ 12.0" inside fill** L= 45.0' CMP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 91.00' / 90.50' S= 0.0111 '/' Cc= 0.900 n= 0.030 Stream, clean & straight, Flow Area= 7.12 sf
#2	Secondary	98.50'	**60.0' long x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=14.38 cfs @ 12.87 hrs HW=93.23' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 14.38 cfs @ 3.52 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=92.00' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 2P: PROPOSED ARCH CULVERT

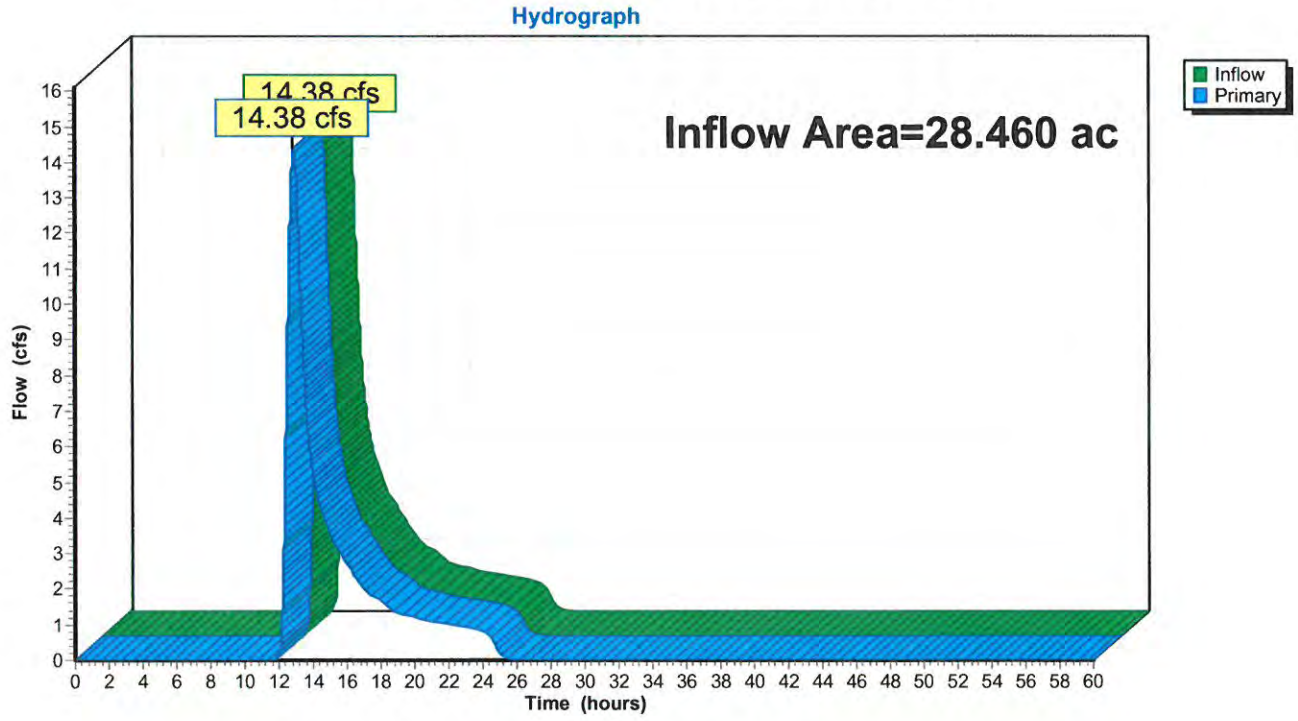


Summary for Pond 3P: POA DOWNSTREAM WETLAND

Inflow Area = 28.460 ac, 12.00% Impervious, Inflow Depth = 1.23" for 25-YR event
Inflow = 14.38 cfs @ 12.87 hrs, Volume= 2.922 af
Primary = 14.38 cfs @ 12.87 hrs, Volume= 2.922 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs

Pond 3P: POA DOWNSTREAM WETLAND



Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: DRAINAGE AREA TO Runoff Area=28.460 ac 12.00% Impervious Runoff Depth=0.12"
Flow Length=2,115' Slope=0.0660 '/' Tc=50.2 min CN=50 Runoff=0.47 cfs 0.281 af

Pond 2P: PROPOSED ARCH CULVERT Peak Elev=92.12' Storage=20 cf Inflow=0.47 cfs 0.281 af
Primary=0.47 cfs 0.281 af Secondary=0.00 cfs 0.000 af Outflow=0.47 cfs 0.281 af

Pond 3P: POA DOWNSTREAM WETLAND Inflow=0.47 cfs 0.281 af
Primary=0.47 cfs 0.281 af

Total Runoff Area = 28.460 ac Runoff Volume = 0.281 af Average Runoff Depth = 0.12"
88.00% Pervious = 25.045 ac 12.00% Impervious = 3.415 ac

Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: DRAINAGE AREA TO Runoff Area=28.460 ac 12.00% Impervious Runoff Depth=0.63"
Flow Length=2,115' Slope=0.0660 '/' Tc=50.2 min CN=50 Runoff=6.03 cfs 1.490 af

Pond 2P: PROPOSED ARCH CULVERT Peak Elev=92.65' Storage=517 cf Inflow=6.03 cfs 1.490 af
Primary=6.00 cfs 1.490 af Secondary=0.00 cfs 0.000 af Outflow=6.00 cfs 1.490 af

Pond 3P: POA DOWNSTREAM WETLAND Inflow=6.00 cfs 1.490 af
Primary=6.00 cfs 1.490 af

Total Runoff Area = 28.460 ac Runoff Volume = 1.490 af Average Runoff Depth = 0.63"
88.00% Pervious = 25.045 ac 12.00% Impervious = 3.415 ac

Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: DRAINAGE AREA TO Runoff Area=28.460 ac 12.00% Impervious Runoff Depth=2.86"
Flow Length=2,115' Slope=0.0660 '/' Tc=50.2 min CN=50 Runoff=38.96 cfs 6.774 af

