

HYDRAULIC REPORT

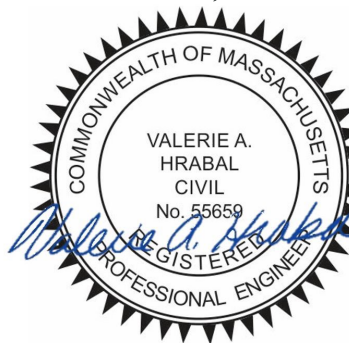
BRANDY BROW ROAD CULVERT OVER EAST MEADOW RIVER CULVERT REPLACEMENT HAVERHILL, MA



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PREPARED FOR:

CITY OF HAVERHILL
4 SUMMER STREET,
HAVERHILL, MA 01830



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MA PE Civil # 55659

JULY, 2024

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Hrabal

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CITY OF HAVERHILL
BRANDY BROW ROAD OVER EAST MEADOW RIVER
HYDRAULIC REPORT
JULY 2024



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1.0 - EXECUTIVE SUMMARY

This report presents the engineering data to support the proposed culvert replacement at the existing stream-roadway crossing where East Meadow River is conveyed beneath Brandy Brow Road. This report documents the analysis of the hydraulic capacity of the existing pipe culvert at the Brandy Brow Road crossing and also the proposed culvert replacement of that existing pipe culvert (at the Brandy Brow Road crossing) to demonstrate compliance with the MassDOT criteria.

The work performed under this task, and summarized in this report, includes the following:

1. Establish hydrology for the purpose of flood routing through the existing and proposed culverts.
2. Construct a "Existing Conditions" HydroCAD flood routing model from which the hydrologic parameters (Drainage Area, Curve Number, and Time of Concentration) will be inserted to construct inflow hydrographs for use in flood routing through the culverts.
3. Create and run a "Proposed Conditions" HydroCAD flood routing model with the proposed culvert geometry.
4. The proposed structure is a 7.33 ft x 34 ft box culvert. The proposed culvert is to be designed to safely convey the runoff generated from the 10-year storm event.
5. Estimate the scour at the proposed culvert outlet using the HY-8 Culvert Analysis Program and consistent with the guidelines set forth in Chapter 5 of Hydraulic Engineering Circular No.14 (HEC_14), Third Edition: Hydraulic Design of Energy Dissipators for Culverts and Channels. The scour hole geometry is calculated for a design storm of 25-year storm event and check storm of 50-year storm event.

NOTE: Topographic Datum for plans and report contained herein is NAVD 1988 unless otherwise noted. NGVD 1929 datum minus 0.70 ft. = NAVD 1988 datum.

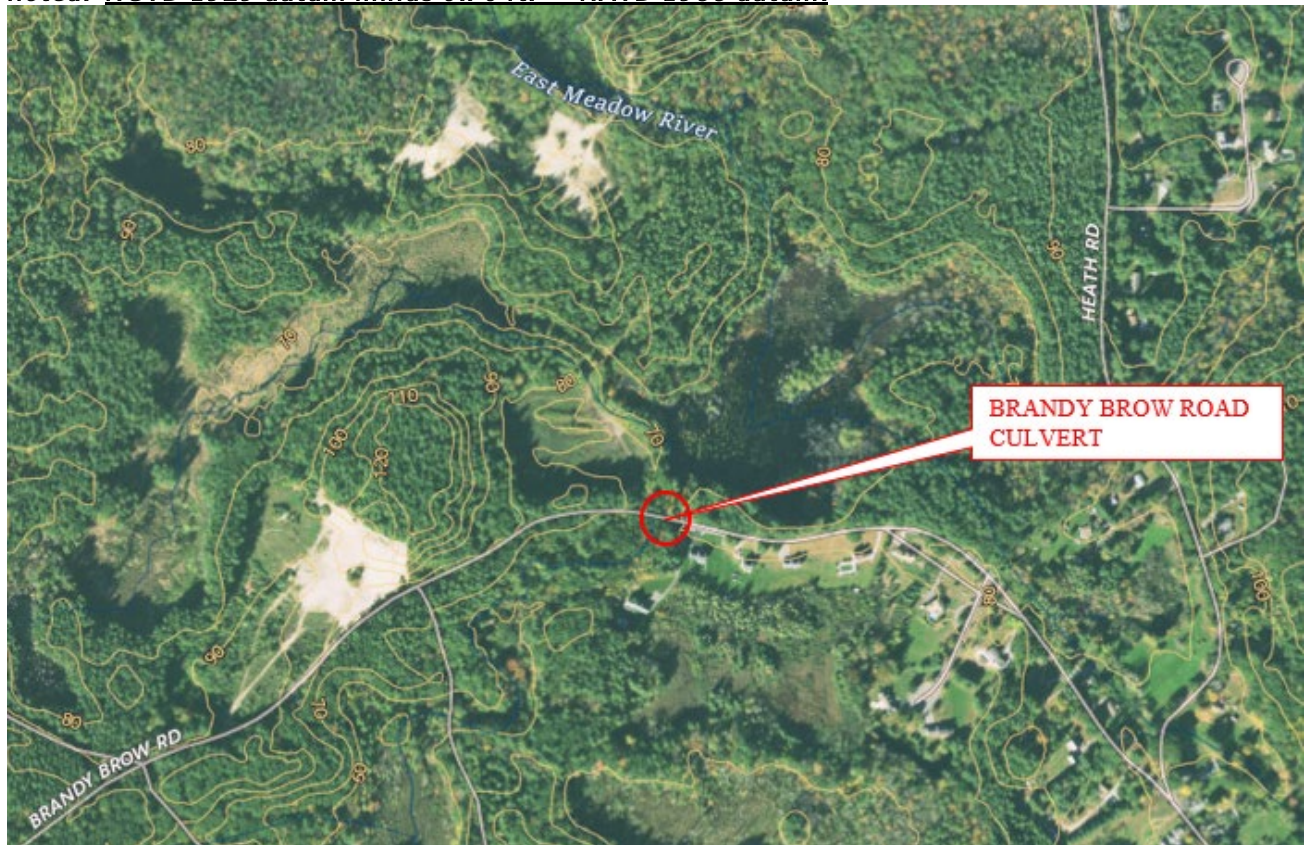


FIGURE 1- PROJECT LOCATION MAP

2.0 - PROJECT DESCRIPTION

2.1 Existing Conditions

In the existing condition, East Meadow River, a perennial stream, is conveyed beneath Brandy Brow Road via a 8 ft wide x 6'-4" high box culvert (**see Appendix C**). This project proposes to replace the existing box culvert with a new box culvert embedded with a minimum 1 feet fill including aft of native stream bed material on top of 1 ft stone, providing for a 7.33 ft x 34 ft hydraulic opening. The proposed channel bed inside the structure has a U-shaped bottom which acts a low flow channel. Enlarging the culvert will allow the stream crossing to meet the MassDOT stream crossing standards.

The pipe crossing has a contributory drainage area of about 3.63 square miles (2,322 ac.) which was refined from the StreamStats drainage area using USGS 1-foot LIDAR contours. The watershed consists of woods, open areas, residential areas, brush, and ponds at the headwaters of East Meadow River. It is riverine in nature and has not been studied or mapped by FEMA, therefore neither hydrology nor hydraulics analysis have been published, nor are available, for the required study reach.

2.2 Proposed Action

As described in the section above, the existing box culvert at the existing stream-roadway crossing at Brandy Brow Road is proposed to be replaced with a hydraulically equivalent 7.33 ft x 34 ft box culvert. Therefore, the net hydraulic opening of the proposed culvert will provide 31.61 openness ratio, which is significantly higher than the required 0.82 openness ratio required by the MassDOT stream crossing standards. Based on the existing topography at the downstream end of the proposed culvert, the invert of the proposed culvert will be raised so as not to alter the existing hydrology/drainage pattern.

3.0 - DATA COLLECTION

3.1 Sources and Applications

Primary information sources for this report are listed below.

1. Field survey data prepared by Greenman-Pedersen, Inc (GPI).
2. 2021 USGS LIDAR Central Eastern Massachusetts (obtained from the NOAA Coastal Management Data Access Viewer Digital Repository)
3. 2019 – 2020 USGS Lidar: NH Costal (QL1) (obtained from the NOAA Coastal Management Data Access Viewer Digital Repository)
4. NRCS TR-55 Watershed Hydrology (1986)
5. NRCS National Engineering Handbook Part 630 Hydrology (1997-2019)
6. NOAA Atlas 14 Point Precipitation Rainfall Data
7. USGS StreamStats
8. FEMA Effective FIRM Panel 25009C0083F (7/3/2012)

3.2 Evaluation of Data Collected

3.2.a – USGS LIDAR

USGS LIDAR shot in 2021 was acquired and processed into 1-ft contours to use in watershed delineation on the Massachusetts section. USGS LIDAR shot in 2019 - 2020 was acquired and processed into 1-ft contours to use in watershed delineation on the New Hampshire section.

3.2.b – Land Use Data

Land use data was acquired to use in curve map delineation. Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS was used on the Massachusetts section. Land Use Data from New Hampshire Geodata Portal by NH GRANIT was used on the New Hampshire section.

3.2.c – USGS StreamStats

USGS StreamStats data was run to provide a starting reference point for watershed size and area which was ultimately refined using the more accurate LIDAR data. The USGS StreamStats report is included as part of **Appendix A** and peak flows are summarized below for reference, but are based on regression analysis of USGS gauges which are not on, nearby or hydrologically similar to the East Meadow River watershed:

USGS StreamStats Peak-Flow Statistics Flow Report Summary						
Recurrence Interval	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Flow Rate (CFS)	92.9	153	200	267	323	382

3.2.d – USGS Gauges

There are no USGS Gauges on East Meadow River. The nearest Gauges are:

- #01100693 MERRIMACK R 0.3 MILES U.S. RT 125 AT HAVERHILL, MA (4.3 miles Southwest)
- #011006712 MERRIMACK RIVER NEAR HAVERHILL, MA (4.5 miles Southwest)
- #01100845 POWWOW RIVER AT MAIN ST AT AMESBURY, MA (6 miles Northeast)

None of the gauged watersheds are on, nearby, or hydrologically similar to East Meadow River and therefore will not be considered in this analysis.

3.2.e – GPI Field Survey mapping

Field survey mapping was performed by GPI within the project limits in February 2024.

3.2.f – FEMA

FEMA has not studied East Meadow River at this location in detail and hydrology is not available from FEMA.

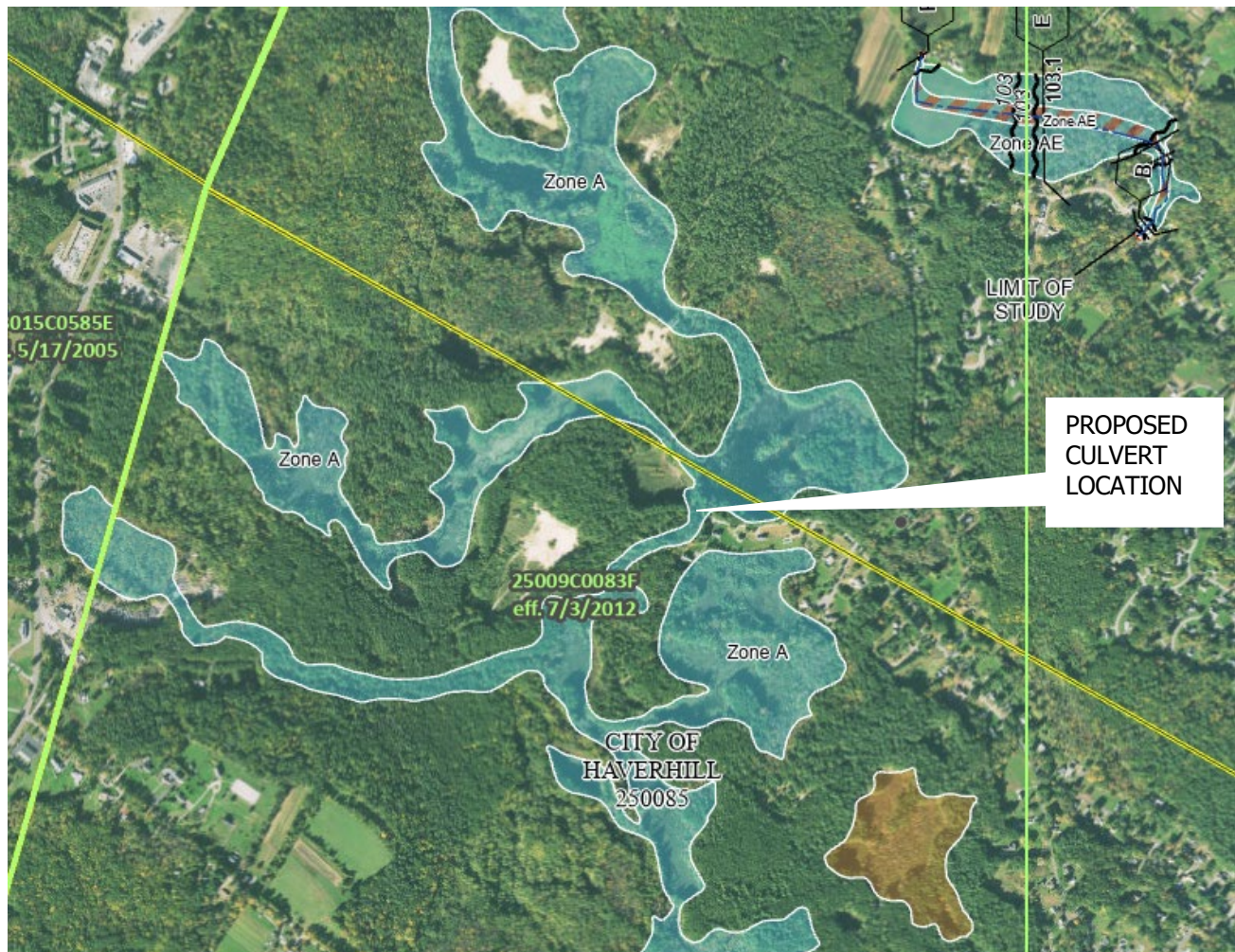


FIGURE 2- FEMA MAPPING OF THE PROJECT LOCATION

4.0 - ENGINEERING METHODS

4.1 Hydrologic Analysis

Inflow hydrographs were generated using NRCS TR-55 methodology. The current NOAA#14 24-hour rainfalls for Haverhill, MA, and the NRCS Type III rainfall distribution will be applied. Storms to be analyzed for adverse impacts assessment are 2-, 5-, 10-, 25-, 50- and 100-year.

The drainage area to the Brandy Brow Road culvert was delineated using 2019 – 2020 and 2021 USGS LIDAR contours.

Table 4.1.a. Summary of Watershed

Watershed ID	Drainage Area (Ac.)	CN	Tc (hours)
Brandy Brow Road	2,322	61	1.29

Table 4.1.b. Summary of Runoff Inflows

Storm Frequency	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Brandy Brow Road (CFS)	212	513	870	1,552	2,268	3,192

*See Drainage Area Map and Tc calculations in **Appendix B**.*

4.2 Hydraulic Analysis

Flood routing for the existing conditions culvert analysis was done using HydroCAD software with the hydrologic parameters generated from above. The model includes the existing, well-defined beaver dam located approximately 150 feet upstream from the culvert.

Elevation/Storage Volume relationships for the ponds upstream of Brandy Brow Road was estimated using Lidar mapping at 1 ft. contour intervals obtained from USGS Lidar, dated 2019 – 2020 and 2021, in datum State Plane NAD83, NAVD88 and the field survey provided from GPI.

A starting water surface elevation of the respective inverts has been assumed in the pond for the culvert (El. 60.67) and at the beaver dam spillway elevation for the dam (El. 66.90) to provide stabilized initial boundary conditions. The Brandy Brow Road culvert has been modeled with reverse slopes under existing conditions based on field survey invert shots. The proposed culvert will closely match the existing downstream stream bed as it is beyond the scope of this project to dredge and realign the stream channel.

4.2.a Existing Conditions Hydraulic Analysis

Existing conditions outlet structure data and road profile data from field survey was used to construct an existing condition discharge rating curve for the outlet control structure (existing culvert). The inflow hydrograph is routed through the “pond” and resulting Water Surface Elevations (WSEL) and discharge outflows from the culvert are analyzed as seen below. Existing culvert opening dimensions and inverts were determined from field survey and can be found in **Appendix C**.

Table 4.2.a Existing Conditions Hydraulic Model Output

Model		Existing		
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
2-Year	Brandy Brow Road	212	212	64.79
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
5-Year	Brandy Brow Road	513	380	67.14
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
10-Year	Brandy Brow Road	868	494	68.52
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
25-Year	Brandy Brow Road	1,545	715	70.36
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
50-Year	Brandy Brow Road	2,255	1,430	71.14
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
100-Year	Brandy Brow Road	3,181	2,456	71.75

**Overtopping occurs at elevation: 69.88 (> 10-year storm)*

Existing conditions HydroCAD Output may be found in Appendix D.

4.2.b Proposed Conditions Hydraulic Analysis

The proposed flood routing model changes the input geometry for the Brandy Brow Road culvert to match the proposed conceptual design plans and the inverts to match the stream bed elevations. The proposed culvert sketch and a sketch showing the available/effective hydraulic opening of the proposed culvert cross section can be found in **Appendix C**. The rest of the model remains unchanged from existing conditions. The WSEL Comparison Table below summarizes these results. The proposed culvert geometry decreases the 10- and 100-year WSEL at the Brandy Brow Culvert by 3.17 ft and 1.87 ft, respectively and no overtopping occurs at Brandy Brow Road for any analyzed storm. Since there are no increases in water surface elevations upstream of Brandy Brow Road, the proposed conditions will not yield any adverse impacts or increase flooding to upstream properties.

Table 4.2.b Proposed Conditions Hydraulic Analysis

Model		Proposed		
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
2-Year	Brandy Brow Road	212	212	62.46
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
5-Year	Brandy Brow Road	513	513	63.97
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
10-Year	Brandy Brow Road	869	869	65.35
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
25-Year	Brandy Brow Road	1,551	1,400	67.14
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
50-Year	Brandy Brow Road	2,265	1,860	68.50
Storm Event	Pond	Peak Inflow (cfs)	Peak Outflow (cfs)	WSEL (ft)
100-Year	Brandy Brow Road	3,188	2,366	69.88

**Overtopping occurs at elevation: 69.88 (> 100-year storm)*

Proposed conditions HydroCAD Output may be found in Appendix D.

Table 4.2.c WSEL Comparison Table

Model		WSEL (ft)		
Storm Event	Pond	Existing	Proposed	Δ
2-Year	Brandy Brow Road	64.79	62.46	-2.33
Storm Event	Pond	Existing	Proposed	Δ
5-Year	Brandy Brow Road	67.14	63.97	-3.17
Storm Event	Pond	Existing	Proposed	Δ
10-Year	Brandy Brow Road	68.52	65.35	-3.17
Storm Event	Pond	Existing	Proposed	Δ
25-Year	Brandy Brow Road	70.36	67.14	-3.22
Storm Event	Pond	Existing	Proposed	Δ
50-Year	Brandy Brow Road	71.14	68.50	-2.64
Storm Event	Pond	Existing	Proposed	Δ
100-Year	Brandy Brow Road	71.75	69.88	-1.87

Potential downstream impacts due to the proposed culvert replacement were analyzed through normal depth calculations at two critical cross-sections downstream of the proposed Brandy Brow Road culvert using. The existing and proposed normal depth calculations along with a map showing where the cross sections are located can be found as part of **Appendix E**. The summary table below and overall results indicate that there are increases in water surface elevations downstream under proposed conditions for the 2-, 5-, 10-, 25- and 50-year storms.

Table 4.2.d WSEL Comparison 50 feet and 200 feet Downstream of Brandy Brow Culvert

Storm Frequency	Existing WSEL (ft)	Proposed WSEL (ft)	Δ (ft)
50 Feet Downstream			
2-Year	62.30	62.30	0.00
5-Year	62.65	62.89	0.24
10-Year	62.86	63.63	0.77
25-Year	63.38	64.20	0.82
50-Year	64.23	64.55	0.32
100-Year	64.88	64.83	-0.05
200 Feet Downstream			
2-Year	60.25	60.26	0.01
5-Year	60.61	60.85	0.24
10-Year	60.81	61.57	0.76
25-Year	61.32	62.09	0.77
50-Year	62.11	62.42	0.31
100-Year	62.72	62.68	-0.04

The increases in WSEL are occurring due to the loss of storage occurring from the expansion of the culvert opening to accommodate the required "1.2 x bank-full" dimension. The increases in water surface elevation should be investigated further to ensure offsite properties are not being affected by the increases in water surface elevation for said storms due the culvert replacement.

4.3 Scour/Stability Analysis

4.3.a Scour Hole Geometry Estimation at the Culvert Outlet

The local scour hole geometry downstream of the proposed culvert outlet has been calculated using parameters obtained from the HEC-RAS model in accordance with the guidelines set forth in HEC-14 Chapter 5. Soil sampling was conducted at the upstream and downstream sides of the proposed culvert by GEI Consultants. The results can be found in their report dated February 12, 2024 included as part of **Appendix F**. Per the soil investigation report, the stream bed material (both upstream and downstream) is classified as "fine to coarse gravel and fine to coarse sand". Therefore, the scour hole geometry calculations have been done for the outflow from the proposed culvert during the 25-year design storm event and 50-year check storm event for "cohesionless" soil criteria.

Table 4.3.a Design Peak Flow Rates

Alternative	Return Frequency (year)	Peak Flow Rate (Q) (cfs)
Proposed	Design (25)	1,400
	Check (50)	1,860

Table 4.3.b Summary of Calculated Scour for Culvert

Alternative	Return Frequency (year)	Upstream Invert	Ymax (ft)	Yo (ft)	Scour Depth: Ys (ft)	Scour Elevation at Culvert Entrance
Proposed	Design (25)	60.55	9.2	6.47	2.7	57.8
	Check (50)	60.55	13.1	7.33	5.7	54.8

Supporting computations for the scour hole geometry calculations follow in **Appendix F**.

4.3.b Scour Countermeasure Design

Based on HEC-23 criteria for scour countermeasures for open-bottom culverts, riprap stream bottom and abutment protection been designed/sized as the scour countermeasure at the upstream side of the proposed culvert. The riprap design has been done in accordance with HEC-23 Design Guideline 18. The dimensions for the riprap basin have been calculated using the effective culvert diameter for the 25-year and 50-year peak culvert outflows. The detailed calculations can be found in **Appendix F** of this report.

Table 4.3.c: Summary of Riprap Protection Design (25-year and 50-year)

Riprap Protection Summary Table: 25-Year Design Storm	
Component	Measurement (ft)
Riprap Size (D50) * Minimum *	1.9
Top of Footing Elevation	56.8
Riprap Layer Thickness, Y _{tot}	5.7
Riprap Top Width, W _t	5.7
Riprap Bottom Width, W _b	25.8

Riprap Protection Summary Table: 50-Year Design Storm	
Component	Measurement (ft)
Riprap Size (D50) * Minimum *	1.9
Top of Footing Elevation	56.8
Riprap Layer Thickness, Y _{tot}	5.7
Riprap Top Width, W _t	5.7
Riprap Bottom Width, W _b	25.8

5.0 - CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The Brandy Broad Road culvert replacement, as proposed, is designed with an openness ratio to comply with the stream crossing standards set forth by MassDOT. The proposed water surface elevations at the upstream end of the Brandy Brow culvert will not adversely impact offsite properties. However, the downstream water surface elevations increased for the 2-, 5-, 10-, 25- and 50-year storms due to the loss of storage caused by increasing the hydraulic capacity of the proposed culvert. The increases in water surface elevation should be investigated further to ensure offsite properties are not being affected by the increases in water surface elevation for said storms due the culvert replacement.