Pond 2P: PROPOSED ARCH CULVERT Peak Elev=94.89' Storage=16,881 cf Inflow=38.96 cfs 6.774 af
Primary=33.11 cfs 6.774 af Secondary=0.00 cfs 0.000 af Outflow=33.11 cfs 6.774 af

Pond 3P: POA DOWNSTREAM WETLAND Inflow=33.11 cfs 6.774 af
Primary=33.11 cfs 6.774 af

Total Runoff Area = 28.460 ac Runoff Volume = 6.774 af Average Runoff Depth = 2.86"
88.00% Pervious = 25.045 ac 12.00% Impervious = 3.415 ac

Events for Pond 2P: PROPOSED ARCH CULVERT

Event	Inflow (cfs)	Outflow (cfs)	Primary (cfs)	Secondary (cfs)	Volume (acre-feet)	Elevation (feet)	Storage (cubic-feet)
2-YR	0.47	0.47	0.47	**0.00**	0.281	92.12	21
10-YR	6.03	6.00	6.00	0.00	1.490	92.65	519
25-YR	14.59	14.38	14.38	0.00	2.922	93.23	1,927
100-YR	**38.96**	**33.11**	**33.11**	0.00	**6.774**	**94.89**	**16,884**

Events for Pond 3P: POA DOWNSTREAM WETLAND

Event	Inflow (cfs)	Primary (cfs)	Volume (acre-feet)	Elevation (feet)	Storage (cubic-feet)
2-YR	0.47	0.47	0.281	**0.00**	**0**
10-YR	6.00	6.00	1.490	0.00	0
25-YR	14.38	14.38	2.922	0.00	0
100-YR	**33.11**	**33.11**	**6.774**	0.00	0

APPENDIX C

PROPOSED CONDITION DRAINAGE CALCULATIONS

(DESIGN ALTERNATIVES)

Summary for Pond 2P: PROPOSED18" RCP

Inflow Area = 28.460 ac, 12.00% Impervious, Inflow Depth = 0.12" for 2-YR event
Inflow = 0.47 cfs @ 14.22 hrs, Volume= 0.281 af
Outflow = 0.47 cfs @ 14.35 hrs, Volume= 0.281 af, Atten= 0%, Lag= 7.6 min
Primary = 0.47 cfs @ 14.35 hrs, Volume= 0.281 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Peak Elev= 92.38' @ 14.35 hrs Surf.Area= 931 sf Storage= 181 cf
Flood Elev= 98.50' Surf.Area= 59,265 sf Storage= 149,134 cf

Plug-Flow detention time= 6.6 min calculated for 0.281 af (100% of inflow)
Center-of-Mass det. time= 6.6 min (1,063.2 - 1,056.6)

Volume	Invert	Avail.Storage	Storage Description
#1	92.00'	180,235 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
92.00	10	0	0
93.00	2,410	1,210	1,210
94.00	8,510	5,460	6,670
95.00	15,260	11,885	18,555
96.00	27,990	21,625	40,180
97.00	40,100	34,045	74,225
98.00	53,390	46,745	120,970
99.00	65,140	59,265	180,235

Device	Routing	Invert	Outlet Devices
#1	Primary	92.00'	**18.0" Round Culvert** L= 45.0' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 92.00' / 91.50' S= 0.0111 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 1.77 sf
#2	Secondary	98.50'	**60.0' long x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=0.47 cfs @ 14.35 hrs HW=92.38' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 0.47 cfs @ 1.96 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=92.00' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Events for Pond 2P: PROPOSED18" RCP

Event	Inflow (cfs)	Outflow (cfs)	Primary (cfs)	Secondary (cfs)	Volume (acre-feet)	Elevation (feet)	Storage (cubic-feet)
2-YR	0.47	0.47	0.47	**0.00**	0.281	92.38	182
10-YR	6.03	5.35	5.35	0.00	1.490	93.48	3,094
25-YR	14.59	9.06	9.06	0.00	2.922	94.86	16,422
100-YR	**38.96**	**13.62**	**13.62**	0.00	**6.774**	**97.19**	**82,082**

Summary for Pond 2P: PROPOSED BOX CULVERT

Inflow Area = 28.460 ac, 12.00% Impervious, Inflow Depth = 2.86" for 100-YR event
Inflow = 38.96 cfs @ 12.77 hrs, Volume= 6.774 af
Outflow = 38.82 cfs @ 12.78 hrs, Volume= 6.774 af, Atten= 0%, Lag= 0.7 min
Primary = 38.82 cfs @ 12.78 hrs, Volume= 6.774 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Peak Elev= 93.48' @ 12.78 hrs Surf.Area= 5,335 sf Storage= 3,067 cf
Flood Elev= 98.50' Surf.Area= 59,265 sf Storage= 149,134 cf

Plug-Flow detention time= 0.8 min calculated for 6.773 af (100% of inflow)
Center-of-Mass det. time= 0.8 min (904.9 - 904.1)

Volume	Invert	Avail.Storage	Storage Description
#1	92.00'	180,235 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
92.00	10	0	0
93.00	2,410	1,210	1,210
94.00	8,510	5,460	6,670
95.00	15,260	11,885	18,555
96.00	27,990	21,625	40,180
97.00	40,100	34,045	74,225
98.00	53,390	46,745	120,970
99.00	65,140	59,265	180,235

Device	Routing	Invert	Outlet Devices
#1	Primary	92.00'	**96.0" W x 96.0" H Box Culvert w/ 42.0" inside fill** L= 45.0' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 88.50' / 88.00' S= 0.0111 '/' Cc= 0.900 n= 0.030 Stream, clean & straight, Flow Area= 36.00 sf
#2	Secondary	98.50'	**60.0' long x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=38.81 cfs @ 12.78 hrs HW=93.48' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 38.81 cfs @ 4.37 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=92.00' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Events for Pond 2P: PROPOSED BOX CULVERT

Event	Inflow (cfs)	Outflow (cfs)	Primary (cfs)	Secondary (cfs)	Volume (acre-feet)	Elevation (feet)	Storage (cubic-feet)
2-YR	0.47	0.47	0.47	**0.00**	0.281	92.09	11
10-YR	6.03	6.02	6.02	0.00	1.490	92.43	232
25-YR	14.59	14.57	14.57	0.00	2.922	92.77	716
100-YR	**38.96**	**38.82**	**38.82**	0.00	**6.774**	**93.48**	**3,072**

APPENDIX D

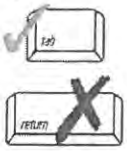
MASSDEP CHECKLIST FOR STORMWATER REPORT

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.