5.2 Recommendations

The proposed culvert can safely convey the 10-year design flood event without overtopping the roadway. The proposed structure will have a downstream impact on the stream hydraulics of East Meadow River due to the culvert replacement that should be investigated further to make sure no offsite properties are being flooded for the smaller storms discussed throughout this report. The information in **Table 6** (which follows) should be presented within **the Hydraulic Data Tables** in the General Notes of the Culvert Sketch Plans for the road crossing.

Table 6

**Proposed Culvert over East Meadow River
City of Haverhill
Essex County, MA**

Hydraulic Data

Drainage Area (At culvert)	3.63 mi²
Design Discharge (At culvert)	869 Ft³/s
Design Frequency	10 Year
Design Flood Stage	65.35
Design Velocity	7.09 fps

Base (100-Year) Flood Data

100 Year Flood Discharge (Model)	2,366 Ft³/s
100 Year Flood Stage	69.88 Ft

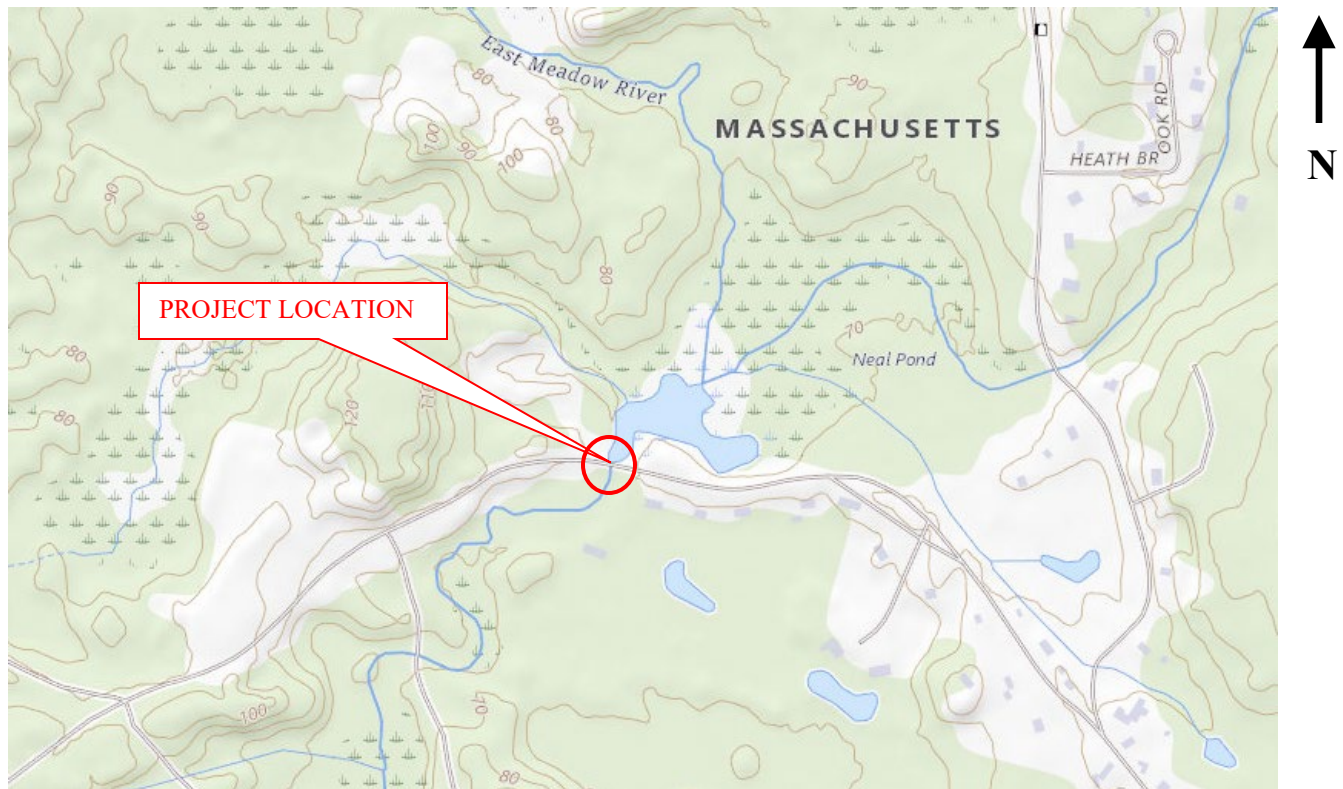
Floods Of Record – None Documented

History Of Ice Floes: None Documented

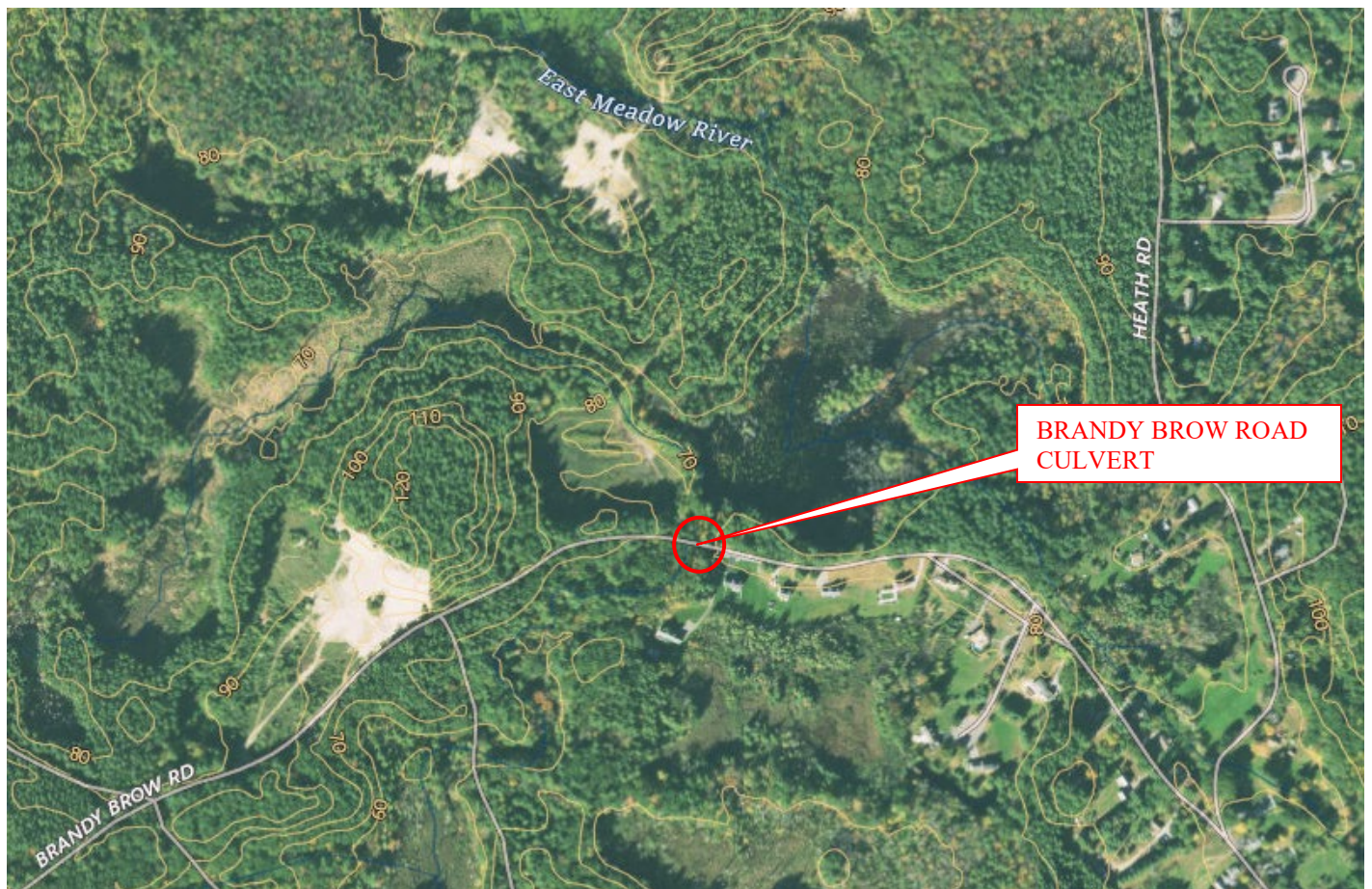
Evidence Of Scour Or Erosion: N/A

APPENDIX A

Location Map, Site Photos and USGS StreamStats Report



Source: USGS Topo 7.5-minute series- Haverhill Quadrangle (Massachusetts- Essex County)



LOCATION MAP

GPI



Brandy Brow Road Culvert (Upstream)



Brandy Brow Road Upstream



Brandy Brow Road Culvert (Downstream)



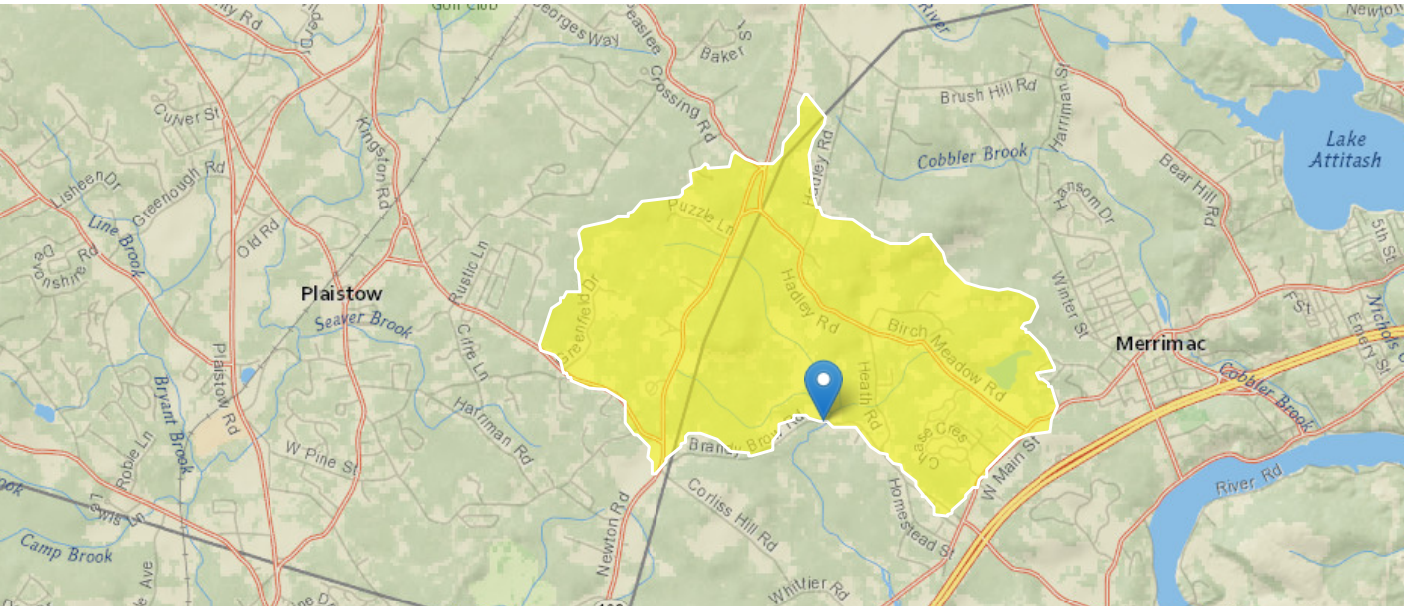
Brandy Brow Road Downstream



Inside Brandy Brow Road Culvert (Downstream)

Brandy Brow Road StreamStats Report

Region ID: MA
Workspace ID: MA20240314155827473000
Clicked Point (Latitude, Longitude): 42.82666, -71.04049
Time: 2024-03-14 11:58:51 -0400



+ Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	3.64	square miles
ELEV	Mean Basin Elevation	136	feet
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	12.04	percent

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Peak Statewide 2016 5156]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	3.64	square miles	0.16	512
ELEV	Mean Basin Elevation	136	feet	80.6	1948
LC06STOR	Percent Storage from NLCD2006	12.04	percent	0	32.3

Peak-Flow Statistics Flow Report [Peak Statewide 2016 5156]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIL	PIU	ASEp
50-percent AEP flood	92.9	ft^3/s	47.5	182	42.3

Statistic	Value	Unit	PIL	PIU	ASEp
20-percent AEP flood	153	ft ³ /s	77.1	304	43.4
10-percent AEP flood	200	ft ³ /s	98.4	406	44.7
4-percent AEP flood	267	ft ³ /s	127	561	47.1
2-percent AEP flood	323	ft ³ /s	149	701	49.4
1-percent AEP flood	382	ft ³ /s	171	855	51.8
0.5-percent AEP flood	446	ft ³ /s	193	1030	54.1
0.2-percent AEP flood	537	ft ³ /s	222	1300	57.6

Peak-Flow Statistics Citations

Zarriello, P.J.,2017, Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016–5156, 99 p. (<https://dx.doi.org/10.3133/sir20165156>)

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

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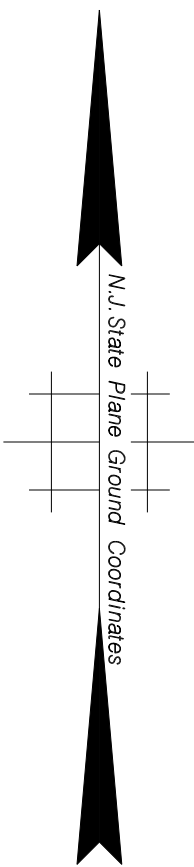
Application Version: 4.19.4

StreamStats Services Version: 1.2.22

NSS Services Version: 2.2.1

APPENDIX B

Drainage Area Map, Curve Number Map and Soils Maps



WATERSHED ID	DRAINAGE AREA (ACRES)	CN	Tc (HRS)
BRANDY BROW ROAD	2322	61	1.29

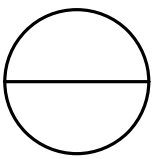
N.T.S.

- NOTE:
- LIDAR CONTOURS UTILIZED FOR DRAINAGE AREA DELINEATION
 - 2019-2020 USGS NEW HAMPSHIRE COSTAL LIDAR CONTOURS ARE IN 1FOOT INTERVALS

DRAINAGE AREA MAP

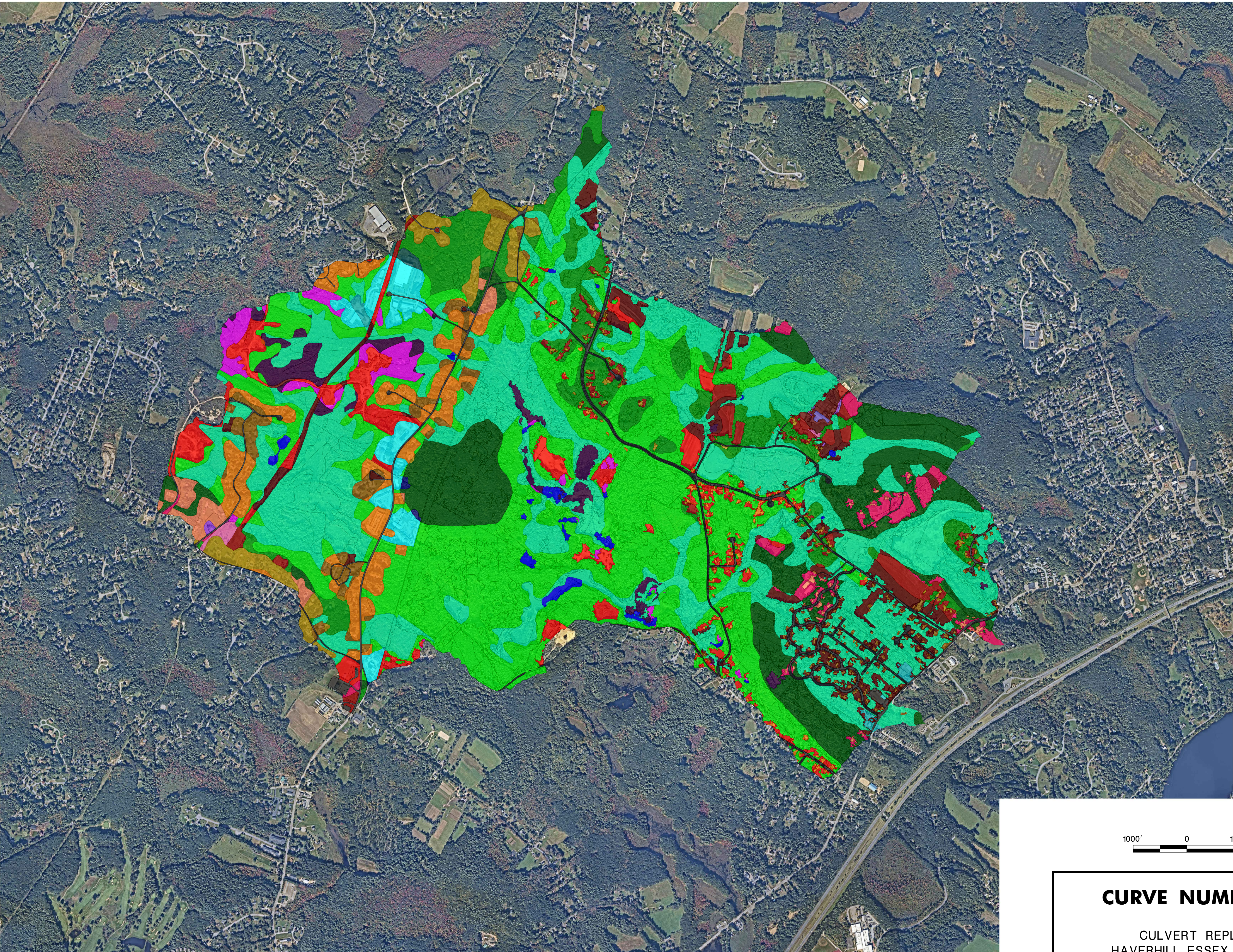
CULVERT REPLACEMENT
HAVERHILL, ESSEX COUNTY, MA

GREENMAN-PEDERSEN, INC.
CERTIFICATION OF AUTHORIZATION NO. 24GA27959500
VALERIE A. HRABAL



LEGEND

- IMPERVIOUS
- BRUSH - A
- BRUSH - B
- BRUSH - C
- BRUSH - D
- COMMERCIAL - A
- COMMERCIAL - B
- COMMERCIAL - C
- COMMERCIAL - D
- FARMSTEADS - B
- FARMSTEADS - C
- FARMSTEADS - D
- OPEN SPACE - A
- OPEN SPACE - B
- OPEN SPACE - C
- OPEN SPACE - D
- RESIDENTIAL 0.25 AC - A
- RESIDENTIAL 0.25 AC - B
- RESIDENTIAL 0.25 AC - C
- RESIDENTIAL 0.25 AC - D
- WOODS - A
- WOODS - B
- WOODS - C
- WOODS - D
- WATER



1000' 0 1000' 2000'

CURVE NUMBER MAP

CULVERT REPLACEMENT
HAVERHILL, ESSEX COUNTY, MA

GREENMAN-PEDERSEN, INC.
CERTIFICATION OF AUTHORIZATION NO. 24GA27959500

VALERIE A. HRABAL



United States
Department of
Agriculture

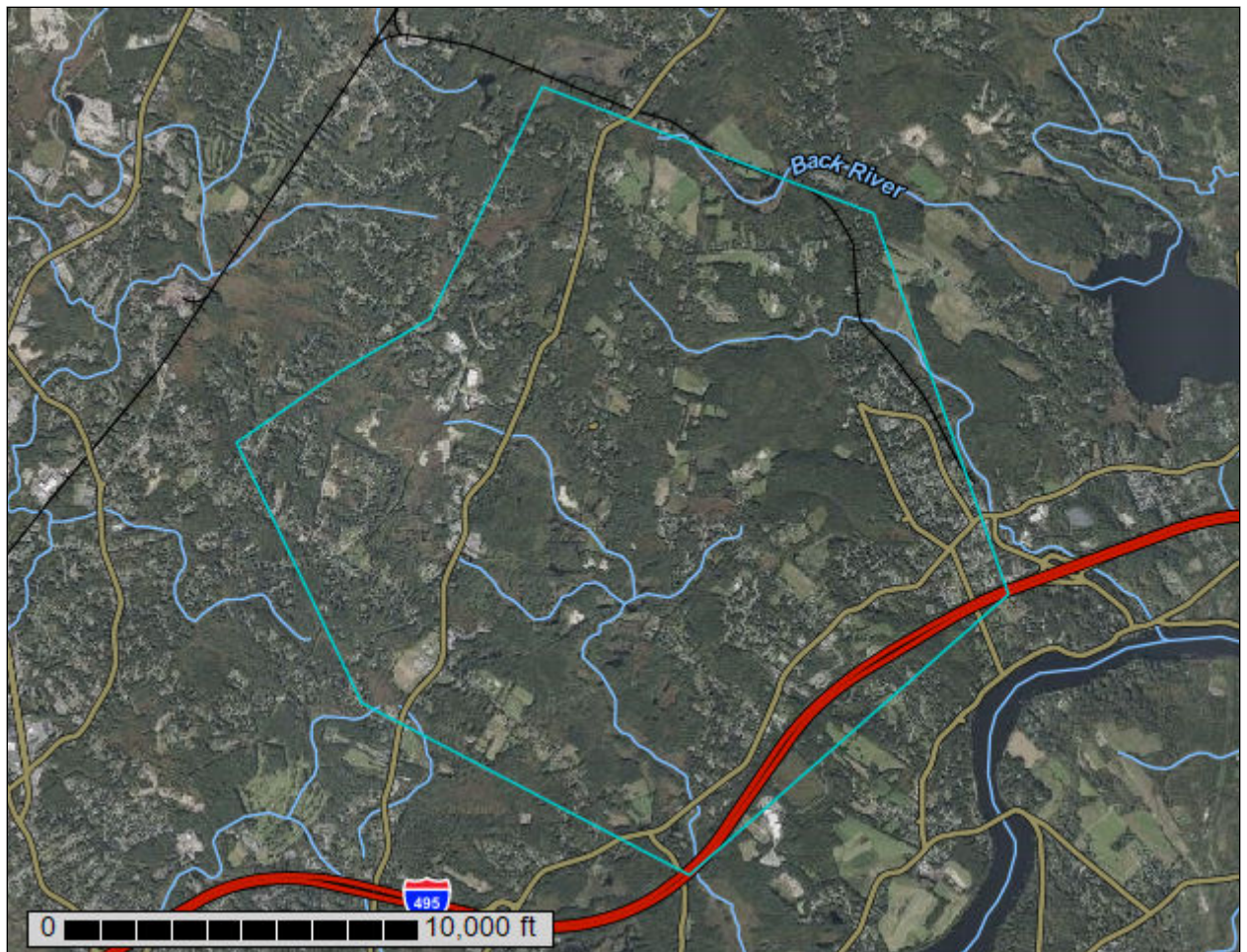
NRCS

Natural
Resources
Conservation
Service

A product of the National
Cooperative Soil Survey,
a joint effort of the United
States Department of
Agriculture and other
Federal agencies, State
agencies including the
Agricultural Experiment
Stations, and local
participants

Custom Soil Resource Report for Essex County, Massachusetts, Northern Part; and Rockingham County, New Hampshire