[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.

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

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.

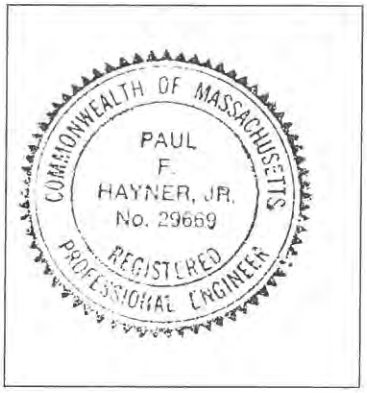
Note: Because stormwater requirements vary from project to project, it is possible that a complete Stormwater Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the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

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 for Stormwater Report

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 for Stormwater Report

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 for Stormwater Report

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 for 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;
- Inspection and Maintenance Log Form.

☒ 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 for 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.

APPENDIX E

OPINION OF PROBABLE COST (OPC)

Opinion of Probable Cost (OPC) - Highland Road, Boxford, MA (18" Culvert)				
Item Description	Quantity	Unit	Unit Cost	Cost
Mobilization	1	LS	$ 3,000.00	$ 3,000.00
Tree Removal/Clearing & Grubbing	1	LS	$ 7,500.00	$ 7,500.00
18" Culvert	45	LF	$ 100.00	$ 4,500.00
Headwall (Stone Masonry)	2	EA	$ 3,500.00	$ 7,000.00
Riprap	15	CY	$ 100.00	$ 1,500.00
Streambed Material	10	CY	$ 150.00	$ 1,500.00
Bituminous Concrete Pavement (4-1/2")	15	TONS	$ 125.00	$ 1,875.00
Processed Gravel (16")	50	CY	$ 35.00	$ 1,750.00
Wetland Mitigation & Planting	1	LS	$ 8,000.00	$ 8,000.00
Erosion Control	1	LS	$ 3,000.00	$ 3,000.00
Traffic Control	1	LS	$ 3,000.00	$ 3,000.00
			Subtotal:	$ 42,625.00
			15% Bonds & Contingency	$ 6,375.00
			Total Estimated Construction Cost:	$ 49,000.00

Notes:

1) Easement and Engineering costs are not included.

Opinion of Probable Cost (OPC) - Highland Road, Boxford, MA (3'x5' Pipe Arch Culvert)				
Item Description	Quantity	Unit	Unit Cost	Cost
Mobilization	1	LS	$ 5,000.00	$ 5,000.00
Tree Removal/Clearing & Grubbing	1	LS	$ 7,500.00	$ 7,500.00
3'x5" Pipe Arch Culvert	45	LF	$ 200.00	$ 9,000.00
Headwall (Stone Masonry)	2	EA	$ 5,000.00	$ 10,000.00
Riprap	25	CY	$ 100.00	$ 2,500.00
Streambed Material	12	CY	$ 150.00	$ 1,800.00
Bituminous Concrete Pavement (4-1/2")	15	TONS	$ 125.00	$ 1,875.00
Processed Gravel (16")	50	CY	$ 35.00	$ 1,750.00
Wetland Mitigation & Planting	1	LS	$ 8,000.00	$ 8,000.00
Erosion Control	1	LS	$ 3,000.00	$ 3,000.00
Traffic Control	1	LS	$ 3,000.00	$ 3,000.00
			Subtotal:	$ 53,425.00
			15% Bonds & Contingency	$ 8,575.00
			Total Estimated Construction Cost:	$ 62,000.00

Notes:

1) Easement and Engineering costs are not included.

Opinion of Probable Cost (OPC) - Highland Road, Boxford, MA (8'x8' Box Culvert)				
Item Description	Quantity	Unit	Unit Cost	Cost
Mobilization	1	LS	$ 10,000.00	$ 10,000.00
Tree Removal/Clearing & Grubbing	1	LS	$ 10,000.00	$ 7,500.00
8'x8' Precast Concrete Box Culvert Culvert	45	LF	$ 1,100.00	$ 49,500.00
Precast Concrete Headwall	2	EA	$ 5,000.00	$ 10,000.00
Riprap	35	CY	$ 100.00	$ 3,500.00
Streambed Material	20	CY	$ 150.00	$ 3,000.00
Bituminous Concrete Pavement (4-1/2")	20	TONS	$ 125.00	$ 2,500.00
Processed Gravel (16")	60	CY	$ 35.00	$ 2,100.00
Wetland Mitigation & Planting	1	LS	$ 8,000.00	$ 8,000.00
Erosion Control	1	LS	$ 3,000.00	$ 3,000.00
Traffic Control	1	LS	$ 5,000.00	$ 5,000.00
			Subtotal:	$ 104,100.00
			15% Bonds & Contingency	$ 15,900.00
			Total Estimated Construction Cost:	$ 120,000.00

Notes:

1) Easement and Engineering costs are not included.

APPENDIX F

OPERATION & MAINTENANCE PLAN

OPERATION AND MAINTENANCE PLAN

Construction Operations:

The operation and maintenance plan for construction operations outlines the installation, inspection, cleaning, and upkeep necessary to keep the siltation and erosion control system in good repair and operating efficiently. It is a critical component to the success of the stormwater best management practices designed for construction work on the site. Construction erosion controls minimize the potential for sedimentation in downstream gradient resource areas and abutting properties.