Haverhill HSG Report



February 29, 2024

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (<http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/>) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (<https://offices.sc.egov.usda.gov/locator/app?agency=nrcs>) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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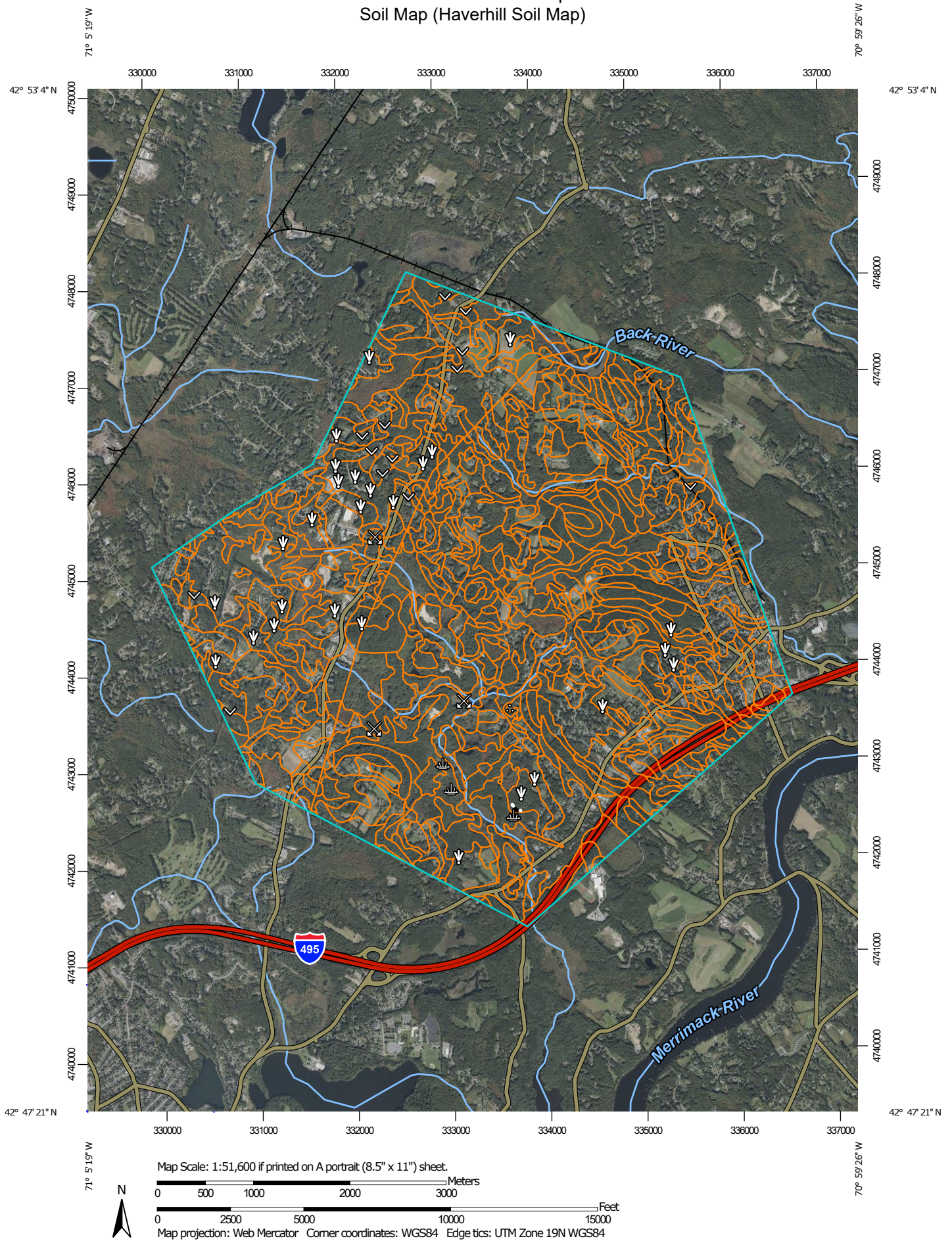
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Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report Soil Map (Haverhill Soil Map)



Custom Soil Resource Report

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Unit Polygons

 Soil Map Unit Lines

 Soil Map Unit Points

Special Point Features

 Blowout

 Borrow Pit

 Clay Spot

 Closed Depression

 Gravel Pit

 Gravelly Spot

 Landfill

 Lava Flow

 Marsh or swamp

 Mine or Quarry

 Miscellaneous Water

 Perennial Water

 Rock Outcrop

 Saline Spot

 Sandy Spot

 Severely Eroded Spot

 Sinkhole

 Slide or Slip

 Sodic Spot

 Spoil Area

 Stony Spot

 Very Stony Spot

 Wet Spot

 Other

 Special Line Features

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 scales ranging from 1:15,800 to 1:24,000.

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

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL:

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 19, Sep 10, 2023

Soil Survey Area: Rockingham County, New Hampshire

Survey Area Data: Version 26, Aug 22, 2023

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

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

Date(s) aerial images were photographed: Mar 1, 2023—Sep 1, 2023

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND

MAP INFORMATION

imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend (Haverhill Soil Map)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Water	5.1	0.1%
6A	Scarboro mucky fine sandy loam, 0 to 3 percent slopes	129.7	1.9%
16A	Scantic silt loam, 0 to 3 percent slopes	10.6	0.2%
30A	Raynham silt loam, 0 to 3 percent slopes	10.7	0.2%
31A	Walpole sandy loam, 0 to 3 percent slopes	17.4	0.3%
31B	Walpole fine sandy loam, 3 to 8 percent slopes	10.4	0.2%
32A	Wareham loamy sand, 0 to 3 percent slopes	26.0	0.4%
32B	Wareham loamy sand, 3 to 8 percent slopes	14.1	0.2%
38A	Pipestone loamy sand, 0 to 3 percent slopes	41.2	0.6%
40A	Swanton fine sandy loam, 0 to 3 percent slopes	10.3	0.2%
51A	Swansea muck, 0 to 1 percent slopes	28.8	0.4%
52A	Freetown muck, 0 to 1 percent slopes	295.1	4.4%
67A	Leicester fine sandy loam, 0 to 3 percent slopes	38.9	0.6%
67B	Leicester fine sandy loam, 3 to 8 percent slopes	3.4	0.1%
70B	Ridgebury fine sandy loam, 3 to 8 percent slopes	19.1	0.3%
72A	Whitman fine sandy loam, 0 to 3 percent slopes	6.9	0.1%
73A	Whitman fine sandy loam, 0 to 3 percent slopes, extremely stony	112.1	1.7%
240A	Elmwood fine sandy loam, 0 to 3 percent slopes	6.3	0.1%
240B	Elmwood fine sandy loam, 3 to 8 percent slopes	0.9	0.0%
253A	Hinckley loamy sand, 0 to 3 percent slopes	1.5	0.0%
253B	Hinckley loamy sand, 3 to 8 percent slopes	194.9	2.9%
253C	Hinckley loamy sand, 8 to 15 percent slopes	184.9	2.8%

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Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
253D	Hinckley loamy sand, 15 to 25 percent slopes	45.0	0.7%
254A	Merrimac fine sandy loam, 0 to 3 percent slopes	1.7	0.0%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	106.1	1.6%
254C	Merrimac fine sandy loam, 8 to 15 percent slopes	23.6	0.4%
254D	Merrimac fine sandy loam, 15 to 25 percent slopes	23.1	0.3%
255B	Windsor loamy sand, 3 to 8 percent slopes	95.1	1.4%
255C	Windsor loamy sand, 8 to 15 percent slopes	103.1	1.5%
255D	Windsor loamy sand, 15 to 25 percent slopes	27.0	0.4%
256A	Deerfield loamy fine sand, 0 to 3 percent slopes	136.2	2.0%
257E	Hinckley and Windsor soils, 25 to 35 percent slopes	159.4	2.4%
259A	Carver loamy coarse sand, 0 to 3 percent slopes	44.9	0.7%
259B	Carver loamy coarse sand, 3 to 8 percent slopes	59.6	0.9%
260A	Sudbury fine sandy loam, 0 to 3 percent slopes	12.3	0.2%
260B	Sudbury fine sandy loam, 3 to 8 percent slopes	35.7	0.5%
305B	Paxton fine sandy loam, 3 to 8 percent slopes	108.6	1.6%
305C	Paxton fine sandy loam, 8 to 15 percent slopes	89.9	1.3%
305D	Paxton fine sandy loam, 15 to 25 percent slopes	31.4	0.5%
306B	Paxton fine sandy loam, 0 to 8 percent slopes, very stony	103.4	1.5%
306C	Paxton fine sandy loam, 8 to 15 percent slopes, very stony	68.3	1.0%
306D	Paxton fine sandy loam, 15 to 25 percent slopes, very stony	137.5	2.1%
307C	Paxton fine sandy loam, 8 to 15 percent slopes, extremely stony	11.5	0.2%
307D	Paxton fine sandy loam, 15 to 25 percent slopes, extremely stony	1.3	0.0%
307E	Paxton fine sandy loam, 25 to 35 percent slopes, extremely stony	167.7	2.5%

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Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
310A	Woodbridge fine sandy loam, 0 to 3 percent slopes	48.2	0.7%
310B	Woodbridge fine sandy loam, 3 to 8 percent slopes	74.5	1.1%
310C	Woodbridge fine sandy loam, 8 to 15 percent slopes	19.6	0.3%
311B	Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony	201.3	3.0%
311C	Woodbridge fine sandy loam, 8 to 15 percent slopes, very stony	35.7	0.5%
311D	Woodbridge fine sandy loam, 15 to 25 percent slopes, very stony	0.0	0.0%
405B	Charlton fine sandy loam, 3 to 8 percent slopes	29.6	0.4%
405C	Charlton fine sandy loam, 8 to 15 percent slopes	24.0	0.4%
405D	Charlton fine sandy loam, 15 to 25 percent slopes	5.3	0.1%
406B	Charlton fine sandy loam, 3 to 8 percent slopes, very stony	11.6	0.2%
406C	Charlton fine sandy loam, 8 to 15 percent slopes, very stony	2.4	0.0%
406D	Charlton fine sandy loam, 15 to 25 percent slopes, very stony	1.4	0.0%
410A	Sutton fine sandy loam, 0 to 3 percent slopes	46.3	0.7%
410B	Sutton fine sandy loam, 3 to 8 percent slopes	168.3	2.5%
410C	Sutton fine sandy loam, 8 to 15 percent slopes	13.0	0.2%
411B	Sutton fine sandy loam, 0 to 8 percent slopes, very stony	236.3	3.5%
411C	Sutton fine sandy loam, 8 to 15 percent slopes, very stony	62.8	0.9%
420B	Canton fine sandy loam, 3 to 8 percent slopes	115.4	1.7%
420C	Canton fine sandy loam, 8 to 15 percent slopes	32.7	0.5%
421B	Canton fine sandy loam, 0 to 8 percent slopes, very stony	75.1	1.1%
421C	Canton fine sandy loam, 8 to 15 percent slopes, very stony	122.1	1.8%
421D	Canton fine sandy loam, 15 to 25 percent slopes, very stony	58.0	0.9%
600	Pits, gravel	205.5	3.1%
602	Urban land	11.1	0.2%

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Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
651	Udorthents, smoothed	76.0	1.1%
652	Udorthents, refuse substratum	4.7	0.1%
710E	Canton and Charlton fine sandy loams, 15 to 35 percent slopes, extremely stony	9.9	0.1%
711B	Charlton-Rock outcrop-Hollis complex, 3 to 8 percent slopes	3.4	0.1%
715A	Ridgebury and Leicester fine sandy loams, 0 to 3 percent slopes, extremely stony	18.8	0.3%
715B	Ridgebury and Leicester fine sandy loams, 3 to 8 percent slopes, extremely stony	118.2	1.8%
720A	Whately variant fine sandy loam, 0 to 3 percent slopes	6.7	0.1%
Subtotals for Soil Survey Area		4,598.6	68.7%
Totals for Area of Interest		6,697.5	100.0%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
12B	Hinckley loamy sand, 3 to 8 percent slopes	313.0	4.7%
12C	Hinckley loamy sand, 8 to 15 percent slopes	101.5	1.5%
12E	Hinckley loamy sand, 15 to 60 percent slopes	9.8	0.1%
26B	Windsor loamy sand, 3 to 8 percent slopes	104.0	1.6%
29B	Woodbridge fine sandy loam, 3 to 8 percent slopes	13.4	0.2%
42B	Canton fine sandy loam, 3 to 8 percent slopes	303.1	4.5%
42C	Canton fine sandy loam, 8 to 15 percent slopes	220.5	3.3%
42D	Canton gravelly fine sandy loam, 15 to 25 percent slopes	41.7	0.6%
43B	Canton fine sandy loam, 0 to 8 percent slopes, very stony	14.4	0.2%
43C	Canton fine sandy loam, 8 to 15 percent slopes, very stony	17.8	0.3%
43E	Canton gravelly fine sandy loam, 25 to 35 percent slopes, very stony	4.1	0.1%
66B	Paxton fine sandy loam, 3 to 8 percent slopes	13.3	0.2%
66C	Paxton fine sandy loam, 8 to 15 percent slopes	55.4	0.8%
66D	Paxton fine sandy loam, 15 to 25 percent slopes	14.3	0.2%

Custom Soil Resource Report

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
67C	Paxton fine sandy loam, 8 to 15 percent slopes, very stony	7.9	0.1%
67E	Paxton fine sandy loam, 25 to 35 percent slopes, very stony	8.8	0.1%
115	Scarboro muck, coastal lowland, 0 to 3 percent slopes	53.6	0.8%
125	Scarboro muck, very stony	6.3	0.1%
140B	Chatfield-Hollis-Canton complex, 0 to 8 percent slopes, rocky	19.4	0.3%
140C	Chatfield-Hollis-Canton complex, 8 to 15 percent slopes, rocky	6.2	0.1%
295	Freetown mucky peat, 0 to 2 percent slopes	137.6	2.1%
298	Pits, sand and gravel	74.0	1.1%
299	Udorthents, smoothed	1.6	0.0%
313A	Deerfield loamy fine sand, 0 to 3 percent slopes	17.0	0.3%
313B	Deerfield loamy fine sand, 3 to 8 percent slopes	47.2	0.7%
314A	Pipestone sand, 0 to 5 percent slopes	138.6	2.1%
395	Swansea mucky peat, 0 to 2 percent slopes	88.1	1.3%
446B	Scituate-Newfields complex, 3 to 8 percent slopes	173.7	2.6%
495	Natchaug mucky peat, 0 to 2 percent slopes	3.5	0.1%
546A	Walpole very fine sandy loam, 0 to 5 percent slopes	19.5	0.3%
547A	Walpole very fine sandy loam, 0 to 3 percent slopes, very stony	16.6	0.2%
547B	Walpole very fine sandy loam, 3 to 8 percent slopes, very stony	52.7	0.8%
Subtotals for Soil Survey Area		2,098.7	31.3%
Totals for Area of Interest		6,697.5	100.0%

Map Unit Descriptions (Haverhill Soil Map)

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named

according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

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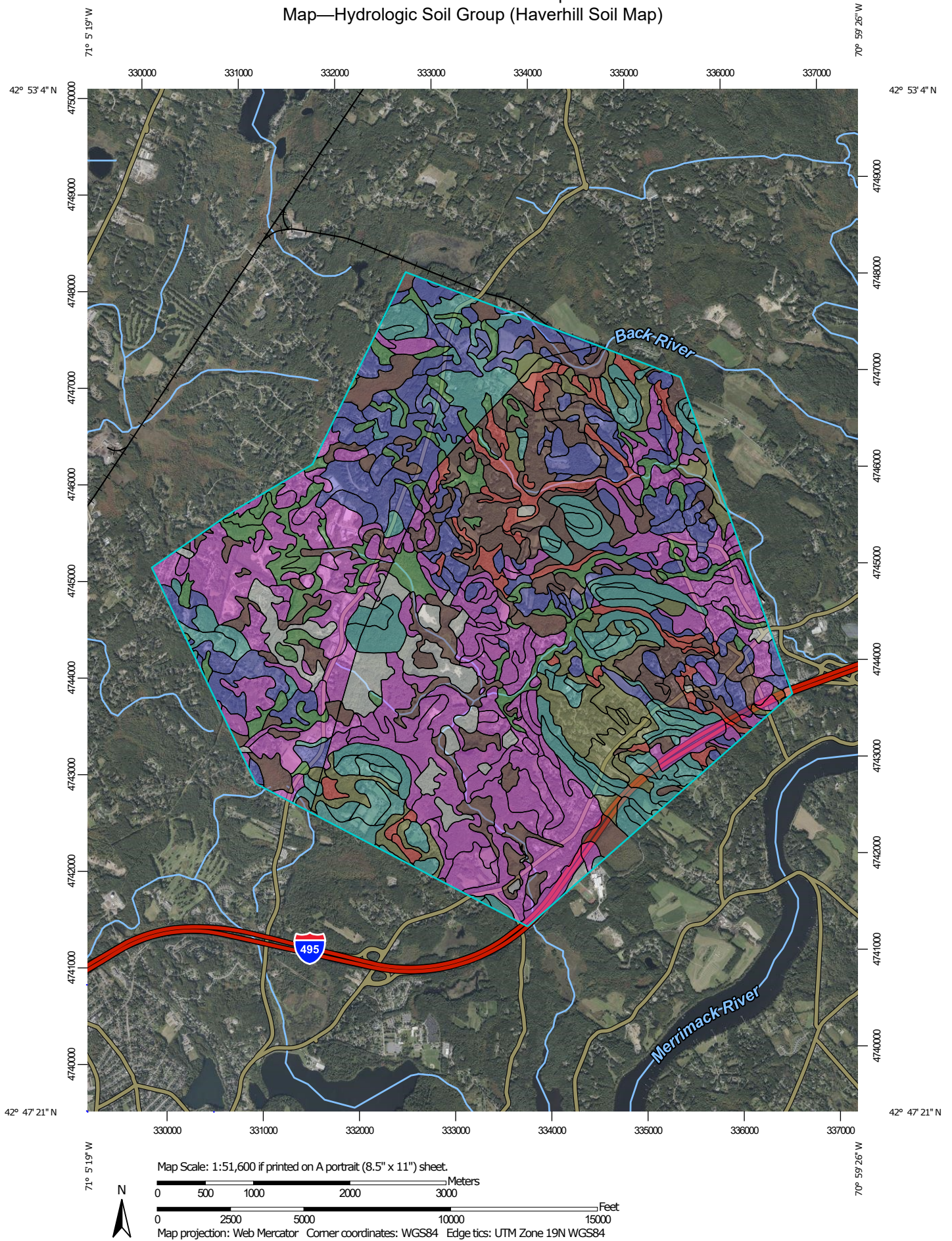
An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Custom Soil Resource Report

Map—Hydrologic Soil Group (Haverhill Soil Map)



Custom Soil Resource Report

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

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

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL:

Coordinate System: Web Mercator (EPSG:3857)

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The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND

MAP INFORMATION

imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—Hydrologic Soil Group (Haverhill Soil Map)

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
1	Water		5.1	0.1%
6A	Scarboro mucky fine sandy loam, 0 to 3 percent slopes	A/D	129.7	1.9%
16A	Scantic silt loam, 0 to 3 percent slopes	C/D	10.6	0.2%
30A	Raynham silt loam, 0 to 3 percent slopes	C/D	10.7	0.2%
31A	Walpole sandy loam, 0 to 3 percent slopes	B/D	17.4	0.3%
31B	Walpole fine sandy loam, 3 to 8 percent slopes	A/D	10.4	0.2%
32A	Wareham loamy sand, 0 to 3 percent slopes	A/D	26.0	0.4%
32B	Wareham loamy sand, 3 to 8 percent slopes	A/D	14.1	0.2%
38A	Pipestone loamy sand, 0 to 3 percent slopes	A	41.2	0.6%
40A	Swanton fine sandy loam, 0 to 3 percent slopes	C/D	10.3	0.2%
51A	Swansea muck, 0 to 1 percent slopes	B/D	28.8	0.4%
52A	Freetown muck, 0 to 1 percent slopes	B/D	295.1	4.4%
67A	Leicester fine sandy loam, 0 to 3 percent slopes	A/D	38.9	0.6%
67B	Leicester fine sandy loam, 3 to 8 percent slopes	A/D	3.4	0.1%
70B	Ridgebury fine sandy loam, 3 to 8 percent slopes	D	19.1	0.3%
72A	Whitman fine sandy loam, 0 to 3 percent slopes	D	6.9	0.1%
73A	Whitman fine sandy loam, 0 to 3 percent slopes, extremely stony	D	112.1	1.7%
240A	Elmwood fine sandy loam, 0 to 3 percent slopes	B	6.3	0.1%
240B	Elmwood fine sandy loam, 3 to 8 percent slopes	B	0.9	0.0%

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Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
253A	Hinckley loamy sand, 0 to 3 percent slopes	A	1.5	0.0%
253B	Hinckley loamy sand, 3 to 8 percent slopes	A	194.9	2.9%
253C	Hinckley loamy sand, 8 to 15 percent slopes	A	184.9	2.8%
253D	Hinckley loamy sand, 15 to 25 percent slopes	A	45.0	0.7%
254A	Merrimac fine sandy loam, 0 to 3 percent slopes	A	1.7	0.0%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	A	106.1	1.6%
254C	Merrimac fine sandy loam, 8 to 15 percent slopes	A	23.6	0.4%
254D	Merrimac fine sandy loam, 15 to 25 percent slopes	A	23.1	0.3%
255B	Windsor loamy sand, 3 to 8 percent slopes	A	95.1	1.4%
255C	Windsor loamy sand, 8 to 15 percent slopes	A	103.1	1.5%
255D	Windsor loamy sand, 15 to 25 percent slopes	A	27.0	0.4%
256A	Deerfield loamy fine sand, 0 to 3 percent slopes	A	136.2	2.0%
257E	Hinckley and Windsor soils, 25 to 35 percent slopes	A	159.4	2.4%
259A	Carver loamy coarse sand, 0 to 3 percent slopes	A	44.9	0.7%
259B	Carver loamy coarse sand, 3 to 8 percent slopes	A	59.6	0.9%
260A	Sudbury fine sandy loam, 0 to 3 percent slopes	B	12.3	0.2%
260B	Sudbury fine sandy loam, 3 to 8 percent slopes	B	35.7	0.5%
305B	Paxton fine sandy loam, 3 to 8 percent slopes	C	108.6	1.6%
305C	Paxton fine sandy loam, 8 to 15 percent slopes	C	89.9	1.3%
305D	Paxton fine sandy loam, 15 to 25 percent slopes	C	31.4	0.5%

Custom Soil Resource Report

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
306B	Paxton fine sandy loam, 0 to 8 percent slopes, very stony	C	103.4	1.5%
306C	Paxton fine sandy loam, 8 to 15 percent slopes, very stony	C	68.3	1.0%
306D	Paxton fine sandy loam, 15 to 25 percent slopes, very stony	C	137.5	2.1%
307C	Paxton fine sandy loam, 8 to 15 percent slopes, extremely stony	C	11.5	0.2%
307D	Paxton fine sandy loam, 15 to 25 percent slopes, extremely stony	C	1.3	0.0%
307E	Paxton fine sandy loam, 25 to 35 percent slopes, extremely stony	C	167.7	2.5%
310A	Woodbridge fine sandy loam, 0 to 3 percent slopes	C/D	48.2	0.7%
310B	Woodbridge fine sandy loam, 3 to 8 percent slopes	C/D	74.5	1.1%
310C	Woodbridge fine sandy loam, 8 to 15 percent slopes	C/D	19.6	0.3%
311B	Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony	C/D	201.3	3.0%
311C	Woodbridge fine sandy loam, 8 to 15 percent slopes, very stony	C/D	35.7	0.5%
311D	Woodbridge fine sandy loam, 15 to 25 percent slopes, very stony	C/D	0	0%
405B	Charlton fine sandy loam, 3 to 8 percent slopes	B	29.6	0.4%
405C	Charlton fine sandy loam, 8 to 15 percent slopes	B	24.0	0.4%
405D	Charlton fine sandy loam, 15 to 25 percent slopes	B	5.3	0.1%
406B	Charlton fine sandy loam, 3 to 8 percent slopes, very stony	B	11.6	0.2%
406C	Charlton fine sandy loam, 8 to 15 percent slopes, very stony	B	2.4	0.0%