Construction erosion controls cover a wide range of practices, including stabilizing the construction entrance roadway, installing hay bales and silt fences, and controlling erosion at catch basins. The guiding principle for construction erosion control for this development is to minimize the volume of runoff and to minimize contact of stormwater with potential pollutants. Accepted construction management practices can reduce these stormwater pollutant loads and quantities.

The following construction best management practices (BMPs) for sediment and erosion control are included in this operation and maintenance plan:

1. Install silt fence, straw bale barriers and the dewatering bag as shown on the plans and as required in the field to prevent sediment from leaving the limits of work.
2. Material stockpile areas shall be stabilized with erosion control matting or temporary seeding whenever necessary.
3. Inspect and maintain BMPs at least weekly and after every major rainfall event.
4. Erosion control measures shall be maintained, repaired or replaced as required or at the direction of the Department of Public Works Director.
5. During periodic inspections, if sediment is found to be exiting the site, measures shall be taken to ensure sediment does not reach the resource areas.
6. The contractor shall comply with the General and Erosion Control Notes show on the plans and in the contract documents.
7. Measures shall be taken to control dust during construction.
8. Stabilize disturbed areas, particularly slopes, which may be prone to erosion by using matting or an erosion control seed mixture.
9. Sediment shall be removed from barriers periodically. Silt fence and straw bales shall not be used as retaining walls.
10. Remove and properly dispose of straw bales, silt fencing, and accumulated sediment following construction operations.

Post-Construction Operations:

The Town of Boxford will assume responsibility for the maintenance and upkeep of the culvert location in accordance with their planned maintenance and inspection schedule. The operation and maintenance plan outlines the regular inspection and cleaning schedule necessary to keep the area in good repair and operating efficiently, and is a critical component of the success of the stormwater runoff erosion control for the proposed development.

Source controls reduce the types and concentrations of contaminants in stormwater runoff, which, in turn, improve water quality. Source controls cover a wide range of practices, including local bylaws and regulations, fertilizer management in residential areas, reduced road salting in winter, erosion and sediment controls at construction sites, and comprehensive snow management. The guiding principle for pollution prevention and control is to minimize the volume of runoff and to minimize contact of stormwater with potential pollutants.

The following source control methods shall be used for this project:

1. Sweeping - Street sweeping is an effective source control, and is implemented on an annual basis. Sweeping efforts are performed during the period immediately following winter snowmelt, when road sand and other accumulated sediment are washed off.

2. Snow and Snow Melt Management - Proper management of snow and snow melt, snow removal and storage, use of deicing compounds, and other practices can minimize major runoff and pollutant loading impacts. The Town of Boxford currently uses a 3:1 sand/salt mix. Use of alternative deicing compounds, such as magnesium chloride, can be investigated to further reduce the pollutant loading impacts. Groundcover shall be evaluated at least twice per year and reseeded if necessary.

3. Vegetation Management - Proper management of roadway side slope vegetation is critical to ensuring the longevity of the roadway and to prevent erosion from developing in the vicinity of resource areas. Vegetated areas shall be inspected annually at a minimum. Eroded areas shall be fixed with loam and seed.

APPENDIX G

SUPPORT MATERIAL

Photo A: Looking south from Highland Road towards downstream end of 12" CMP culvert

(Photo taken by P. Hayner on 11/15/16)

Photo B: Looking south towards upstream end of existing 12" CMP culvert

(Photo taken by P. Hayner on 11/15/16)

Extreme Precipitation Tables

Northeast Regional Climate Center

ıta represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing	Yes
State	Massachusetts
Location	
Longitude	71.034 degrees West
Latitude	42.699 degrees North
Elevation	Unknown/Unavailable
Date/Time	Thu, 17 Nov 2016 08:21:21 -0500

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.27	0.42	0.52	0.68	0.85	1.07	**1yr**	0.73	1.01	1.25	1.59	2.04	2.63	2.88	**1yr**	2.33	2.77	3.20	3.88	4.55	**1yr**
2yr	0.33	0.51	0.64	0.85	1.06	1.34	**2yr**	0.92	1.23	1.56	1.97	2.49	3.15	3.49	**2yr**	2.79	3.36	3.88	4.59	5.25	**2yr**
5yr	0.40	0.62	0.77	1.03	1.32	1.69	**5yr**	1.14	1.54	1.97	2.50	3.17	4.02	4.48	**5yr**	3.56	4.30	4.94	5.86	6.62	**5yr**
10yr	0.44	0.70	0.88	1.20	1.56	2.01	**10yr**	1.35	1.83	2.36	3.01	3.82	4.84	5.40	**10yr**	4.28	5.20	5.95	7.04	7.90	**10yr**
25yr	0.53	0.83	1.06	1.46	1.94	2.53	**25yr**	1.67	2.30	2.98	3.82	4.87	6.18	6.94	**25yr**	5.47	6.67	7.59	8.98	9.98	**25yr**
50yr	0.59	0.94	1.21	1.70	2.30	3.03	**50yr**	1.98	2.73	3.58	4.61	5.88	7.44	8.38	**50yr**	6.58	8.06	9.14	10.81	11.91	**50yr**
100yr	0.68	1.09	1.41	1.99	2.72	3.61	**100yr**	2.34	3.25	4.28	5.53	7.06	8.96	10.13	**100yr**	7.93	9.74	11.01	13.01	14.23	**100yr**
200yr	0.77	1.25	1.62	2.32	3.21	4.31	**200yr**	2.77	3.86	5.13	6.64	8.50	10.79	12.25	**200yr**	9.55	11.78	13.25	15.67	17.00	**200yr**
500yr	0.92	1.51	1.97	2.87	4.02	5.44	**500yr**	3.47	4.86	6.51	8.47	10.87	13.82	15.75	**500yr**	12.23	15.15	16.96	20.04	21.52	**500yr**

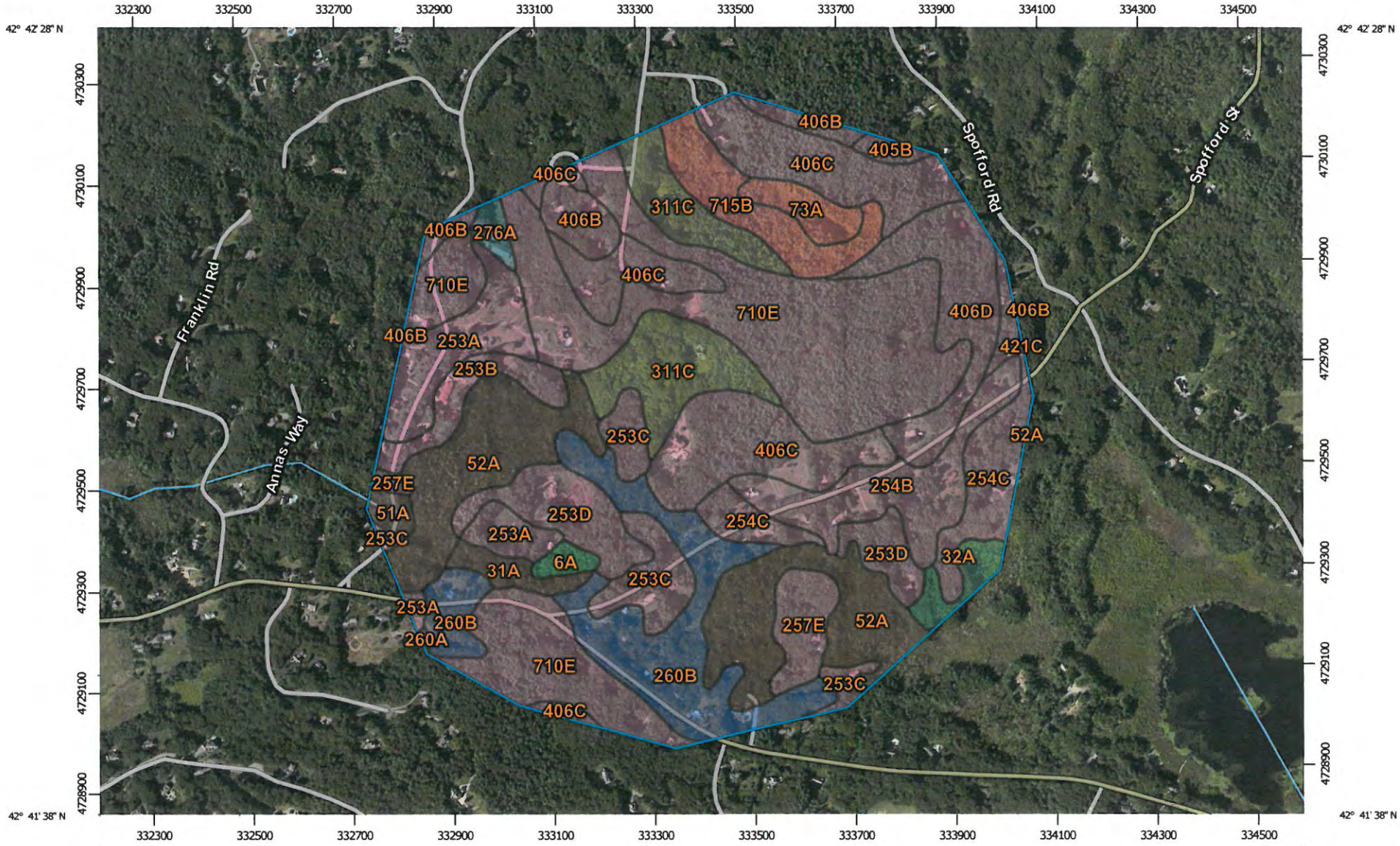
Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.25	0.38	0.46	0.62	0.76	0.88	1yr	0.66	0.86	1.08	1.32	1.62	2.44	2.66	1yr	2.16	2.56	2.96	3.46	4.14	1yr
2yr	0.32	0.50	0.61	0.83	1.03	1.23	2yr	0.89	1.20	1.40	1.85	2.37	3.07	3.39	2yr	2.72	3.26	3.77	4.47	5.12	2yr
5yr	0.37	0.58	0.72	0.98	1.25	1.47	5yr	1.08	1.44	1.66	2.15	2.76	3.75	4.15	5yr	3.32	3.99	4.61	5.45	6.19	5yr
10yr	0.42	0.64	0.79	1.11	1.43	1.69	10yr	1.24	1.65	1.89	2.43	3.09	4.37	4.82	10yr	3.86	4.64	5.39	6.33	7.14	10yr
25yr	0.48	0.73	0.91	1.30	1.71	2.02	25yr	1.48	1.98	2.21	2.82	3.60	5.33	5.87	25yr	4.72	5.64	6.61	7.71	8.61	25yr
50yr	0.54	0.82	1.02	1.46	1.97	2.33	50yr	1.70	2.28	2.49	3.17	4.05	6.19	6.79	50yr	5.48	6.53	7.71	8.96	9.90	50yr
100yr	0.61	0.91	1.15	1.65	2.27	2.67	100yr	1.96	2.61	2.81	3.56	4.54	7.19	7.84	100yr	6.36	7.54	9.00	10.42	11.38	100yr
200yr	0.68	1.02	1.30	1.88	2.62	3.07	200yr	2.26	3.00	3.17	3.99	5.10	8.36	9.08	200yr	7.40	8.73	10.51	12.12	13.08	200yr
500yr	0.80	1.19	1.53	2.23	3.17	3.70	500yr	2.73	3.61	3.70	4.65	5.97	10.20	11.01	500yr	9.03	10.59	12.91	14.80	15.71	500yr