Custom Soil Resource Report

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
406D	Charlton fine sandy loam, 15 to 25 percent slopes, very stony	A	1.4	0.0%
410A	Sutton fine sandy loam, 0 to 3 percent slopes	B/D	46.3	0.7%
410B	Sutton fine sandy loam, 3 to 8 percent slopes	B/D	168.3	2.5%
410C	Sutton fine sandy loam, 8 to 15 percent slopes	B/D	13.0	0.2%
411B	Sutton fine sandy loam, 0 to 8 percent slopes, very stony	B/D	236.3	3.5%
411C	Sutton fine sandy loam, 8 to 15 percent slopes, very stony	B/D	62.8	0.9%
420B	Canton fine sandy loam, 3 to 8 percent slopes	B	115.4	1.7%
420C	Canton fine sandy loam, 8 to 15 percent slopes	B	32.7	0.5%
421B	Canton fine sandy loam, 0 to 8 percent slopes, very stony	B	75.1	1.1%
421C	Canton fine sandy loam, 8 to 15 percent slopes, very stony	B	122.1	1.8%
421D	Canton fine sandy loam, 15 to 25 percent slopes, very stony	A	58.0	0.9%
600	Pits, gravel		205.5	3.1%
602	Urban land		11.1	0.2%
651	Udorthents, smoothed	A	76.0	1.1%
652	Udorthents, refuse substratum		4.7	0.1%
710E	Canton and Charlton fine sandy loams, 15 to 35 percent slopes, extremely stony	B	9.9	0.1%
711B	Charlton-Rock outcrop-Hollis complex, 3 to 8 percent slopes	A	3.4	0.1%
715A	Ridgebury and Leicester fine sandy loams, 0 to 3 percent slopes, extremely stony	D	18.8	0.3%
715B	Ridgebury and Leicester fine sandy loams, 3 to 8 percent slopes, extremely stony	D	118.2	1.8%
720A	Whately variant fine sandy loam, 0 to 3 percent slopes	C/D	6.7	0.1%

Custom Soil Resource Report

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Subtotals for Soil Survey Area			4,598.6	68.7%
Totals for Area of Interest			6,697.5	100.0%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
12B	Hinckley loamy sand, 3 to 8 percent slopes	A	313.0	4.7%
12C	Hinckley loamy sand, 8 to 15 percent slopes	A	101.5	1.5%
12E	Hinckley loamy sand, 15 to 60 percent slopes	A	9.8	0.1%
26B	Windsor loamy sand, 3 to 8 percent slopes	A	104.0	1.6%
29B	Woodbridge fine sandy loam, 3 to 8 percent slopes	C/D	13.4	0.2%
42B	Canton fine sandy loam, 3 to 8 percent slopes	B	303.1	4.5%
42C	Canton fine sandy loam, 8 to 15 percent slopes	B	220.5	3.3%
42D	Canton gravelly fine sandy loam, 15 to 25 percent slopes	A	41.7	0.6%
43B	Canton fine sandy loam, 0 to 8 percent slopes, very stony	B	14.4	0.2%
43C	Canton fine sandy loam, 8 to 15 percent slopes, very stony	B	17.8	0.3%
43E	Canton gravelly fine sandy loam, 25 to 35 percent slopes, very stony	A	4.1	0.1%
66B	Paxton fine sandy loam, 3 to 8 percent slopes	C	13.3	0.2%
66C	Paxton fine sandy loam, 8 to 15 percent slopes	C	55.4	0.8%
66D	Paxton fine sandy loam, 15 to 25 percent slopes	C	14.3	0.2%
67C	Paxton fine sandy loam, 8 to 15 percent slopes, very stony	C	7.9	0.1%
67E	Paxton fine sandy loam, 25 to 35 percent slopes, very stony	C	8.8	0.1%
115	Scarboro muck, coastal lowland, 0 to 3 percent slopes	A/D	53.6	0.8%
125	Scarboro muck, very stony	A/D	6.3	0.1%

Custom Soil Resource Report

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
140B	Chatfield-Hollis-Canton complex, 0 to 8 percent slopes, rocky	B	19.4	0.3%
140C	Chatfield-Hollis-Canton complex, 8 to 15 percent slopes, rocky	B	6.2	0.1%
295	Freetown mucky peat, 0 to 2 percent slopes	B/D	137.6	2.1%
298	Pits, sand and gravel		74.0	1.1%
299	Udorthents, smoothed		1.6	0.0%
313A	Deerfield loamy fine sand, 0 to 3 percent slopes	A	17.0	0.3%
313B	Deerfield loamy fine sand, 3 to 8 percent slopes	A	47.2	0.7%
314A	Pipestone sand, 0 to 5 percent slopes	A/D	138.6	2.1%
395	Swansea mucky peat, 0 to 2 percent slopes	B/D	88.1	1.3%
446B	Scituate-Newfields complex, 3 to 8 percent slopes	C	173.7	2.6%
495	Natchaug mucky peat, 0 to 2 percent slopes	B/D	3.5	0.1%
546A	Walpole very fine sandy loam, 0 to 5 percent slopes	A/D	19.5	0.3%
547A	Walpole very fine sandy loam, 0 to 3 percent slopes, very stony	A/D	16.6	0.2%
547B	Walpole very fine sandy loam, 3 to 8 percent slopes, very stony	A/D	52.7	0.8%
Subtotals for Soil Survey Area			2,098.7	31.3%
Totals for Area of Interest			6,697.5	100.0%

Rating Options—Hydrologic Soil Group (Haverhill Soil Map)

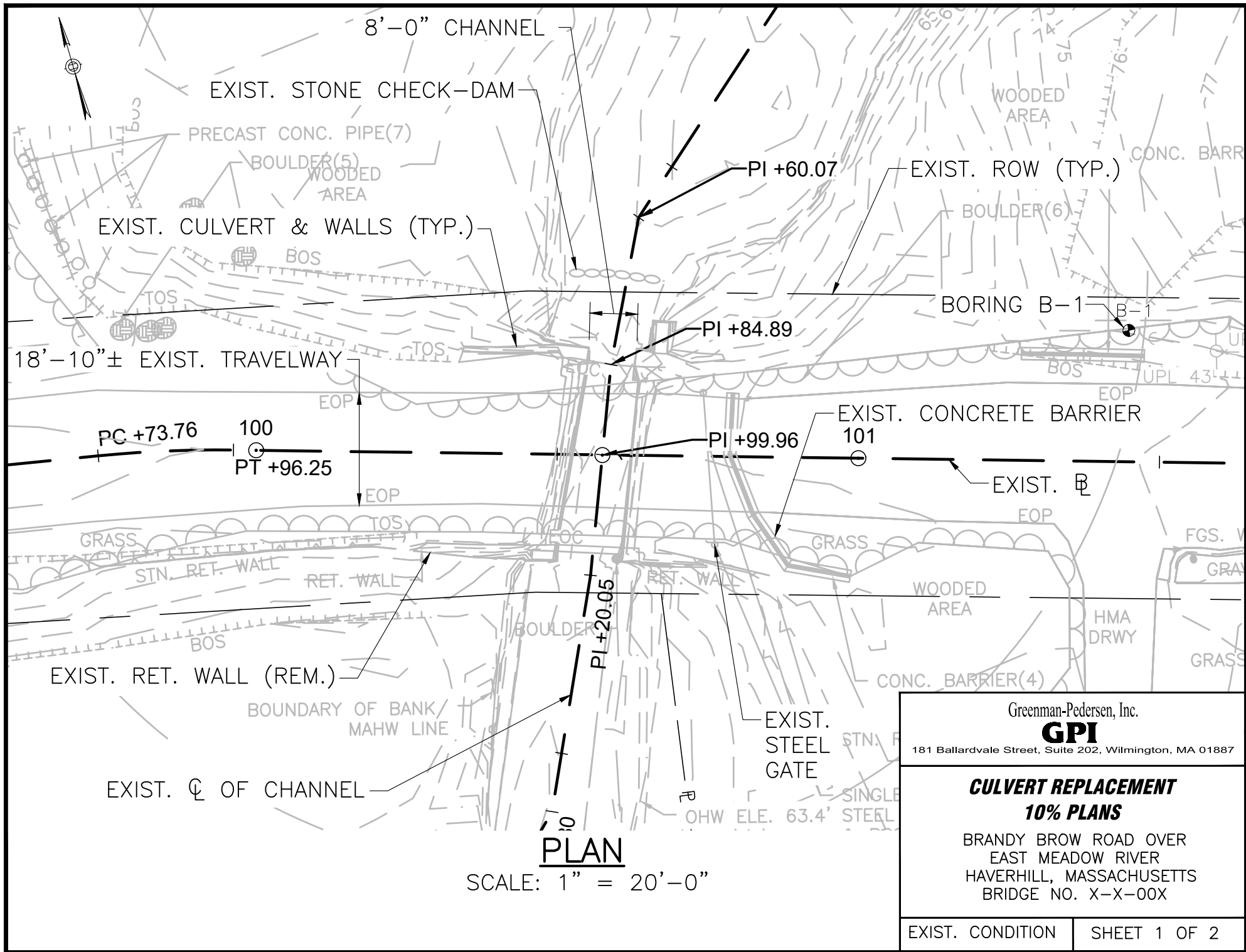
Aggregation Method: Dominant Condition

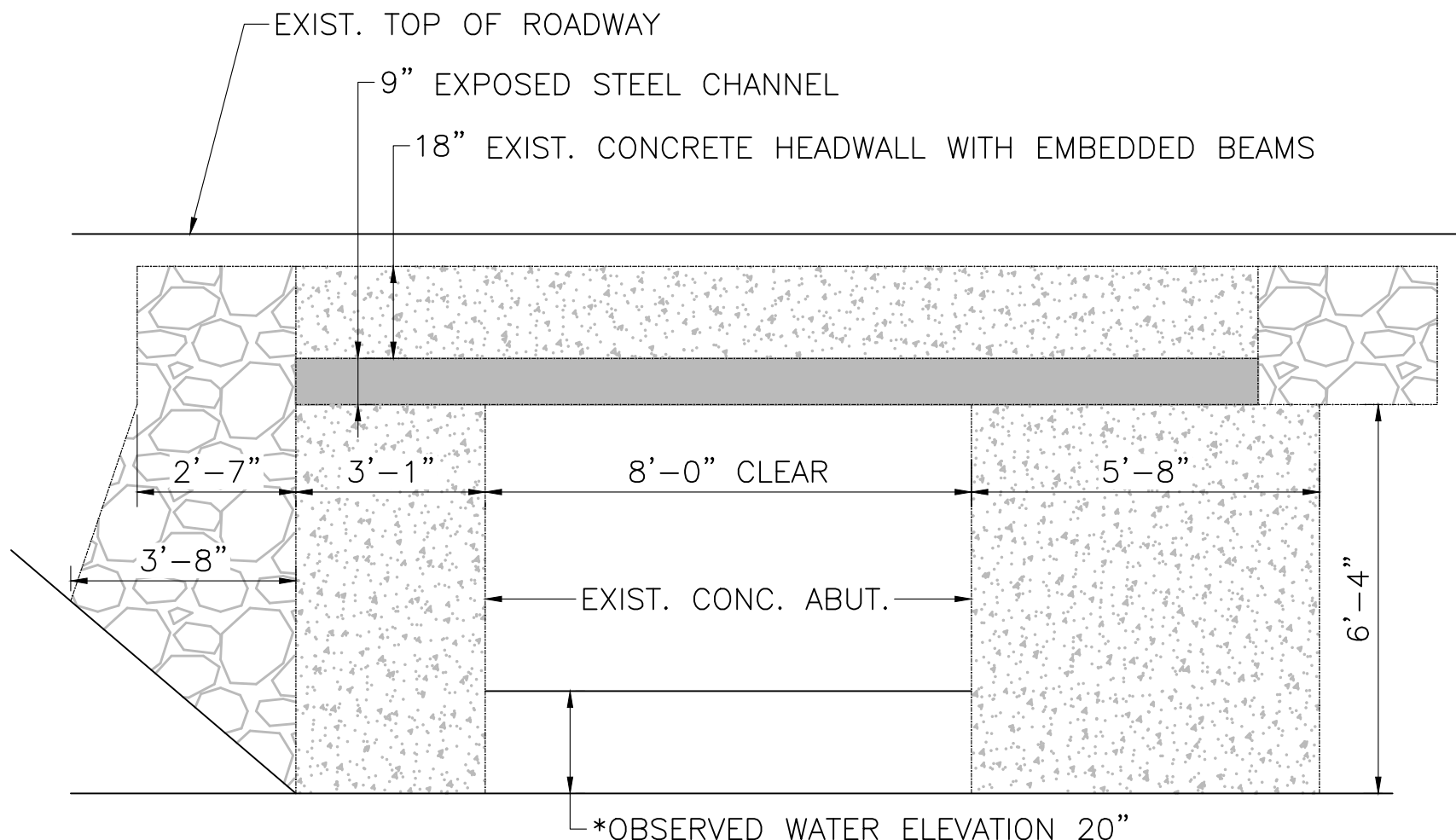
Component Percent Cutoff: None Specified

Tie-break Rule: Higher

APPENDIX C

Existing and Proposed Culvert Plans





NORTH ELEVATION

SCALE: $\frac{3}{8}" = 1'-0"$

*OBSERVATION DATE 2/09/2024

Greenman-Pedersen, Inc.

GPI

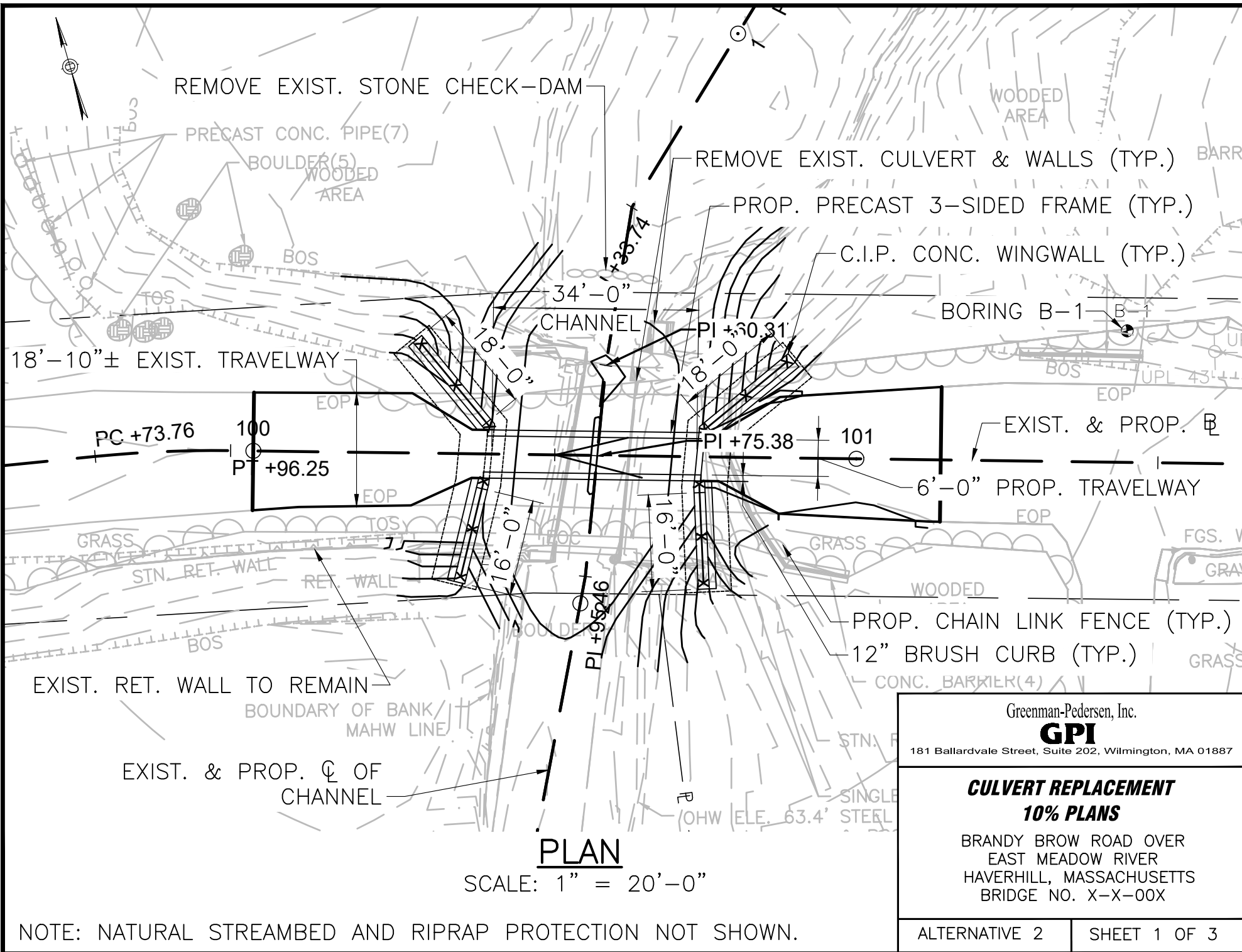
181 Ballardvale Street, Suite 202, Wilmington, MA 01887

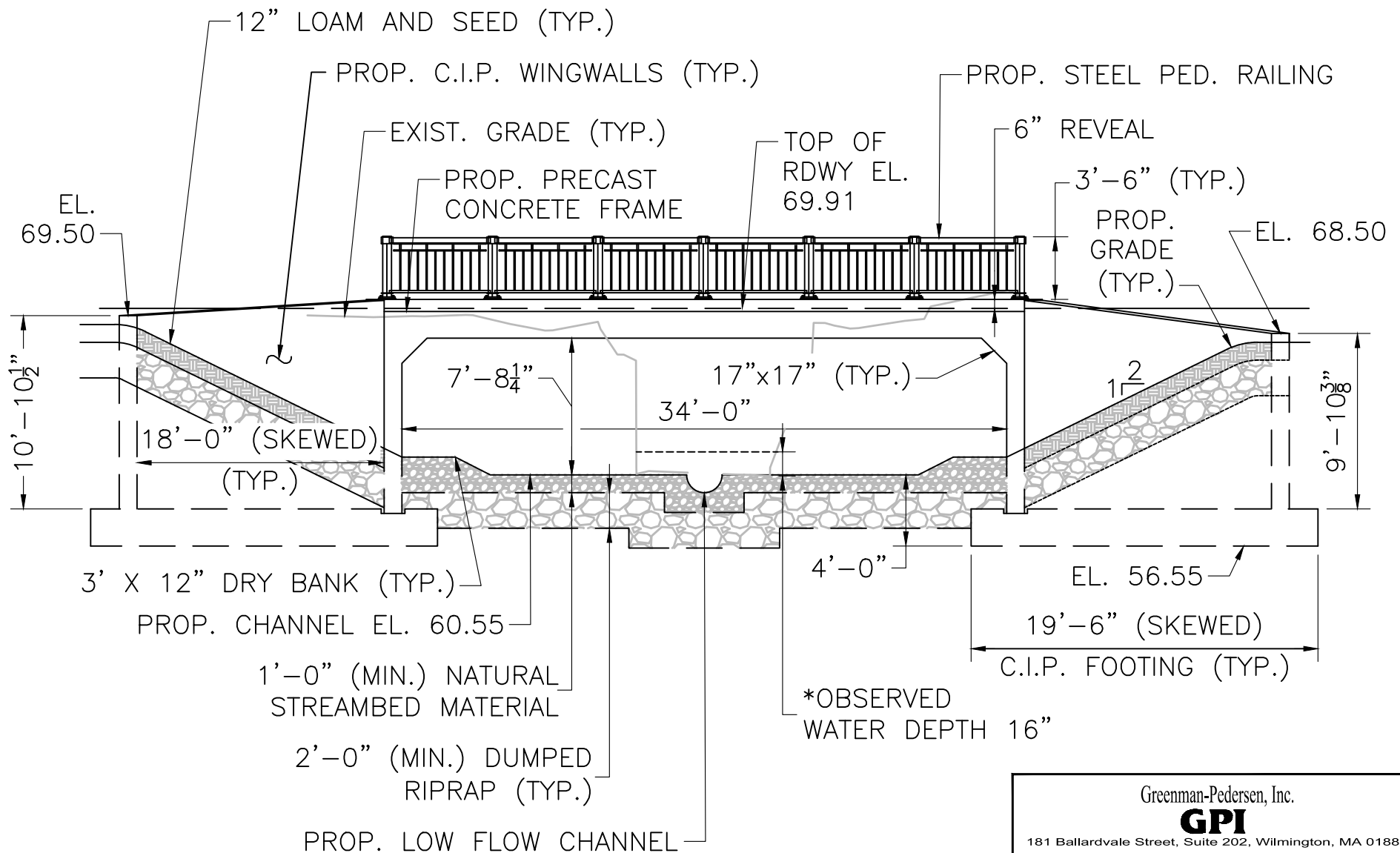
CULVERT REPLACEMENT 10% PLANS

BRANDY BROW ROAD OVER
EAST MEADOW RIVER
HAVERHILL, MASSACHUSETTS
BRIDGE NO. X-X-00X

EXIST. CONDITION

SHEET 2 OF 2





NORTH ELEVATION

SCALE: 1 $\frac{1}{2}$ " = 1'-0"

NOTE: CHAIN LINK FENCES
NOT SHOWN.

OPENNESS RATIO: 31.61 FT
*OBSERVATION DATE 4/16/2024

Greenman-Pedersen, Inc.

GPI

181 Ballardvale Street, Suite 202, Wilmington, MA 01887

CULVERT REPLACEMENT 10% PLANS

BRANDY BROW ROAD OVER
EAST MEADOW RIVER
HAVERHILL, MASSACHUSETTS
BRIDGE NO. X-X-00X

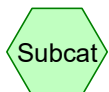
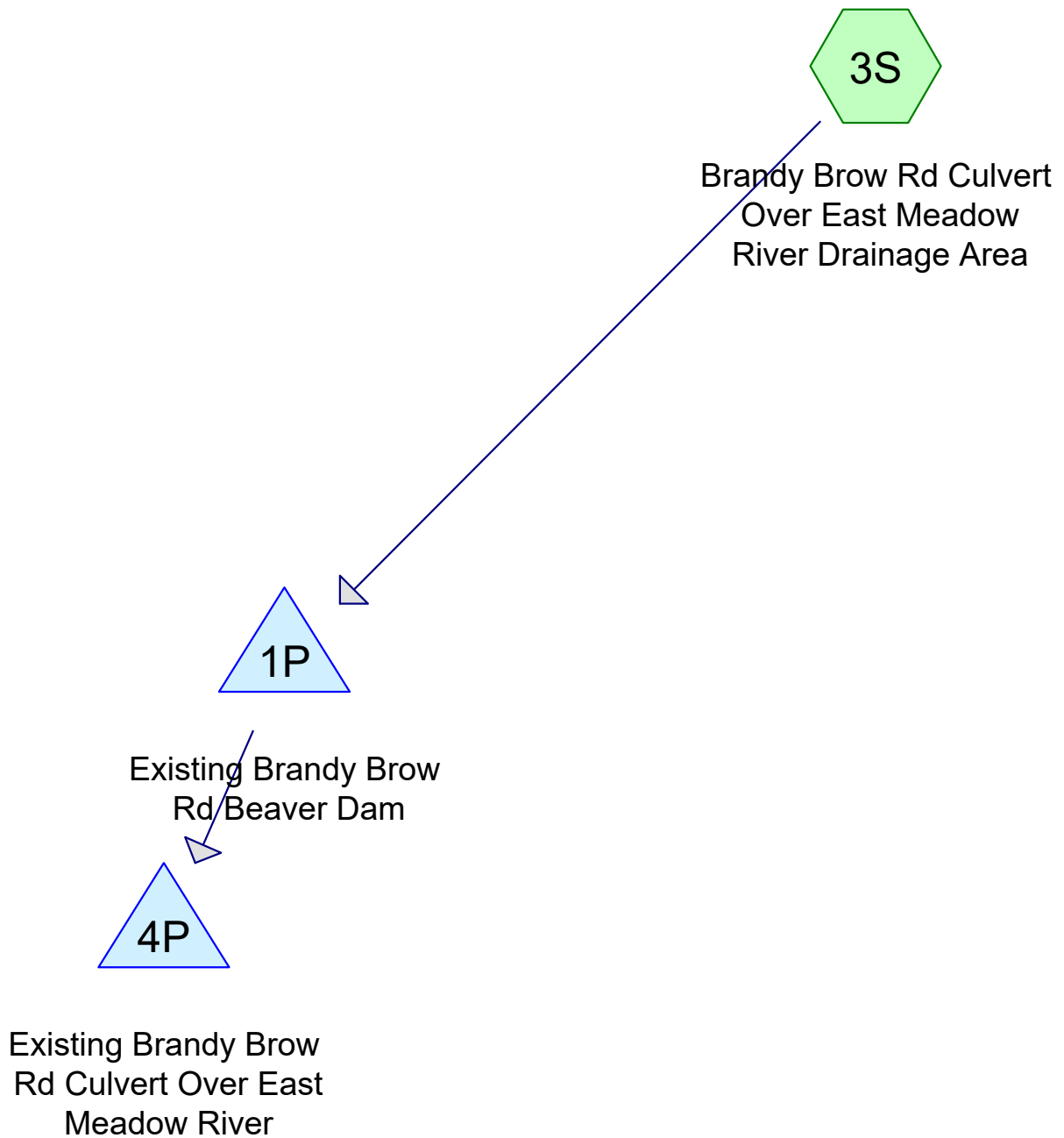
ALTERNATIVE 2

SHEET 2 OF 3

APPENDIX D

Existing and Proposed HydroCAD Flood Routing Model Reports

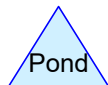
EXISTING CONDITIONS



Subcat



Reach



Pond



Link

Routing Diagram for Haverhill Brandy Brow Culvert

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Haverhill Brandy Brow Culvert

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Project Notes

Rainfall events imported from "NRCS-Rain.txt" for 4127 MA Haverhill Essex County

HydroCAD model for proposed culvert at Brandy Brow Rd. The area was modeled as 1 drainage area.