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.30	0.46	0.56	0.75	0.92	1.09	1yr	0.80	1.07	1.29	1.69	2.16	2.82	3.08	1yr	2.50	2.96	3.42	4.14	4.83	1yr
2yr	0.35	0.53	0.66	0.89	1.10	1.31	2yr	0.95	1.28	1.52	1.98	2.53	3.26	3.62	2yr	2.89	3.48	4.00	4.74	5.42	2yr
5yr	0.43	0.66	0.82	1.12	1.43	1.70	5yr	1.23	1.66	1.96	2.54	3.23	4.30	4.82	5yr	3.81	4.63	5.32	6.29	7.06	5yr
10yr	0.52	0.79	0.98	1.37	1.77	2.09	10yr	1.53	2.04	2.39	3.09	3.89	5.32	5.99	10yr	4.71	5.76	6.59	7.80	8.67	10yr
25yr	0.66	1.00	1.25	1.78	2.34	2.73	25yr	2.02	2.67	3.12	3.99	4.97	7.06	8.01	25yr	6.25	7.70	8.77	10.36	11.37	25yr
50yr	0.79	1.20	1.50	2.15	2.90	3.36	50yr	2.50	3.28	3.83	4.85	6.00	8.76	9.99	50yr	7.75	9.60	10.88	12.87	13.97	50yr
100yr	0.96	1.44	1.81	2.61	3.58	4.11	100yr	3.09	4.02	4.71	5.91	7.24	10.84	12.46	100yr	9.60	11.98	13.51	15.99	17.19	100yr
200yr	1.15	1.73	2.19	3.17	4.42	5.05	200yr	3.82	4.94	5.79	7.19	8.73	13.44	15.55	200yr	11.89	14.95	16.77	19.86	21.15	200yr
500yr	1.48	2.20	2.83	4.11	5.84	6.62	500yr	5.04	6.48	7.62	9.34	11.20	17.84	20.84	500yr	15.79	20.04	22.34	26.47	27.87	500yr

Hydrologic Soil Group—Essex County, Massachusetts, Northern Part
(Highland Rd, Boxford, MA)



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 1:15,800.

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: Essex County, Massachusetts, Northern Part
Survey Area Data: Version 11, 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: Aug 29, 2014—Sep 19, 2014

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 — Essex County, Massachusetts, Northern Part (MA605)				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
6A	Scarboro mucky fine sandy loam, 0 to 3 percent slopes	A/D	1.6	0.5%
31A	Walpole sandy loam, 0 to 3 percent slopes	B/D	3.2	1.0%
32A	Wareham loamy sand, 0 to 3 percent slopes	A/D	3.5	1.1%
51A	Swansea muck, 0 to 1 percent slopes	B/D	1.7	0.5%
52A	Freetown muck, 0 to 1 percent slopes	B/D	35.8	11.1%
73A	Whitman loam, 0 to 3 percent slopes, extremely stony	D	4.0	1.3%
253A	Hinckley loamy sand, 0 to 3 percent slopes	A	15.0	4.7%
253B	Hinckley loamy sand, 3 to 8 percent slopes	A	6.1	1.9%
253C	Hinckley loamy sand, 8 to 15 percent slopes	A	11.2	3.5%
253D	Hinckley loamy sand, 15 to 25 percent slopes	A	13.4	4.2%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	A	15.2	4.7%
254C	Merrimac fine sandy loam, 8 to 15 percent slopes	A	12.3	3.8%
257E	Hinckley and Windsor soils, 25 to 35 percent slopes	A	6.6	2.0%
260A	Sudbury fine sandy loam, 0 to 3 percent slopes	B	0.2	0.1%
260B	Sudbury fine sandy loam, 3 to 8 percent slopes	B	28.2	8.8%
276A	Ninigret fine sandy loam, 0 to 3 percent slopes	C	1.8	0.5%
311C	Woodbridge fine sandy loam, 8 to 15 percent slopes, very stony	C/D	19.9	6.2%
405B	Charlton fine sandy loam, 3 to 8 percent slopes	A	1.4	0.4%

Hydrologic Soil Group— Summary by Map Unit — Essex County, Massachusetts, Northern Part (MA605)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
406B	Charlton fine sandy loam, 3 to 8 percent slopes, very stony	A	9.0	2.8%
406C	Charlton fine sandy loam, 8 to 15 percent slopes, very stony	A	38.0	11.8%
406D	Charlton fine sandy loam, 15 to 25 percent slopes, very stony	A	15.1	4.7%
421C	Canton fine sandy loam, 8 to 15 percent slopes, very stony	A	0.1	0.0%
710E	Canton and Charlton fine sandy loams, steep, extremely stony	A	68.7	21.3%
715B	Ridgebury and Leicester fine sandy loams, 3 to 8 percent slopes, extremely stony	D	10.4	3.2%
Totals for Area of Interest			**322.1**	**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.

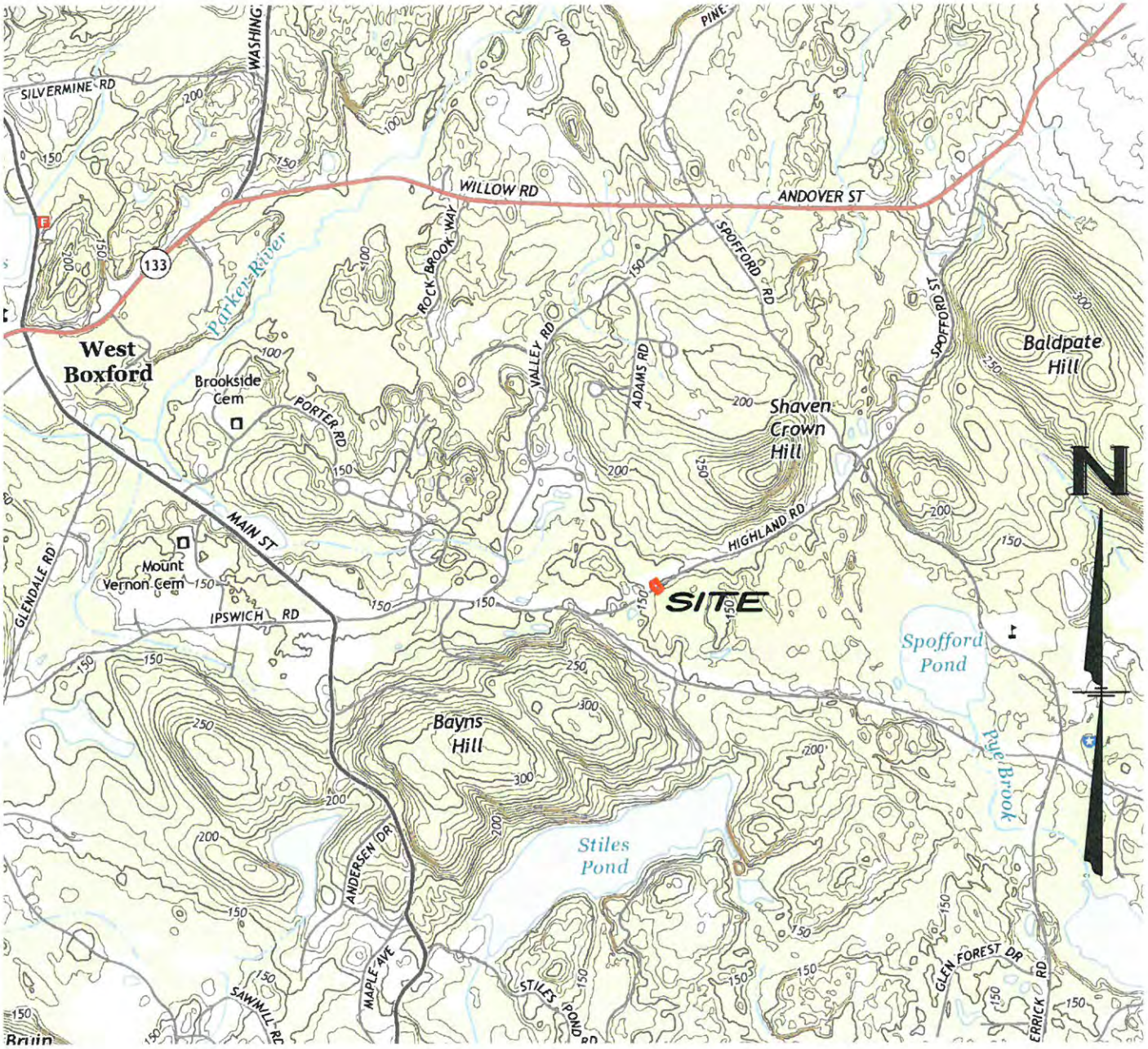
Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

EXHIBITS



1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
NORTH AMERICAN VERTICAL DATUM ON 1988

SOUTH GROVELAND, MA
QUAD MAP (2015)

FIG. 1

VICINITY PLAN
HIGHLAND ROAD
BOXFORD, MA

PREPARED FOR:
TOWN OF BOXFORD
7B SPOFFORD RD. BOXFORD, MA 01921 (978) 352-6555

NOVEMBER 2016

HSI Hayner/Swanson, Inc.
Three Congress Street Nashua, New Hampshire 03062-3301
Tel (603) 883-2057 www.hayner-swanson.com Fax (603) 883-5057

DRAWING: 5387 USGS
LOCATION: C:\Q\5387\DWG

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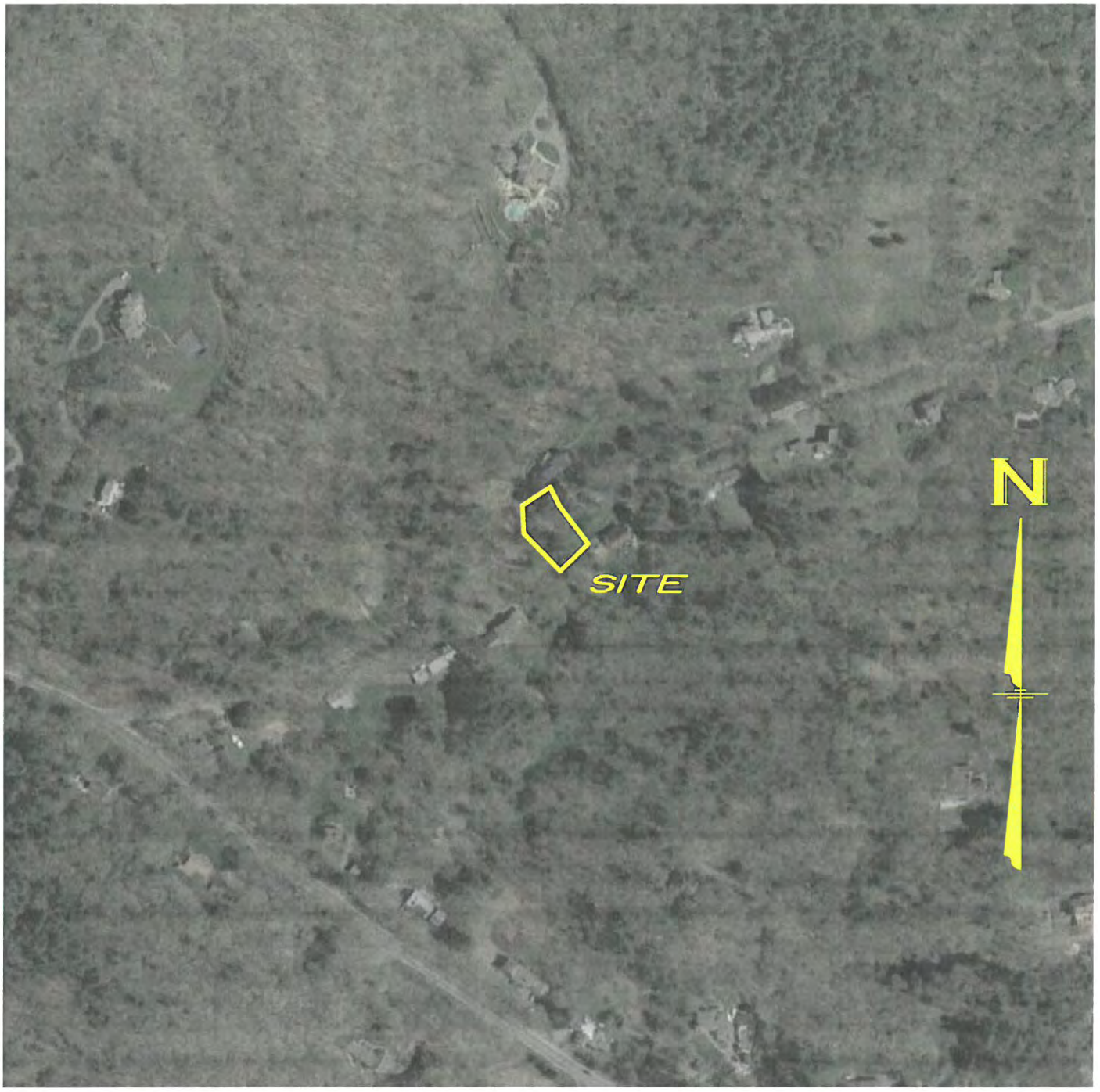
File Number