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA)
MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source:
MassGIS.

(<https://resilientma-mapcenter-mass-eoea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use
Source: (https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Soils Data From the United States Department of Agriculture Natural Resources Conservation
Service's Web Soil Survey. (<https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>)

Drainage Area, land use, and Tc Path for subcatchment was obtained using 1 ft contours. Backup
can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Elevation-area curves to compute storage were obtained using 1 ft contours. Backups can be
found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Haverhill Brandy Brow Culvert

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Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-Year	NRCC 24-hr	D	Default	24.00	1	3.15	2
2	5-Year	NRCC 24-hr	D	Default	24.00	1	4.02	2
3	10-Year	NRCC 24-hr	D	Default	24.00	1	4.83	2
4	25-Year	NRCC 24-hr	D	Default	24.00	1	6.16	2
5	50-Year	NRCC 24-hr	D	Default	24.00	1	7.42	2
6	100-Year	NRCC 24-hr	D	Default	24.00	1	8.94	2

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment3S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=0.42"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=212.09 cfs 81.970 af

Pond 1P: Existing Brandy Brow Rd Peak Elev=67.93' Storage=1.611 af Inflow=212.09 cfs 81.970 af
Outflow=212.06 cfs 81.970 af

Pond 4P: Existing Brandy Brow Rd Peak Elev=64.79' Storage=0.581 af Inflow=212.06 cfs 81.970 af
Primary=211.65 cfs 81.970 af Secondary=0.00 cfs 0.000 af Outflow=211.65 cfs 81.970 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 81.970 af Average Runoff Depth = 0.42"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 212.09 cfs @ 13.30 hrs, Volume= 81.970 af, Depth= 0.42"
Routed to Pond 1P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 2-Year Rainfall=3.15"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Haverhill Brandy Brow Culvert

NRCC 24-hr D 2-Year Rainfall=3.15"

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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

Prepared by Greenman-Pedersen, Inc

NRCC 24-hr D 2-Year Rainfall=3.15"

Printed 7/24/2024

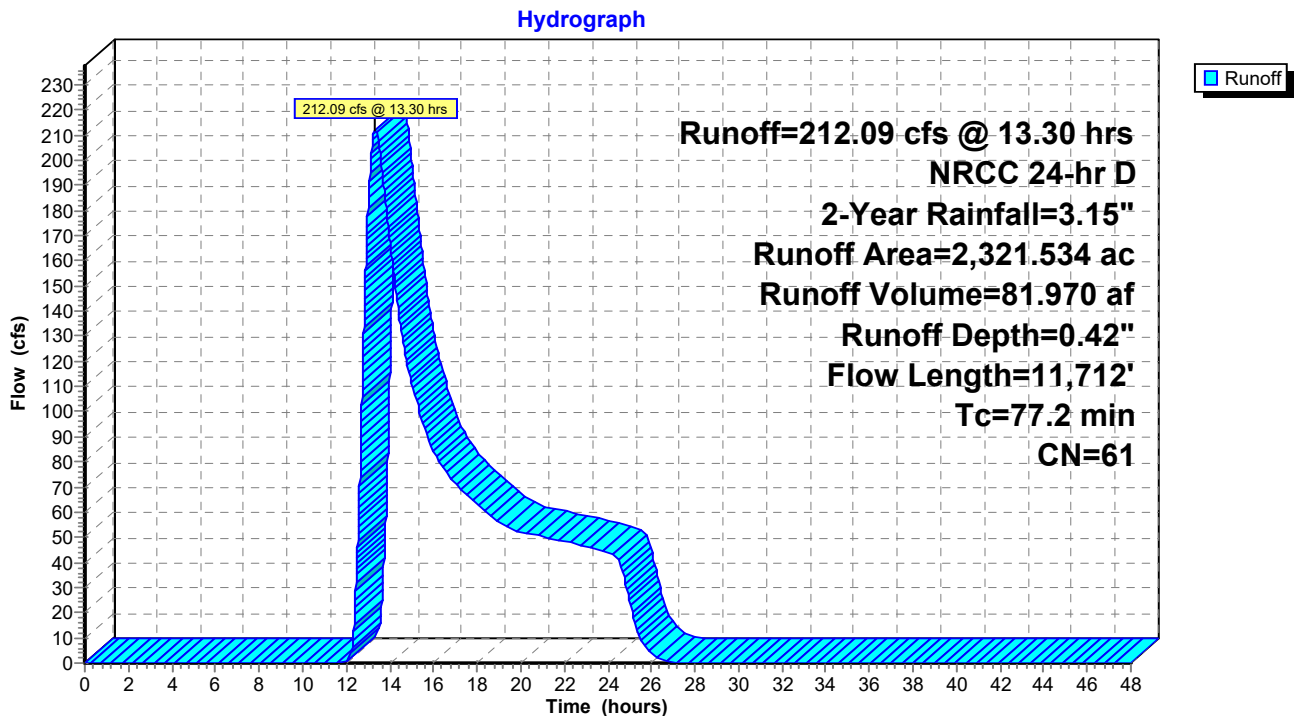
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 0.42" for 2-Year event
 Inflow = 212.09 cfs @ 13.30 hrs, Volume= 81.970 af
 Outflow = 212.06 cfs @ 13.35 hrs, Volume= 81.970 af, Atten= 0%, Lag= 3.2 min
 Primary = 212.06 cfs @ 13.35 hrs, Volume= 81.970 af
 Routed to Pond 4P : Existing Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 67.93' @ 13.35 hrs Surf.Area= 0.357 ac Storage= 1.611 af (0.355 af above start)

Plug-Flow detention time= 13.9 min calculated for 80.714 af (98% of inflow)
 Center-of-Mass det. time= 1.7 min (1,029.4 - 1,027.7)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

Haverhill Brandy Brow Culvert

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Brandy Brow Road Culvert HydroCAD Report - Existing Conditions

NRCC 24-hr D 2-Year Rainfall=3.15"

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125.83

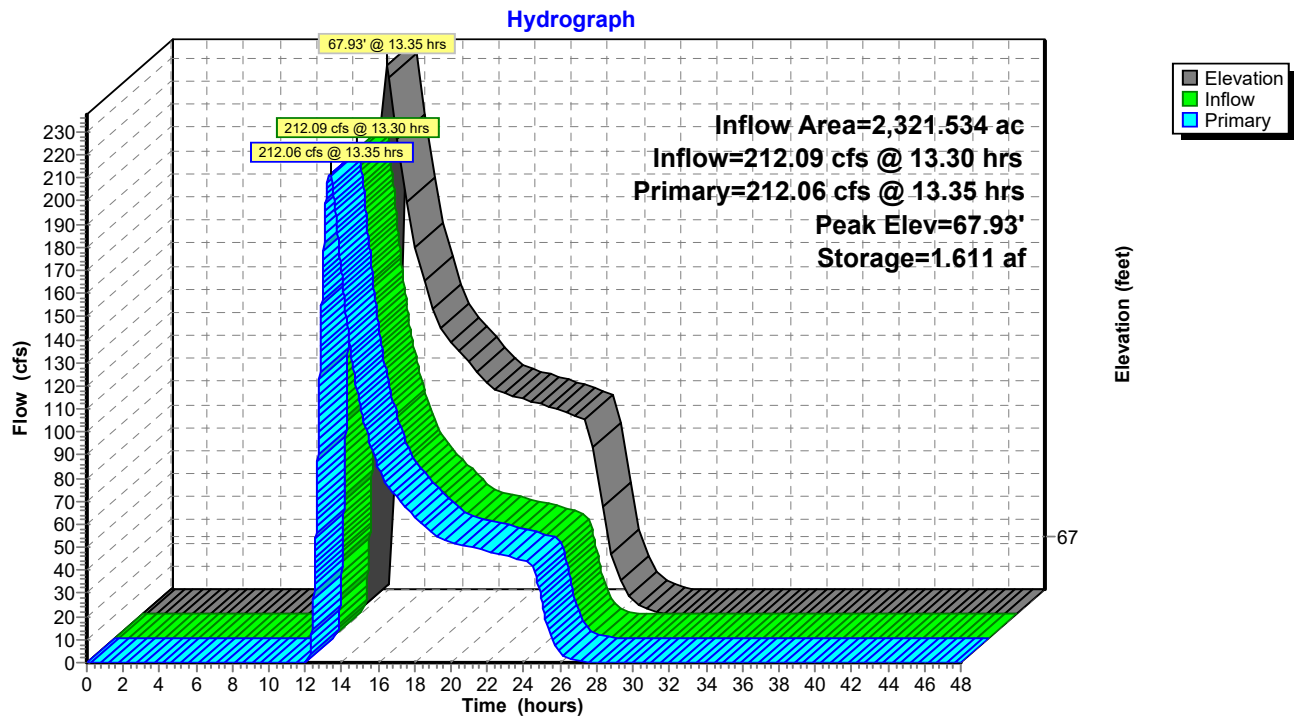
Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00

66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=212.05 cfs @ 13.35 hrs HW=67.93' TW=64.78' (Dynamic Tailwater)

1=Dam Asymmetrical Weir (Weir Controls 212.05 cfs @ 3.17 fps)

Pond 1P: Existing Brandy Brow Rd Beaver Dam



Haverhill Brandy Brow Culvert

NRCC 24-hr D 2-Year Rainfall=3.15"

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Stage-Discharge for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert*NRCC 24-hr D 2-Year Rainfall=3.15"*

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Stage-Area-Storage for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Summary for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 0.42" for 2-Year event
 Inflow = 212.06 cfs @ 13.35 hrs, Volume= 81.970 af
 Outflow = 211.65 cfs @ 13.40 hrs, Volume= 81.970 af, Atten= 0%, Lag= 3.1 min
 Primary = 211.65 cfs @ 13.40 hrs, Volume= 81.970 af
 Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 64.79' @ 13.40 hrs Surf.Area= 0.252 ac Storage= 0.581 af

Plug-Flow detention time= 2.0 min calculated for 81.953 af (100% of inflow)
 Center-of-Mass det. time= 2.0 min (1,031.4 - 1,029.4)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	95.0" W x 76.0" H Box Haverhill Brandy Brow Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 59.81' / 60.67' S= -0.0263 '/' Cc= 0.900 n= 0.013, Flow Area= 50.14 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00 71.00 72.00 73.00

Haverhill Brandy Brow Culvert

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Brandy Brow Road Culvert HydroCAD Report - Existing Conditions

NRCC 24-hr D 2-Year Rainfall=3.15"

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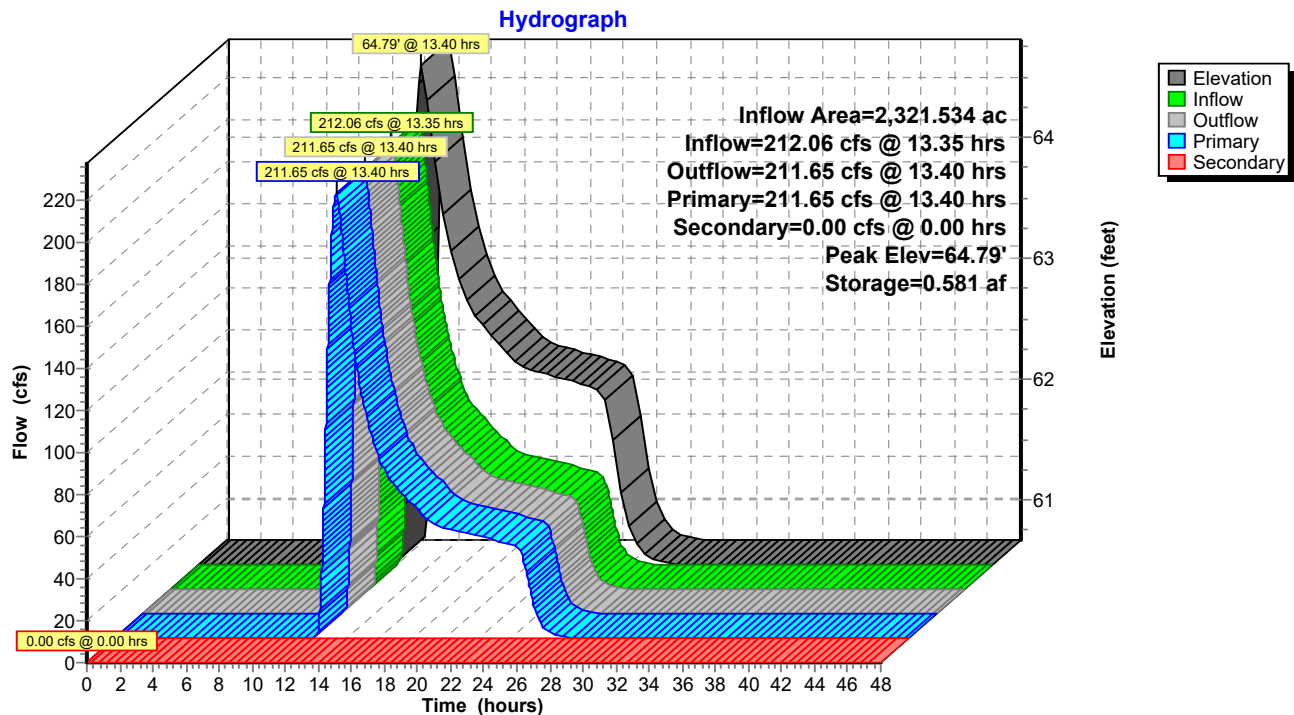
Primary OutFlow Max=211.64 cfs @ 13.40 hrs HW=64.79' (Free Discharge)

↑1=Haverhill Brandy Brow Box Culvert(Barrel Controls 211.64 cfs @ 7.15 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=60.67' (Free Discharge)

↑2=Overtopping Asymmetrical Weir(Controls 0.00 cfs)

Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert*NRCC 24-hr D 2-Year Rainfall=3.15"*

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Stage-Discharge for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	1,104.27	634.62	469.65
60.87	2.27	2.27	0.00	71.07	1,340.36	643.90	696.46
61.07	6.43	6.43	0.00	71.27	1,622.27	653.04	969.23
61.27	11.81	11.81	0.00	71.47	1,944.66	662.05	1,282.61
61.47	18.18	18.18	0.00	71.67	2,305.44	670.93	1,634.51
61.67	25.41	25.41	0.00	71.87	2,703.49	679.69	2,023.80
61.87	33.41	33.41	0.00	72.07	3,138.10	688.32	2,449.78
62.07	42.10	42.10	0.00	72.27	3,607.96	696.85	2,911.11
62.27	51.43	51.43	0.00	72.47	4,111.70	705.26	3,406.43
62.47	61.37	61.37	0.00	72.67	4,648.53	713.58	3,934.95
62.67	71.88	71.88	0.00	72.87	5,217.91	721.79	4,496.12
62.87	82.92	82.92	0.00				
63.07	94.48	94.48	0.00				
63.27	106.54	106.54	0.00				
63.47	119.06	119.06	0.00				
63.67	132.05	132.05	0.00				
63.87	145.47	145.47	0.00				
64.07	159.32	159.32	0.00				
64.27	173.58	173.58	0.00				
64.47	188.24	188.24	0.00				
64.67	203.30	203.30	0.00				
64.87	216.63	216.63	0.00				
65.07	229.72	229.72	0.00				
65.27	243.07	243.07	0.00				
65.47	256.67	256.67	0.00				
65.67	270.51	270.51	0.00				
65.87	284.59	284.59	0.00				
66.07	298.91	298.91	0.00				
66.27	313.46	313.46	0.00				
66.47	328.24	328.24	0.00				
66.67	343.24	343.24	0.00				
66.87	358.46	358.46	0.00				
67.07	373.90	373.90	0.00				
67.27	389.56	389.56	0.00				
67.47	405.43	405.43	0.00				
67.67	421.51	421.51	0.00				
67.87	437.80	437.80	0.00				
68.07	454.29	454.29	0.00				
68.27	467.37	467.37	0.00				
68.47	488.86	488.86	0.00				
68.67	509.43	509.43	0.00				
68.87	529.21	529.21	0.00				
69.07	543.18	543.18	0.00				
69.27	554.18	554.18	0.00				
69.47	564.94	564.94	0.00				
69.67	575.47	575.47	0.00				
69.87	585.79	585.79	0.00				
70.07	613.67	595.91	17.76				
70.27	676.50	605.84	70.66				
70.47	776.30	615.60	160.71				
70.67	917.48	625.19	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 2-Year Rainfall=3.15"

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Stage-Area-Storage for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment3S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=0.82"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=513.21 cfs 159.153 af

Pond 1P: Existing Brandy Brow Rd Peak Elev=68.72' Storage=1.906 af Inflow=513.21 cfs 159.153 af
Outflow=513.02 cfs 159.153 af

Pond 4P: Existing Brandy Brow Rd Peak Elev=67.14' Storage=10.259 af Inflow=513.02 cfs 159.153 af
Primary=379.70 cfs 159.153 af Secondary=0.00 cfs 0.000 af Outflow=379.70 cfs 159.153 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 159.153 af Average Runoff Depth = 0.82"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 513.21 cfs @ 13.21 hrs, Volume= 159.153 af, Depth= 0.82"
Routed to Pond 1P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 5-Year Rainfall=4.02"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Haverhill Brandy Brow Culvert

NRCC 24-hr D 5-Year Rainfall=4.02"

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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 5-Year Rainfall=4.02"

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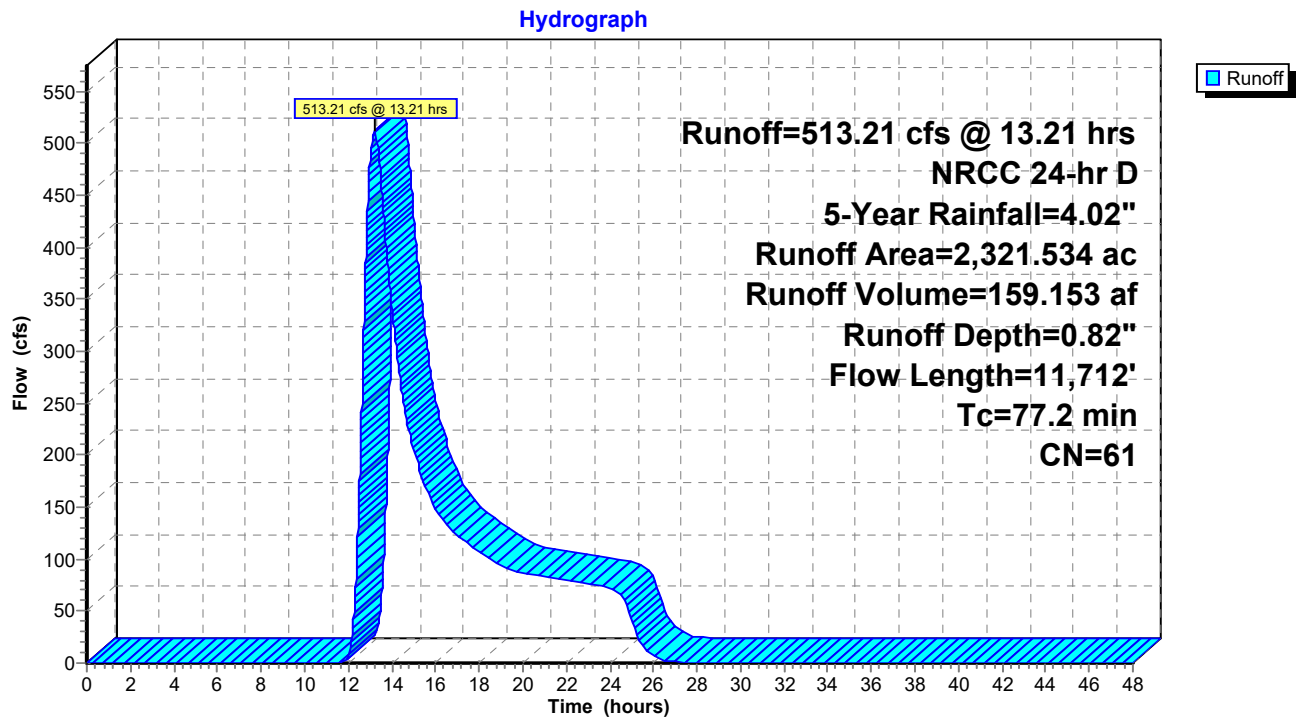
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 0.82" for 5-Year event
 Inflow = 513.21 cfs @ 13.21 hrs, Volume= 159.153 af
 Outflow = 513.02 cfs @ 13.22 hrs, Volume= 159.153 af, Atten= 0%, Lag= 0.4 min
 Primary = 513.02 cfs @ 13.22 hrs, Volume= 159.153 af
 Routed to Pond 4P : Existing Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 68.72' @ 13.22 hrs Surf.Area= 0.389 ac Storage= 1.906 af (0.651 af above start)

Plug-Flow detention time= 7.8 min calculated for 157.897 af (99% of inflow)
 Center-of-Mass det. time= 1.3 min (996.7 - 995.4)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

Haverhill Brandy Brow Culvert

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Brandy Brow Road Culvert HydroCAD Report - Existing Conditions

NRCC 24-hr D 5-Year Rainfall=4.02"

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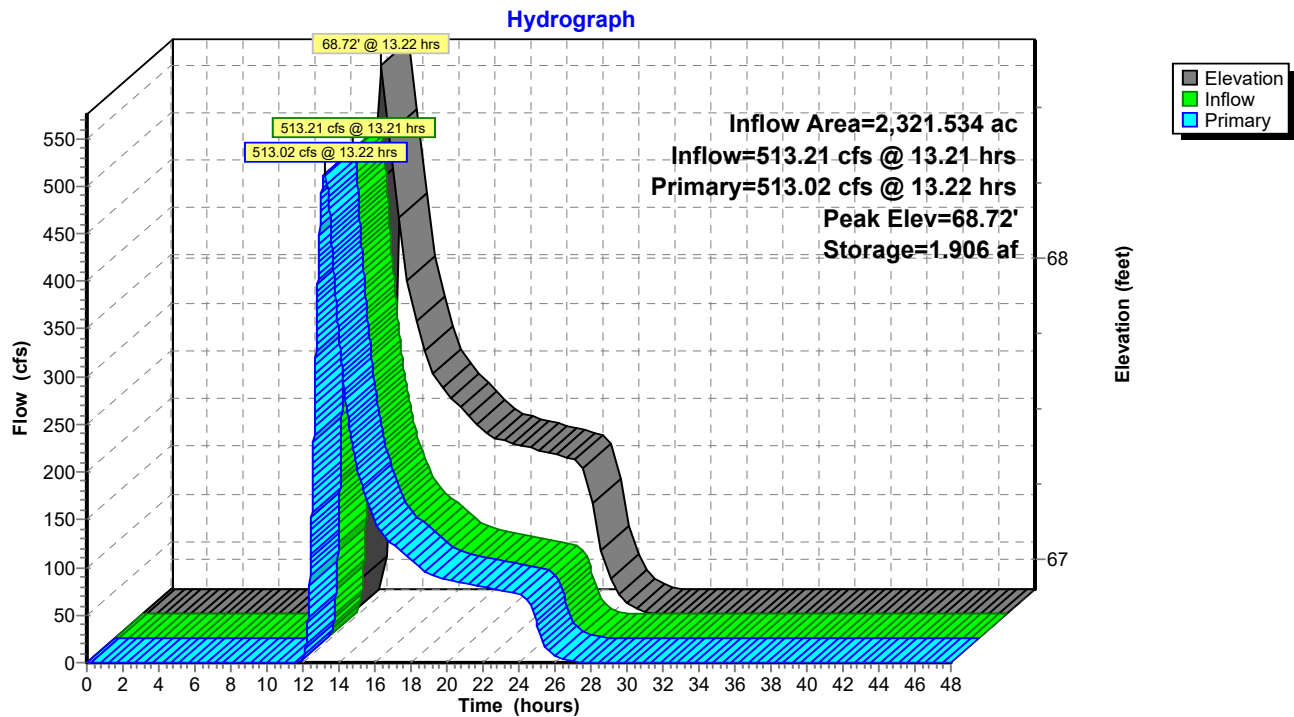
Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00

66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=512.99 cfs @ 13.22 hrs HW=68.72' TW=66.82' (Dynamic Tailwater)

1=Dam Asymmetrical Weir (Weir Controls 512.99 cfs @ 4.20 fps)

Pond 1P: Existing Brandy Brow Rd Beaver Dam



Stage-Discharge for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert*NRCC 24-hr D 5-Year Rainfall=4.02"*

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Stage-Area-Storage for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Summary for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area =	2,321.534 ac,	9.32% Impervious,	Inflow Depth = 0.82"	for 5-Year event
Inflow =	513.02 cfs @	13.22 hrs,	Volume=	159.153 af
Outflow =	379.70 cfs @	13.84 hrs,	Volume=	159.153 af, Atten= 26%, Lag= 37.3 min
Primary =	379.70 cfs @	13.84 hrs,	Volume=	159.153 af
Secondary =	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 67.14' @ 13.84 hrs Surf.Area= 14.701 ac Storage= 10.259 af

Plug-Flow detention time= 6.9 min calculated for 159.119 af (100% of inflow)
 Center-of-Mass det. time= 6.9 min (1,003.7 - 996.7)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	95.0" W x 76.0" H Box Haverhill Brandy Brow Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 59.81' / 60.67' S= -0.0263 '/' Cc= 0.900 n= 0.013, Flow Area= 50.14 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00 71.00 72.00 73.00

Haverhill Brandy Brow Culvert

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NRCC 24-hr D 5-Year Rainfall=4.02"

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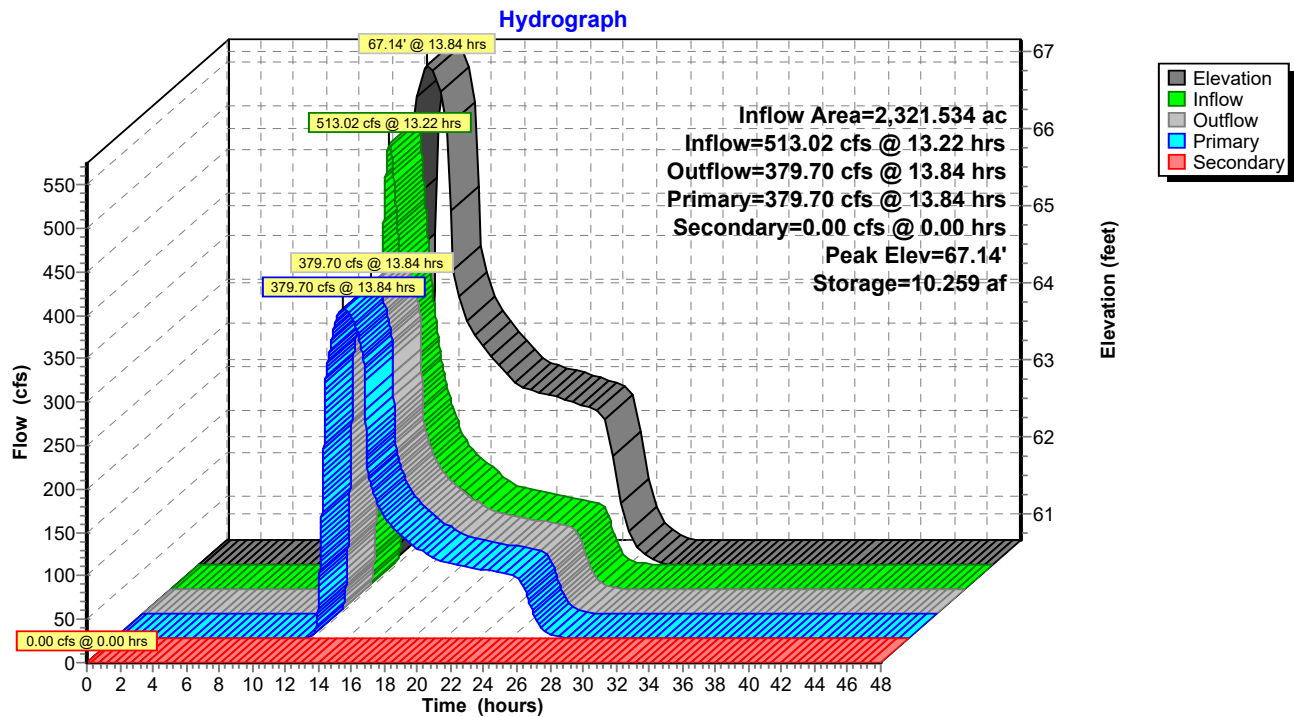
Primary OutFlow Max=379.70 cfs @ 13.84 hrs HW=67.14' (Free Discharge)

↑1=Haverhill Brandy Brow Box Culvert(Barrel Controls 379.70 cfs @ 8.72 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=60.67' (Free Discharge)

↑2=Overtopping Asymmetrical Weir(Controls 0.00 cfs)

Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert

NRCC 24-hr D 5-Year Rainfall=4.02"

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Stage-Discharge for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	1,104.27	634.62	469.65
60.87	2.27	2.27	0.00	71.07	1,340.36	643.90	696.46
61.07	6.43	6.43	0.00	71.27	1,622.27	653.04	969.23
61.27	11.81	11.81	0.00	71.47	1,944.66	662.05	1,282.61
61.47	18.18	18.18	0.00	71.67	2,305.44	670.93	1,634.51
61.67	25.41	25.41	0.00	71.87	2,703.49	679.69	2,023.80
61.87	33.41	33.41	0.00	72.07	3,138.10	688.32	2,449.78
62.07	42.10	42.10	0.00	72.27	3,607.96	696.85	2,911.11
62.27	51.43	51.43	0.00	72.47	4,111.70	705.26	3,406.43
62.47	61.37	61.37	0.00	72.67	4,648.53	713.58	3,934.95
62.67	71.88	71.88	0.00	72.87	5,217.91	721.79	4,496.12
62.87	82.92	82.92	0.00				
63.07	94.48	94.48	0.00				
63.27	106.54	106.54	0.00				
63.47	119.06	119.06	0.00				
63.67	132.05	132.05	0.00				
63.87	145.47	145.47	0.00				
64.07	159.32	159.32	0.00				
64.27	173.58	173.58	0.00				
64.47	188.24	188.24	0.00				
64.67	203.30	203.30	0.00				
64.87	216.63	216.63	0.00				
65.07	229.72	229.72	0.00				
65.27	243.07	243.07	0.00				
65.47	256.67	256.67	0.00				
65.67	270.51	270.51	0.00				
65.87	284.59	284.59	0.00				
66.07	298.91	298.91	0.00				
66.27	313.46	313.46	0.00				
66.47	328.24	328.24	0.00				
66.67	343.24	343.24	0.00				
66.87	358.46	358.46	0.00				
67.07	373.90	373.90	0.00				
67.27	389.56	389.56	0.00				
67.47	405.43	405.43	0.00				
67.67	421.51	421.51	0.00				
67.87	437.80	437.80	0.00				
68.07	454.29	454.29	0.00				
68.27	467.37	467.37	0.00				
68.47	488.86	488.86	0.00				
68.67	509.43	509.43	0.00				
68.87	529.21	529.21	0.00				
69.07	543.18	543.18	0.00				
69.27	554.18	554.18	0.00				
69.47	564.94	564.94	0.00				
69.67	575.47	575.47	0.00				
69.87	585.79	585.79	0.00				
70.07	613.67	595.91	17.76				
70.27	676.50	605.84	70.66				
70.47	776.30	615.60	160.71				
70.67	917.48	625.19	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 5-Year Rainfall=4.02"

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Stage-Area-Storage for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment3S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=1.27"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=870.09 cfs 245.345 af

Pond 1P: Existing Brandy Brow Rd Peak Elev=69.51' Storage=2.236 af Inflow=870.09 cfs 245.345 af
Outflow=867.77 cfs 245.345 af

Pond 4P: Existing Brandy Brow Rd Peak Elev=68.52' Storage=35.405 af Inflow=867.77 cfs 245.345 af
Primary=494.49 cfs 245.345 af Secondary=0.00 cfs 0.000 af Outflow=494.49 cfs 245.345 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 245.345 af Average Runoff Depth = 1.27"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 870.09 cfs @ 13.13 hrs, Volume= 245.345 af, Depth= 1.27"
Routed to Pond 1P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 10-Year Rainfall=4.83"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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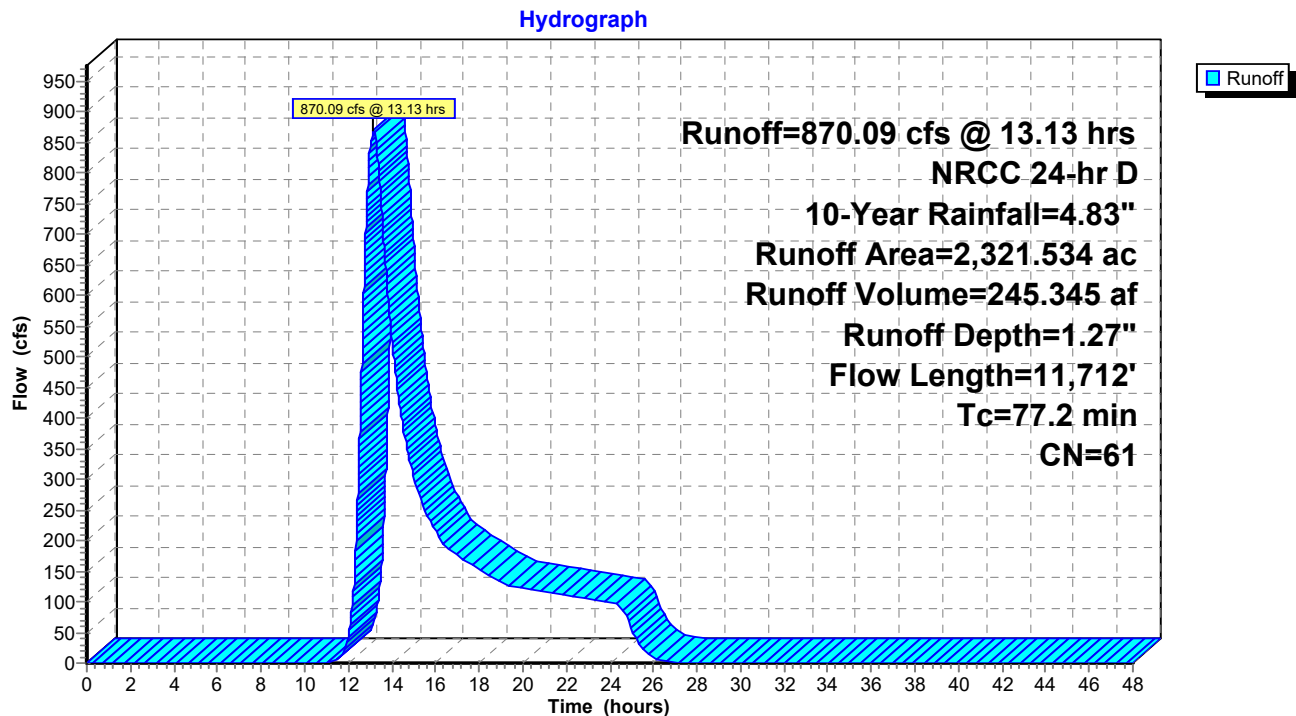
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 1.27" for 10-Year event
 Inflow = 870.09 cfs @ 13.13 hrs, Volume= 245.345 af
 Outflow = 867.77 cfs @ 13.14 hrs, Volume= 245.345 af, Atten= 0%, Lag= 0.6 min
 Primary = 867.77 cfs @ 13.14 hrs, Volume= 245.345 af
 Routed to Pond 4P : Existing Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 69.51' @ 13.30 hrs Surf.Area= 0.458 ac Storage= 2.236 af (0.980 af above start)

Plug-Flow detention time= 5.6 min calculated for 244.038 af (99% of inflow)
 Center-of-Mass det. time= 1.2 min (978.1 - 976.9)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) isted below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

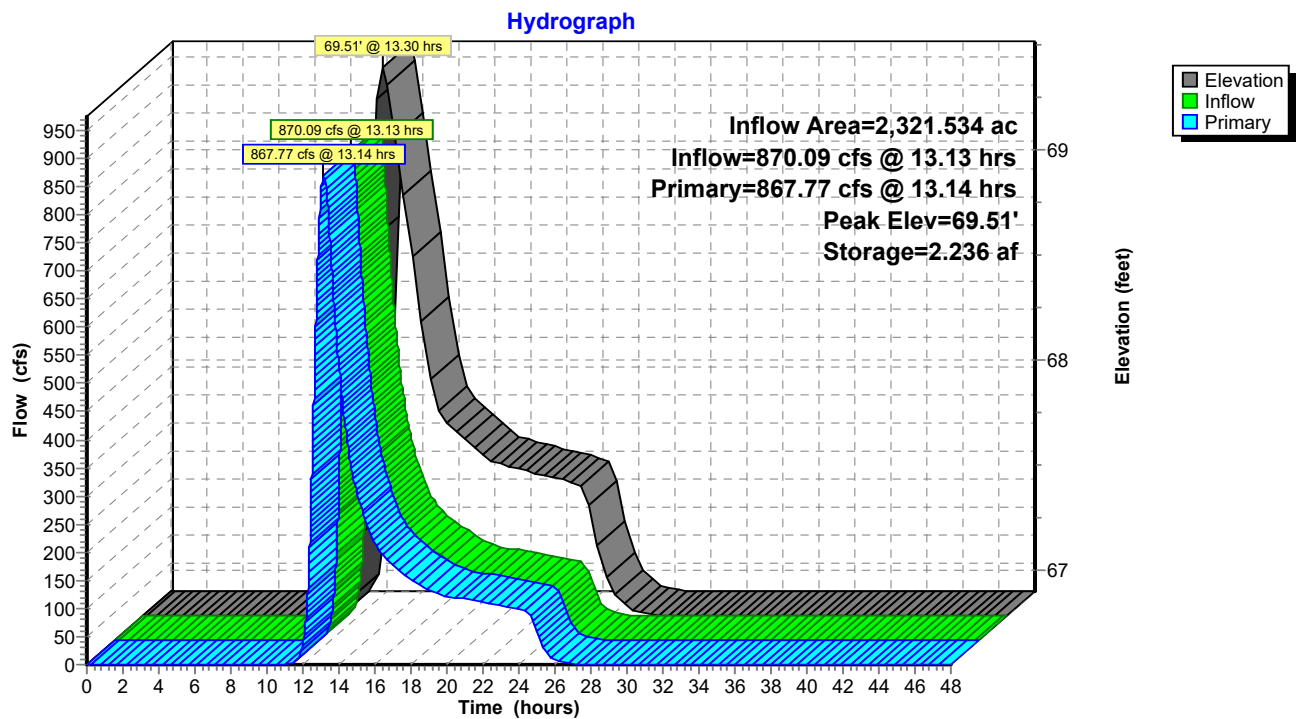
Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

125.83

Elev. (feet)	74.00	73.00	72.00	71.00	70.00	69.00	68.00	67.00
	66.90	66.90	67.00	68.00	69.00	70.00	71.00	72.00
							73.00	74.00

Primary OutFlow Max=867.74 cfs @ 13.14 hrs HW=69.49' TW=67.60' (Dynamic Tailwater)
1=Dam Asymmetrical Weir (Weir Controls 867.74 cfs @ 4.84 fps)

Pond 1P: Existing Brandy Brow Rd Beaver Dam



Stage-Discharge for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert*NRCC 24-hr D 10-Year Rainfall=4.83"*

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Stage-Area-Storage for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Summary for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area =	2,321.534 ac,	9.32% Impervious,	Inflow Depth = 1.27"	for 10-Year event
Inflow =	867.77 cfs @	13.14 hrs,	Volume=	245.345 af
Outflow =	494.49 cfs @	14.11 hrs,	Volume=	245.345 af, Atten= 43%, Lag= 58.5 min
Primary =	494.49 cfs @	14.11 hrs,	Volume=	245.345 af
Secondary =	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 68.52' @ 14.11 hrs Surf.Area= 24.681 ac Storage= 35.405 af

Plug-Flow detention time= 22.8 min calculated for 245.294 af (100% of inflow)
 Center-of-Mass det. time= 22.8 min (1,000.9 - 978.1)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	95.0" W x 76.0" H Box Haverhill Brandy Brow Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 59.81' / 60.67' S= -0.0263 '/' Cc= 0.900 n= 0.013, Flow Area= 50.14 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00 71.00 72.00 73.00

Haverhill Brandy Brow Culvert

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Brandy Brow Road Culvert HydroCAD Report - Existing Conditions

NRCC 24-hr D 10-Year Rainfall=4.83"

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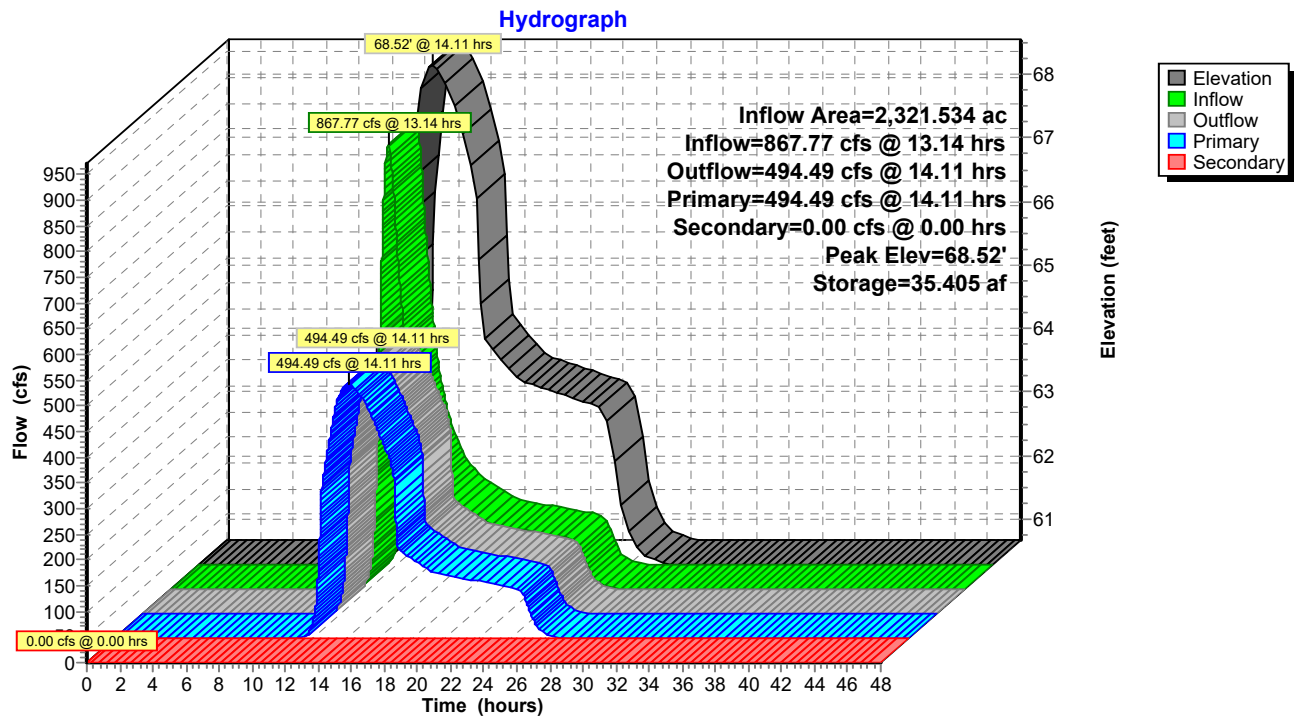
Primary OutFlow Max=494.49 cfs @ 14.11 hrs HW=68.52' (Free Discharge)

1=Haverhill Brandy Brow Box Culvert(Barrel Controls 494.49 cfs @ 9.86 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=60.67' (Free Discharge)

2=Overtopping Asymmetrical Weir(Controls 0.00 cfs)

Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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Stage-Discharge for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	1,104.27	634.62	469.65
60.87	2.27	2.27	0.00	71.07	1,340.36	643.90	696.46
61.07	6.43	6.43	0.00	71.27	1,622.27	653.04	969.23
61.27	11.81	11.81	0.00	71.47	1,944.66	662.05	1,282.61
61.47	18.18	18.18	0.00	71.67	2,305.44	670.93	1,634.51
61.67	25.41	25.41	0.00	71.87	2,703.49	679.69	2,023.80
61.87	33.41	33.41	0.00	72.07	3,138.10	688.32	2,449.78
62.07	42.10	42.10	0.00	72.27	3,607.96	696.85	2,911.11
62.27	51.43	51.43	0.00	72.47	4,111.70	705.26	3,406.43
62.47	61.37	61.37	0.00	72.67	4,648.53	713.58	3,934.95
62.67	71.88	71.88	0.00	72.87	5,217.91	721.79	4,496.12
62.87	82.92	82.92	0.00				
63.07	94.48	94.48	0.00				
63.27	106.54	106.54	0.00				
63.47	119.06	119.06	0.00				
63.67	132.05	132.05	0.00				
63.87	145.47	145.47	0.00				
64.07	159.32	159.32	0.00				
64.27	173.58	173.58	0.00				
64.47	188.24	188.24	0.00				
64.67	203.30	203.30	0.00				
64.87	216.63	216.63	0.00				
65.07	229.72	229.72	0.00				
65.27	243.07	243.07	0.00				
65.47	256.67	256.67	0.00				
65.67	270.51	270.51	0.00				
65.87	284.59	284.59	0.00				
66.07	298.91	298.91	0.00				
66.27	313.46	313.46	0.00				
66.47	328.24	328.24	0.00				
66.67	343.24	343.24	0.00				
66.87	358.46	358.46	0.00				
67.07	373.90	373.90	0.00				
67.27	389.56	389.56	0.00				
67.47	405.43	405.43	0.00				
67.67	421.51	421.51	0.00				
67.87	437.80	437.80	0.00				
68.07	454.29	454.29	0.00				
68.27	467.37	467.37	0.00				
68.47	488.86	488.86	0.00				
68.67	509.43	509.43	0.00				
68.87	529.21	529.21	0.00				
69.07	543.18	543.18	0.00				
69.27	554.18	554.18	0.00				
69.47	564.94	564.94	0.00				
69.67	575.47	575.47	0.00				
69.87	585.79	585.79	0.00				
70.07	613.67	595.91	17.76				
70.27	676.50	605.84	70.66				
70.47	776.30	615.60	160.71				
70.67	917.48	625.19	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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Stage-Area-Storage for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment3S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=2.11"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=1,551.54 cfs 408.846 af