0 300 600 900 FEET

AERIAL PLAN

HIGHLAND ROAD

BOXFORD, MA

FIG. 2

PREPARED FOR:

TOWN OF BOXFORD

7B SPOFFORD RD. BOXFORD, MA 01921 (978) 352-6555

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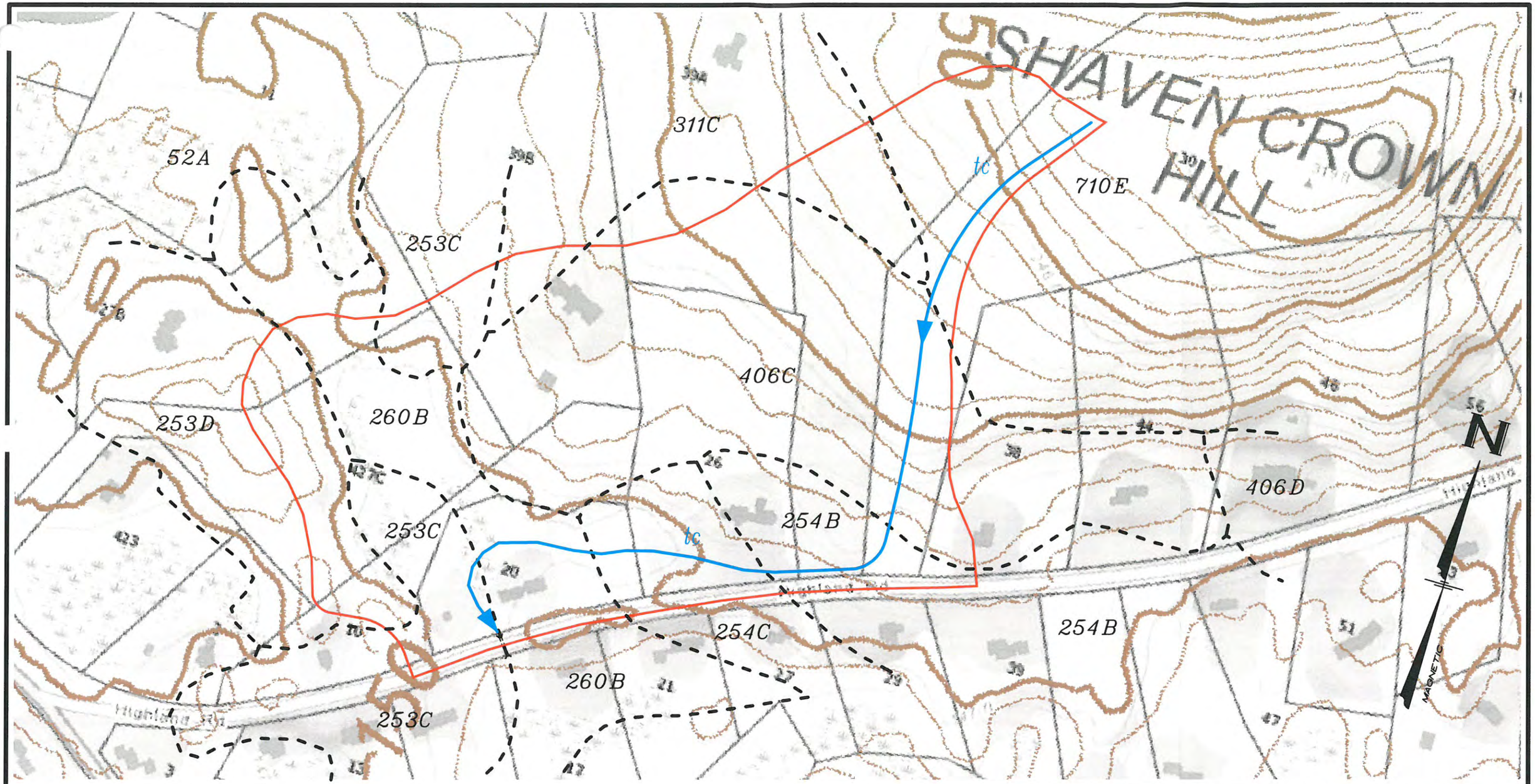

LEGEND

tc — TIME OF CONCENTRATION LINE

SUBCATCHMENT BOUNDARY

SOIL TYPE BOUNDARY

447B — SOIL TYPE

0 200 400 600 FEET

DRAINAGE AREA MAP

HIGHLAND ROAD

BOXFORD, MA

FIG. 1

PREPARED FOR:

TOWN OF BOXFORD

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