Pond 1P: Existing Brandy Brow Rd Peak Elev=70.91' Storage=2.970 af Inflow=1,551.54 cfs 408.846 af
Outflow=1,544.67 cfs 408.846 af

Pond 4P: Existing Brandy Brow Rd Peak Elev=70.36' Storage=94.054 af Inflow=1,544.67 cfs 408.846 af
Primary=610.11 cfs 399.426 af Secondary=105.02 cfs 9.420 af Outflow=715.12 cfs 408.846 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 408.846 af Average Runoff Depth = 2.11"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 1,551.54 cfs @ 13.12 hrs, Volume= 408.846 af, Depth= 2.11"
Routed to Pond 1P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 25-Year Rainfall=6.16"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

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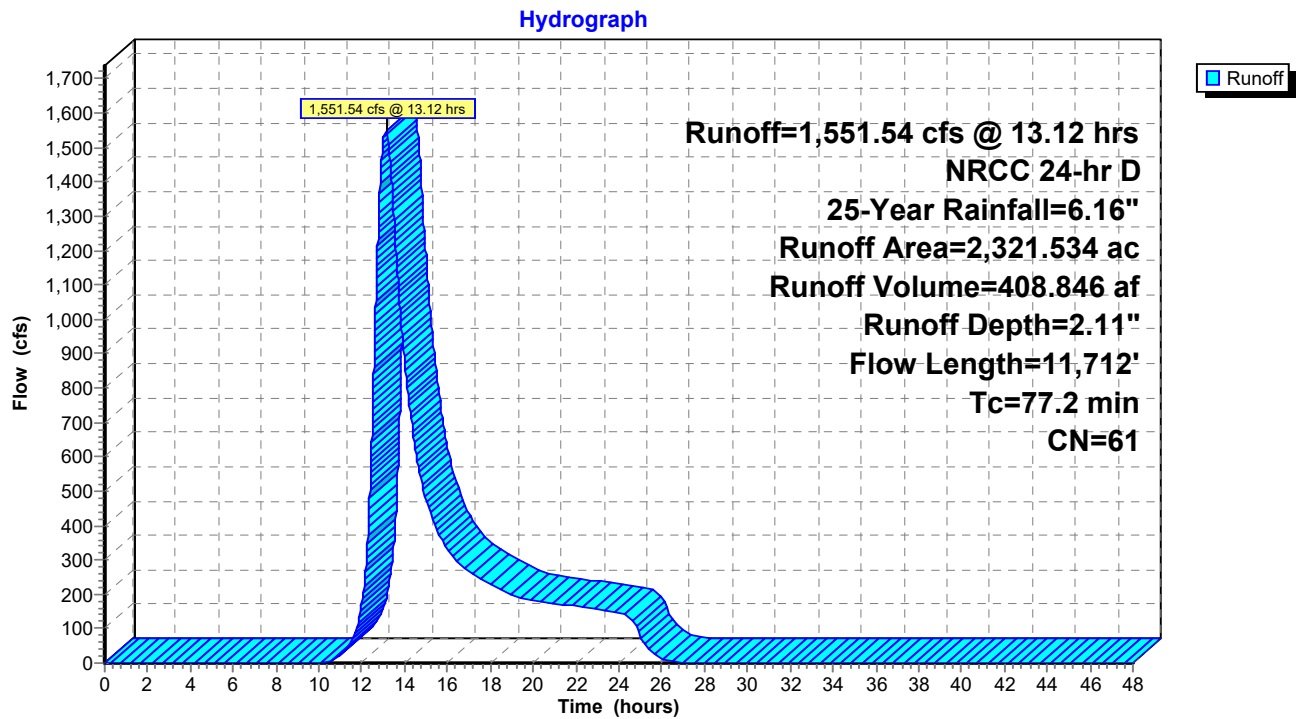
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 2.11" for 25-Year event
Inflow = 1,551.54 cfs @ 13.12 hrs, Volume= 408.846 af
Outflow = 1,544.67 cfs @ 13.13 hrs, Volume= 408.846 af, Atten= 0%, Lag= 0.4 min
Primary = 1,544.67 cfs @ 13.13 hrs, Volume= 408.846 af
Routed to Pond 4P : Existing Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
Peak Elev= 70.91' @ 13.31 hrs Surf.Area= 0.582 ac Storage= 2.970 af (1.714 af above start)

Plug-Flow detention time= 4.3 min calculated for 407.590 af (100% of inflow)
Center-of-Mass det. time= 1.4 min (958.0 - 956.6)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

Haverhill Brandy Brow Culvert

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Brandy Brow Road Culvert HydroCAD Report - Existing Conditions

NRCC 24-hr D 25-Year Rainfall=6.16"

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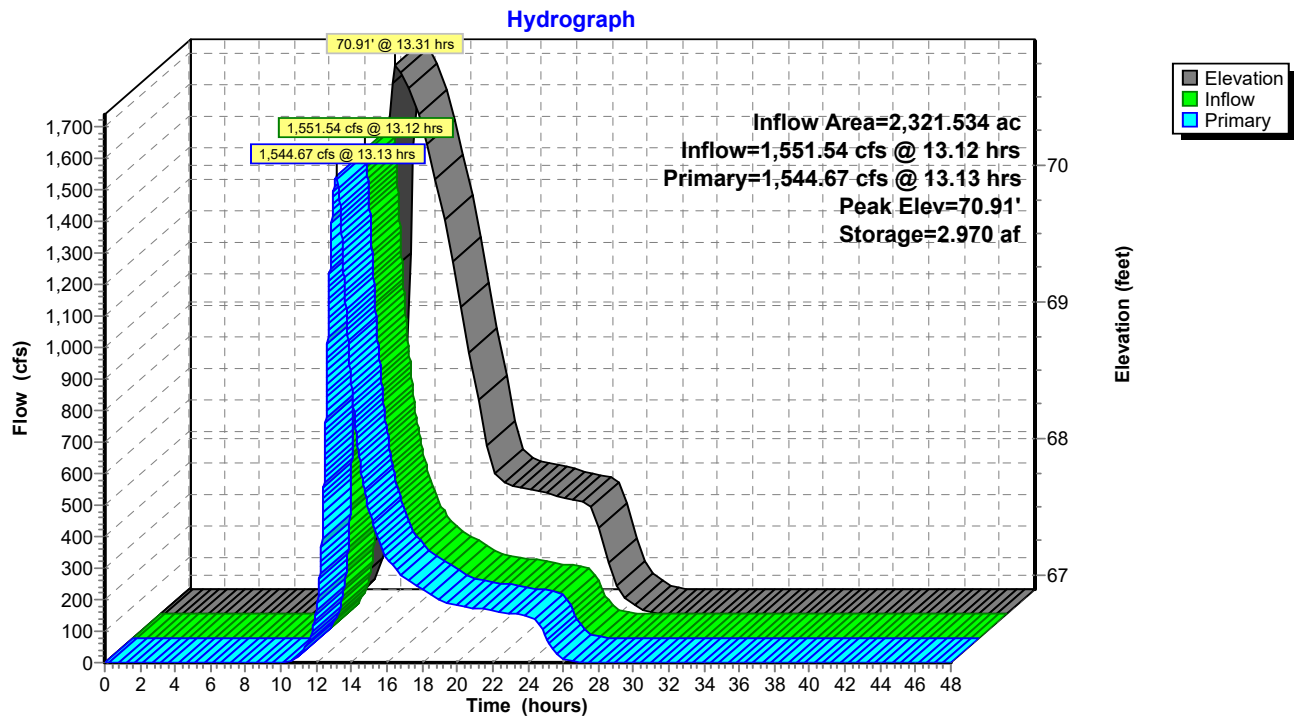
125.83

Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00
66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=1,544.55 cfs @ 13.13 hrs HW=70.84' TW=68.93' (Dynamic Tailwater)

↑1=Dam Asymmetrical Weir (Weir Controls 1,544.55 cfs @ 5.35 fps)

Pond 1P: Existing Brandy Brow Rd Beaver Dam



Stage-Discharge for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert*NRCC 24-hr D 25-Year Rainfall=6.16"*

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Stage-Area-Storage for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Summary for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 2.11" for 25-Year event
 Inflow = 1,544.67 cfs @ 13.13 hrs, Volume= 408.846 af
 Outflow = 715.12 cfs @ 14.29 hrs, Volume= 408.846 af, Atten= 54%, Lag= 69.8 min
 Primary = 610.11 cfs @ 14.29 hrs, Volume= 399.426 af
 Secondary = 105.02 cfs @ 14.29 hrs, Volume= 9.420 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 70.36' @ 14.29 hrs Surf.Area= 37.774 ac Storage= 94.054 af

Plug-Flow detention time= 55.5 min calculated for 408.761 af (100% of inflow)
 Center-of-Mass det. time= 55.4 min (1,013.5 - 958.0)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	95.0" W x 76.0" H Box Haverhill Brandy Brow Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 59.81' / 60.67' S= -0.0263 '/' Cc= 0.900 n= 0.013, Flow Area= 50.14 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00 71.00 72.00 73.00

Haverhill Brandy Brow Culvert

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Brandy Brow Road Culvert HydroCAD Report - Existing Conditions

NRCC 24-hr D 25-Year Rainfall=6.16"

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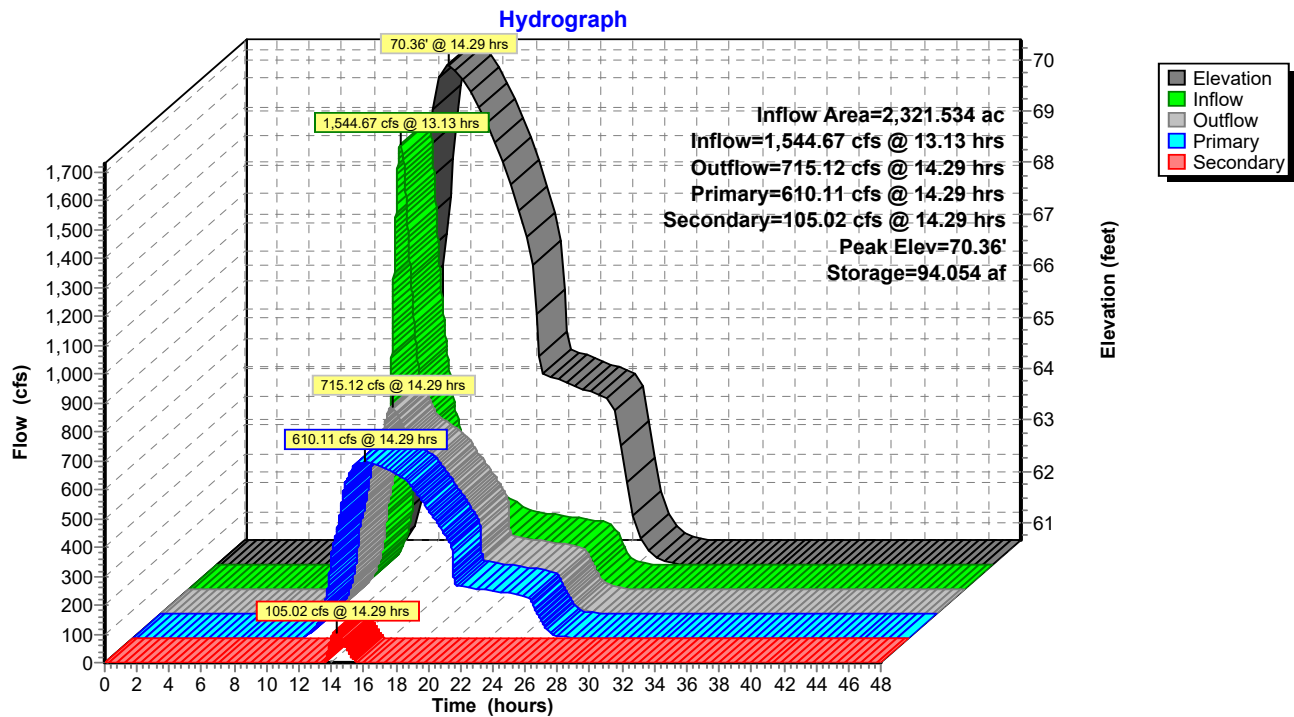
Primary OutFlow Max=610.11 cfs @ 14.29 hrs HW=70.36' (Free Discharge)

↑1=Haverhill Brandy Brow Box Culvert(Inlet Controls 610.11 cfs @ 12.17 fps)

Secondary OutFlow Max=105.01 cfs @ 14.29 hrs HW=70.36' (Free Discharge)

↑2=Overtopping Asymmetrical Weir(Weir Controls 105.01 cfs @ 1.53 fps)

Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

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Stage-Discharge for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	1,104.27	634.62	469.65
60.87	2.27	2.27	0.00	71.07	1,340.36	643.90	696.46
61.07	6.43	6.43	0.00	71.27	1,622.27	653.04	969.23
61.27	11.81	11.81	0.00	71.47	1,944.66	662.05	1,282.61
61.47	18.18	18.18	0.00	71.67	2,305.44	670.93	1,634.51
61.67	25.41	25.41	0.00	71.87	2,703.49	679.69	2,023.80
61.87	33.41	33.41	0.00	72.07	3,138.10	688.32	2,449.78
62.07	42.10	42.10	0.00	72.27	3,607.96	696.85	2,911.11
62.27	51.43	51.43	0.00	72.47	4,111.70	705.26	3,406.43
62.47	61.37	61.37	0.00	72.67	4,648.53	713.58	3,934.95
62.67	71.88	71.88	0.00	72.87	5,217.91	721.79	4,496.12
62.87	82.92	82.92	0.00				
63.07	94.48	94.48	0.00				
63.27	106.54	106.54	0.00				
63.47	119.06	119.06	0.00				
63.67	132.05	132.05	0.00				
63.87	145.47	145.47	0.00				
64.07	159.32	159.32	0.00				
64.27	173.58	173.58	0.00				
64.47	188.24	188.24	0.00				
64.67	203.30	203.30	0.00				
64.87	216.63	216.63	0.00				
65.07	229.72	229.72	0.00				
65.27	243.07	243.07	0.00				
65.47	256.67	256.67	0.00				
65.67	270.51	270.51	0.00				
65.87	284.59	284.59	0.00				
66.07	298.91	298.91	0.00				
66.27	313.46	313.46	0.00				
66.47	328.24	328.24	0.00				
66.67	343.24	343.24	0.00				
66.87	358.46	358.46	0.00				
67.07	373.90	373.90	0.00				
67.27	389.56	389.56	0.00				
67.47	405.43	405.43	0.00				
67.67	421.51	421.51	0.00				
67.87	437.80	437.80	0.00				
68.07	454.29	454.29	0.00				
68.27	467.37	467.37	0.00				
68.47	488.86	488.86	0.00				
68.67	509.43	509.43	0.00				
68.87	529.21	529.21	0.00				
69.07	543.18	543.18	0.00				
69.27	554.18	554.18	0.00				
69.47	564.94	564.94	0.00				
69.67	575.47	575.47	0.00				
69.87	585.79	585.79	0.00				
70.07	613.67	595.91	17.76				
70.27	676.50	605.84	70.66				
70.47	776.30	615.60	160.71				
70.67	917.48	625.19	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

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Stage-Area-Storage for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment3S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=3.01"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=2,268.01 cfs 582.104 af

Pond 1P: Existing Brandy Brow Rd Peak Elev=72.17' Storage=3.750 af Inflow=2,268.01 cfs 582.104 af
Outflow=2,255.44 cfs 582.104 af

Pond 4P: Existing Brandy Brow Rd Peak Elev=71.14' Storage=126.378 af Inflow=2,255.44 cfs 582.104 af
Primary=646.98 cfs 489.235 af Secondary=782.99 cfs 92.869 af Outflow=1,429.96 cfs 582.104 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 582.104 af Average Runoff Depth = 3.01"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 2,268.01 cfs @ 13.12 hrs, Volume= 582.104 af, Depth= 3.01"
Routed to Pond 1P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 50-Year Rainfall=7.42"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

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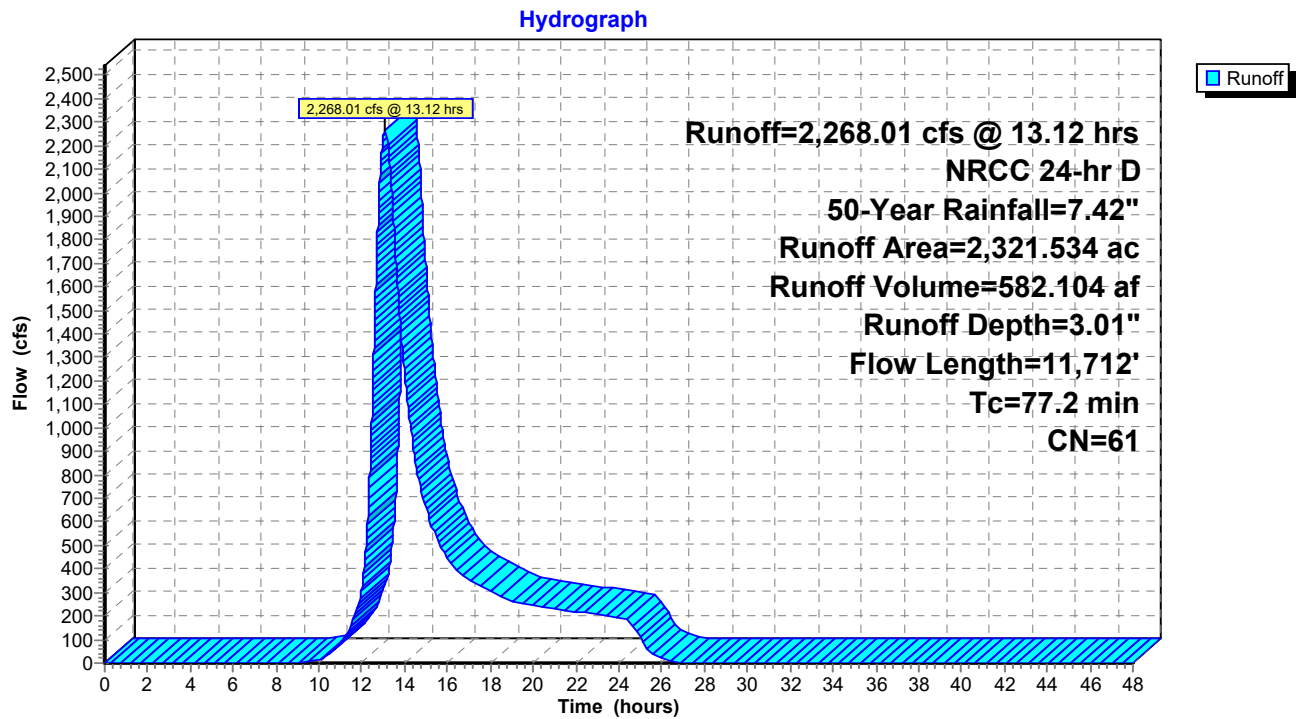
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 3.01" for 50-Year event
 Inflow = 2,268.01 cfs @ 13.12 hrs, Volume= 582.104 af
 Outflow = 2,255.44 cfs @ 13.12 hrs, Volume= 582.104 af, Atten= 1%, Lag= 0.2 min
 Primary = 2,255.44 cfs @ 13.12 hrs, Volume= 582.104 af
 Routed to Pond 4P : Existing Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 72.17' @ 13.33 hrs Surf.Area= 0.649 ac Storage= 3.750 af (2.494 af above start)

Plug-Flow detention time= 3.5 min calculated for 580.848 af (100% of inflow)
 Center-of-Mass det. time= 1.3 min (944.6 - 943.2)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

Haverhill Brandy Brow Culvert

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Brandy Brow Road Culvert HydroCAD Report - Existing Conditions

NRCC 24-hr D 50-Year Rainfall=7.42"

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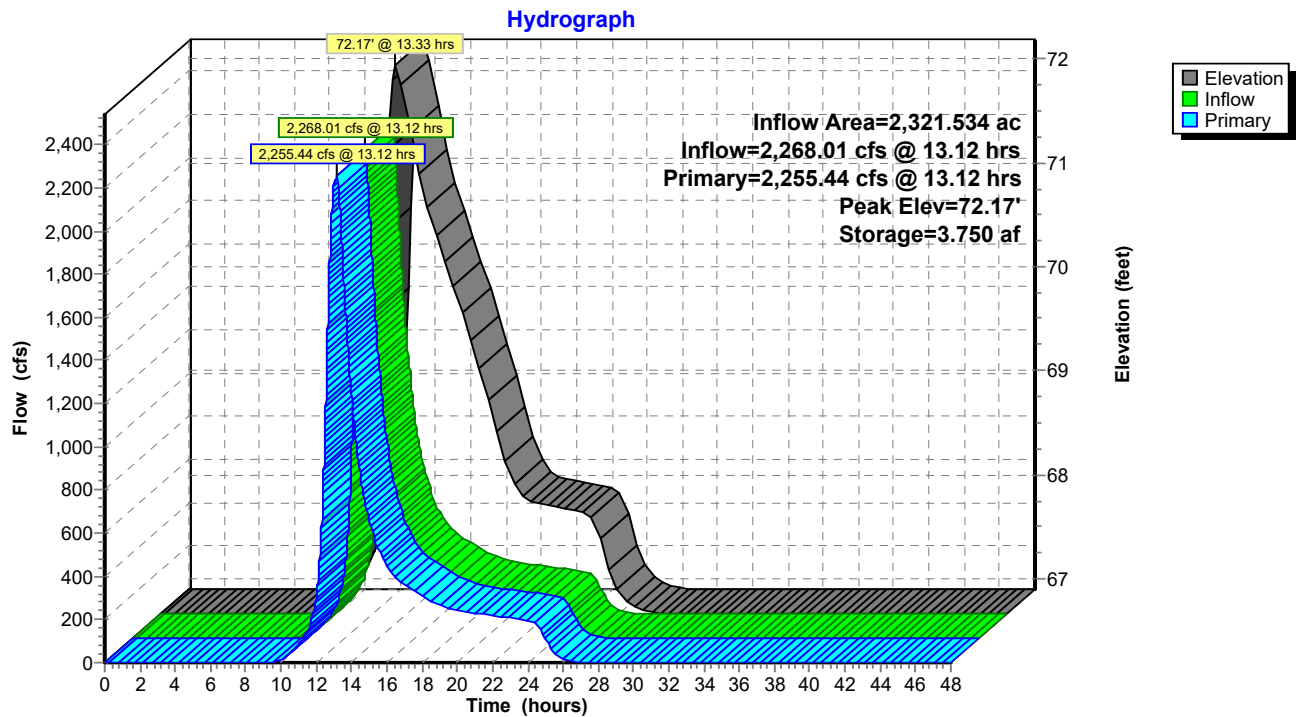
Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00

66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=2,255.39 cfs @ 13.12 hrs HW=72.04' TW=70.02' (Dynamic Tailwater)

1=Dam Asymmetrical Weir (Weir Controls 2,255.39 cfs @ 5.67 fps)

Pond 1P: Existing Brandy Brow Rd Beaver Dam



Stage-Discharge for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

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Stage-Area-Storage for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Summary for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 3.01" for 50-Year event
 Inflow = 2,255.44 cfs @ 13.12 hrs, Volume= 582.104 af
 Outflow = 1,429.96 cfs @ 13.82 hrs, Volume= 582.104 af, Atten= 37%, Lag= 41.6 min
 Primary = 646.98 cfs @ 13.82 hrs, Volume= 489.235 af
 Secondary = 782.99 cfs @ 13.82 hrs, Volume= 92.869 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 71.14' @ 13.82 hrs Surf.Area= 44.543 ac Storage= 126.378 af

Plug-Flow detention time= 58.3 min calculated for 581.982 af (100% of inflow)
 Center-of-Mass det. time= 58.3 min (1,002.9 - 944.6)

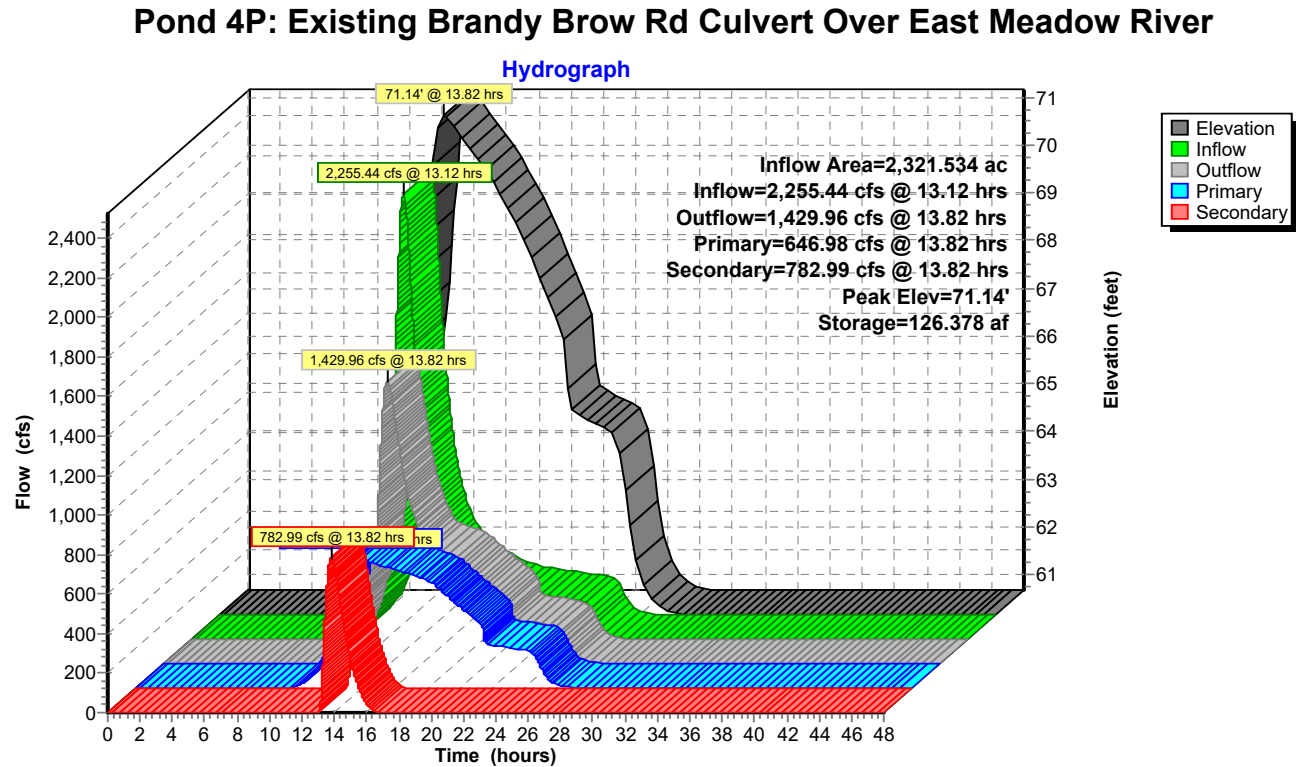
Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	95.0" W x 76.0" H Box Haverhill Brandy Brow Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 59.81' / 60.67' S= -0.0263 '/' Cc= 0.900 n= 0.013, Flow Area= 50.14 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00 71.00 72.00 73.00

Primary OutFlow Max=646.98 cfs @ 13.82 hrs HW=71.14' (Free Discharge)
 ↳1=**Haverhill Brandy Brow Box Culvert**(Inlet Controls 646.98 cfs @ 12.90 fps)

Secondary OutFlow Max=782.95 cfs @ 13.82 hrs HW=71.14' (Free Discharge)
 ↳2=**Overtopping Asymmetrical Weir**(Weir Controls 782.95 cfs @ 2.15 fps)



Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

Prepared by Greenman-Pedersen, Inc

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Stage-Discharge for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	1,104.27	634.62	469.65
60.87	2.27	2.27	0.00	71.07	1,340.36	643.90	696.46
61.07	6.43	6.43	0.00	71.27	1,622.27	653.04	969.23
61.27	11.81	11.81	0.00	71.47	1,944.66	662.05	1,282.61
61.47	18.18	18.18	0.00	71.67	2,305.44	670.93	1,634.51
61.67	25.41	25.41	0.00	71.87	2,703.49	679.69	2,023.80
61.87	33.41	33.41	0.00	72.07	3,138.10	688.32	2,449.78
62.07	42.10	42.10	0.00	72.27	3,607.96	696.85	2,911.11
62.27	51.43	51.43	0.00	72.47	4,111.70	705.26	3,406.43
62.47	61.37	61.37	0.00	72.67	4,648.53	713.58	3,934.95
62.67	71.88	71.88	0.00	72.87	5,217.91	721.79	4,496.12
62.87	82.92	82.92	0.00				
63.07	94.48	94.48	0.00				
63.27	106.54	106.54	0.00				
63.47	119.06	119.06	0.00				
63.67	132.05	132.05	0.00				
63.87	145.47	145.47	0.00				
64.07	159.32	159.32	0.00				
64.27	173.58	173.58	0.00				
64.47	188.24	188.24	0.00				
64.67	203.30	203.30	0.00				
64.87	216.63	216.63	0.00				
65.07	229.72	229.72	0.00				
65.27	243.07	243.07	0.00				
65.47	256.67	256.67	0.00				
65.67	270.51	270.51	0.00				
65.87	284.59	284.59	0.00				
66.07	298.91	298.91	0.00				
66.27	313.46	313.46	0.00				
66.47	328.24	328.24	0.00				
66.67	343.24	343.24	0.00				
66.87	358.46	358.46	0.00				
67.07	373.90	373.90	0.00				
67.27	389.56	389.56	0.00				
67.47	405.43	405.43	0.00				
67.67	421.51	421.51	0.00				
67.87	437.80	437.80	0.00				
68.07	454.29	454.29	0.00				
68.27	467.37	467.37	0.00				
68.47	488.86	488.86	0.00				
68.67	509.43	509.43	0.00				
68.87	529.21	529.21	0.00				
69.07	543.18	543.18	0.00				
69.27	554.18	554.18	0.00				
69.47	564.94	564.94	0.00				
69.67	575.47	575.47	0.00				
69.87	585.79	585.79	0.00				
70.07	613.67	595.91	17.76				
70.27	676.50	605.84	70.66				
70.47	776.30	615.60	160.71				
70.67	917.48	625.19	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

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Stage-Area-Storage for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment3S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=4.18"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=3,191.97 cfs 807.936 af

Pond 1P: Existing Brandy Brow Rd Peak Elev=73.37' Storage=4.560 af Inflow=3,191.97 cfs 807.936 af
Outflow=3,181.05 cfs 807.936 af

Pond 4P: Existing Brandy Brow Rd Peak Elev=71.75' Storage=154.430 af Inflow=3,181.05 cfs 807.936 af
Primary=674.36 cfs 580.929 af Secondary=1,781.86 cfs 227.007 af Outflow=2,456.21 cfs 807.936 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 807.936 af Average Runoff Depth = 4.18"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 3,191.97 cfs @ 13.12 hrs, Volume= 807.936 af, Depth= 4.18"
Routed to Pond 1P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 100-Year Rainfall=8.94"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 100-Year Rainfall=8.94"

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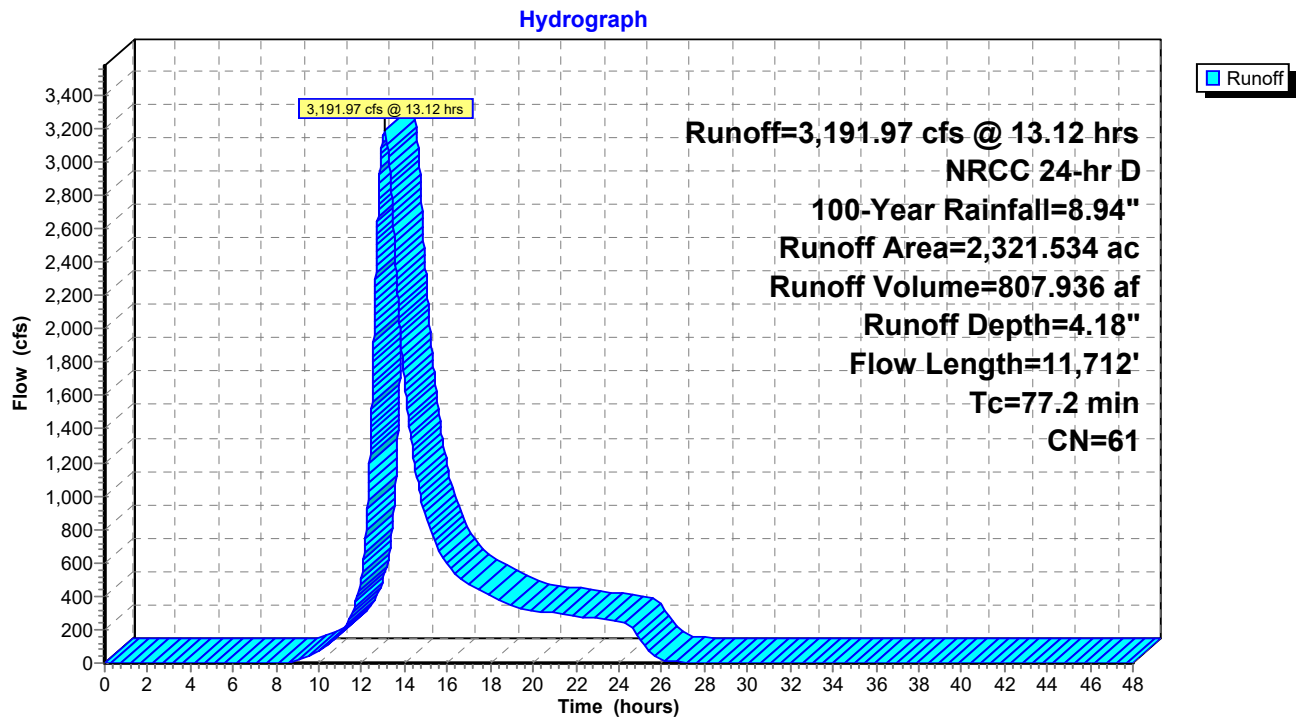
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 3S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 4.18" for 100-Year event
 Inflow = 3,191.97 cfs @ 13.12 hrs, Volume= 807.936 af
 Outflow = 3,181.05 cfs @ 13.12 hrs, Volume= 807.936 af, Atten= 0%, Lag= 0.0 min
 Primary = 3,181.05 cfs @ 13.12 hrs, Volume= 807.936 af
 Routed to Pond 4P : Existing Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 73.37' @ 13.22 hrs Surf.Area= 0.704 ac Storage= 4.560 af (3.304 af above start)

Plug-Flow detention time= 2.9 min calculated for 806.512 af (100% of inflow)
 Center-of-Mass det. time= 1.2 min (932.2 - 931.0)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

Haverhill Brandy Brow Culvert

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Brandy Brow Road Culvert HydroCAD Report - Existing Conditions

NRCC 24-hr D 100-Year Rainfall=8.94"

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125.83

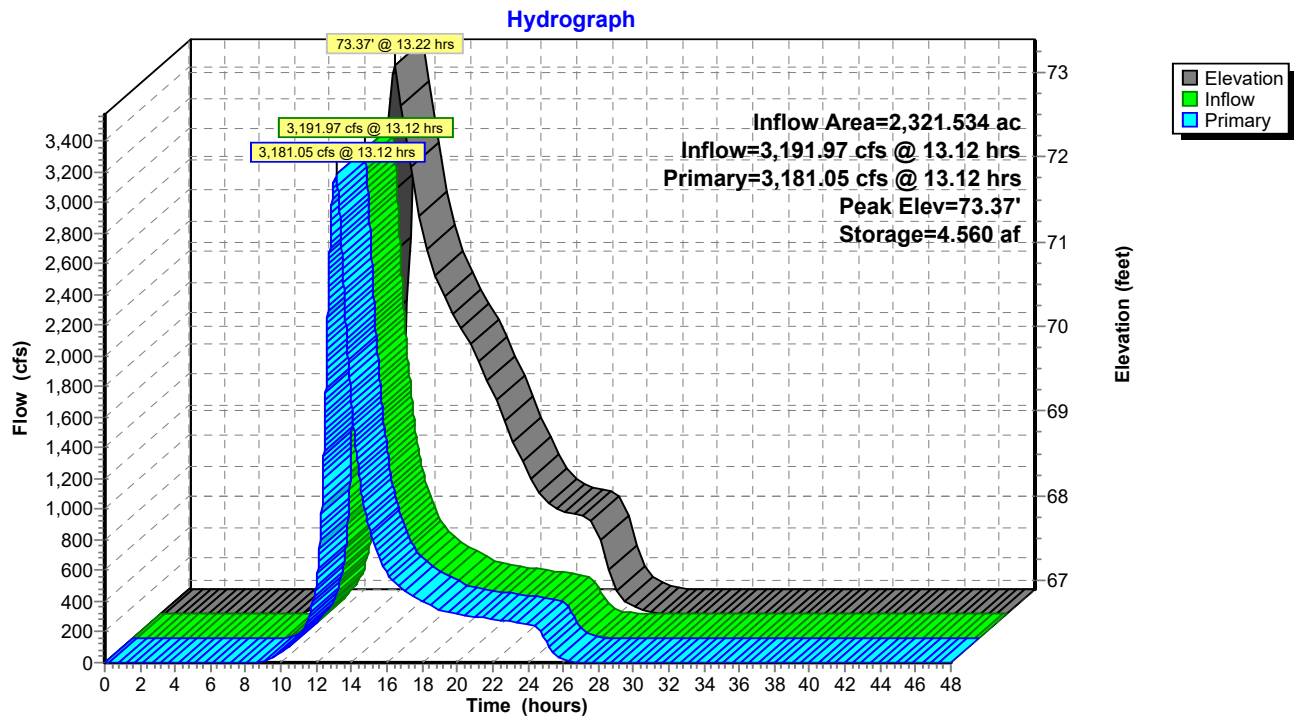
Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00

66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=3,180.82 cfs @ 13.12 hrs HW=73.32' TW=71.15' (Dynamic Tailwater)

1=Dam Asymmetrical Weir (Weir Controls 3,180.82 cfs @ 5.87 fps)

Pond 1P: Existing Brandy Brow Rd Beaver Dam



Stage-Discharge for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert*NRCC 24-hr D 100-Year Rainfall=8.94"*

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Stage-Area-Storage for Pond 1P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Summary for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 4.18" for 100-Year event
 Inflow = 3,181.05 cfs @ 13.12 hrs, Volume= 807.936 af
 Outflow = 2,456.21 cfs @ 13.56 hrs, Volume= 807.936 af, Atten= 23%, Lag= 26.4 min
 Primary = 674.36 cfs @ 13.56 hrs, Volume= 580.929 af
 Secondary = 1,781.86 cfs @ 13.56 hrs, Volume= 227.007 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 71.75' @ 13.56 hrs Surf.Area= 47.273 ac Storage= 154.430 af

Plug-Flow detention time= 57.0 min calculated for 807.767 af (100% of inflow)
 Center-of-Mass det. time= 57.0 min (989.2 - 932.2)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

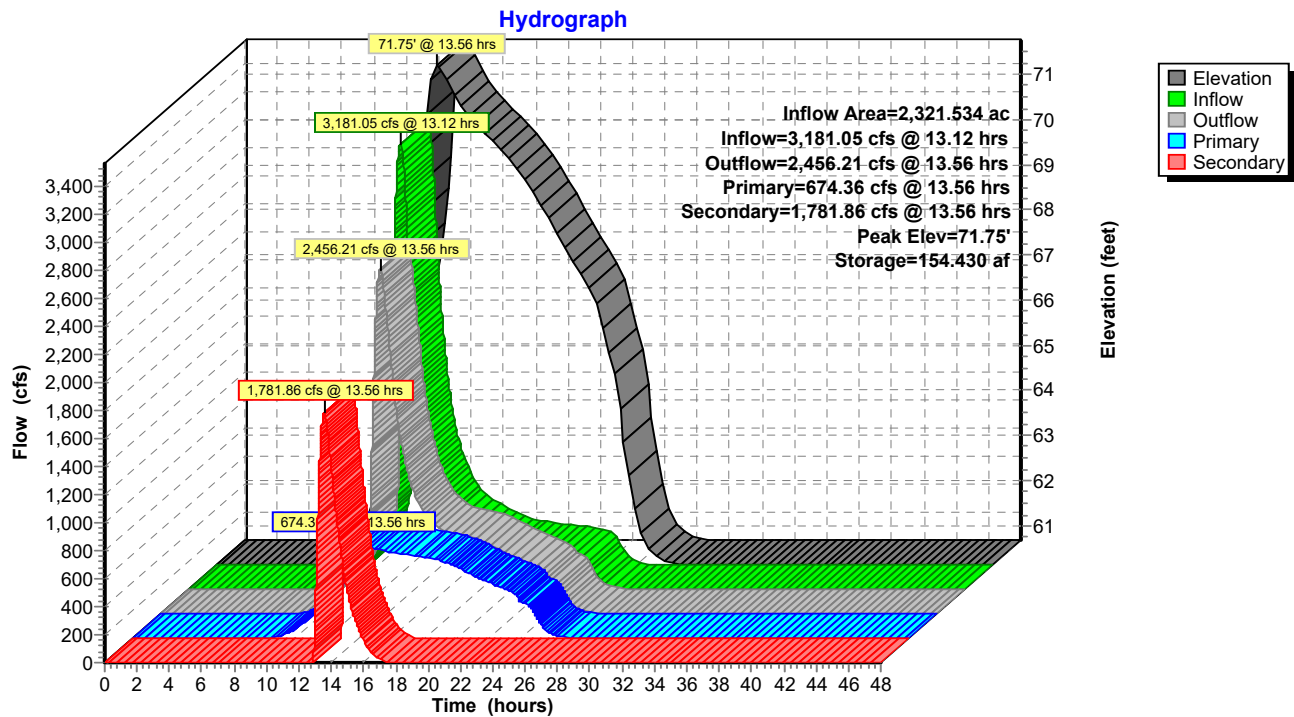
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	95.0" W x 76.0" H Box Haverhill Brandy Brow Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 59.81' / 60.67' S= -0.0263 '/' Cc= 0.900 n= 0.013, Flow Area= 50.14 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00 71.00 72.00 73.00

Primary OutFlow Max=674.36 cfs @ 13.56 hrs HW=71.75' (Free Discharge)
 ↳1=Haverhill Brandy Brow Box Culvert(Inlet Controls 674.36 cfs @ 13.45 fps)

Secondary OutFlow Max=1,781.77 cfs @ 13.56 hrs HW=71.75' (Free Discharge)
 ↳2=Overtopping Asymmetrical Weir(Weir Controls 1,781.77 cfs @ 3.03 fps)

Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert*NRCC 24-hr D 100-Year Rainfall=8.94"*

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Stage-Discharge for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	1,104.27	634.62	469.65
60.87	2.27	2.27	0.00	71.07	1,340.36	643.90	696.46
61.07	6.43	6.43	0.00	71.27	1,622.27	653.04	969.23
61.27	11.81	11.81	0.00	71.47	1,944.66	662.05	1,282.61
61.47	18.18	18.18	0.00	71.67	2,305.44	670.93	1,634.51
61.67	25.41	25.41	0.00	71.87	2,703.49	679.69	2,023.80
61.87	33.41	33.41	0.00	72.07	3,138.10	688.32	2,449.78
62.07	42.10	42.10	0.00	72.27	3,607.96	696.85	2,911.11
62.27	51.43	51.43	0.00	72.47	4,111.70	705.26	3,406.43
62.47	61.37	61.37	0.00	72.67	4,648.53	713.58	3,934.95
62.67	71.88	71.88	0.00	72.87	5,217.91	721.79	4,496.12
62.87	82.92	82.92	0.00				
63.07	94.48	94.48	0.00				
63.27	106.54	106.54	0.00				
63.47	119.06	119.06	0.00				
63.67	132.05	132.05	0.00				
63.87	145.47	145.47	0.00				
64.07	159.32	159.32	0.00				
64.27	173.58	173.58	0.00				
64.47	188.24	188.24	0.00				
64.67	203.30	203.30	0.00				
64.87	216.63	216.63	0.00				
65.07	229.72	229.72	0.00				
65.27	243.07	243.07	0.00				
65.47	256.67	256.67	0.00				
65.67	270.51	270.51	0.00				
65.87	284.59	284.59	0.00				
66.07	298.91	298.91	0.00				
66.27	313.46	313.46	0.00				
66.47	328.24	328.24	0.00				
66.67	343.24	343.24	0.00				
66.87	358.46	358.46	0.00				
67.07	373.90	373.90	0.00				
67.27	389.56	389.56	0.00				
67.47	405.43	405.43	0.00				
67.67	421.51	421.51	0.00				
67.87	437.80	437.80	0.00				
68.07	454.29	454.29	0.00				
68.27	467.37	467.37	0.00				
68.47	488.86	488.86	0.00				
68.67	509.43	509.43	0.00				
68.87	529.21	529.21	0.00				
69.07	543.18	543.18	0.00				
69.27	554.18	554.18	0.00				
69.47	564.94	564.94	0.00				
69.67	575.47	575.47	0.00				
69.87	585.79	585.79	0.00				
70.07	613.67	595.91	17.76				
70.27	676.50	605.84	70.66				
70.47	776.30	615.60	160.71				
70.67	917.48	625.19	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 100-Year Rainfall=8.94"

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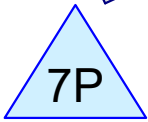
Stage-Area-Storage for Pond 4P: Existing Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

PROPOSED
CONDITIONS



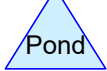
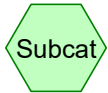
Brandy Brow Rd Culvert
Over East Meadow
River Drainage Area



Existing Brandy Brow
Rd/Beaver Dam



Alternative 2 - Proposed
Brandy Brow Rd
Culvert Over East
Meadow River



Haverhill Brandy Brow Culvert

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Project Notes

Rainfall events imported from "NRCS-Rain.txt" for 4127 MA Haverhill Essex County

HydroCAD model for proposed culvert at Brandy Brow Rd. The area was modeled as 1 drainage area.

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA)
MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source:
MassGIS.

(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use
Source: (https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Soils Data From the United States Department of Agriculture Natural Resources Conservation
Service's Web Soil Survey. (<https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>)

Drainage Area, land use, and Tc Path for subcatchment was obtained using 1 ft contours. Backup
can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Elevation-area curves to compute storage were obtained using 1 ft contours. Backups can be
found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Haverhill Brandy Brow Culvert

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Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-Year	NRCC 24-hr	D	Default	24.00	1	3.15	2
2	5-Year	NRCC 24-hr	D	Default	24.00	1	4.02	2
3	10-Year	NRCC 24-hr	D	Default	24.00	1	4.83	2
4	25-Year	NRCC 24-hr	D	Default	24.00	1	6.16	2
5	50-Year	NRCC 24-hr	D	Default	24.00	1	7.42	2
6	100-Year	NRCC 24-hr	D	Default	24.00	1	8.94	2

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment8S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=0.42"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=212.09 cfs 81.970 af

Pond 6P: Alternative2 - Proposed Brandy Peak Elev=62.46' Storage=0.166 af Inflow=212.06 cfs 81.970 af
Primary=212.05 cfs 81.970 af Secondary=0.00 cfs 0.000 af Outflow=212.05 cfs 81.970 af

Pond 7P: Existing Brandy Brow Rd Peak Elev=67.93' Storage=1.611 af Inflow=212.09 cfs 81.970 af
Outflow=212.06 cfs 81.970 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 81.970 af Average Runoff Depth = 0.42"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 212.09 cfs @ 13.30 hrs, Volume= 81.970 af, Depth= 0.42"
Routed to Pond 7P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 2-Year Rainfall=3.15"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 2-Year Rainfall=3.15"

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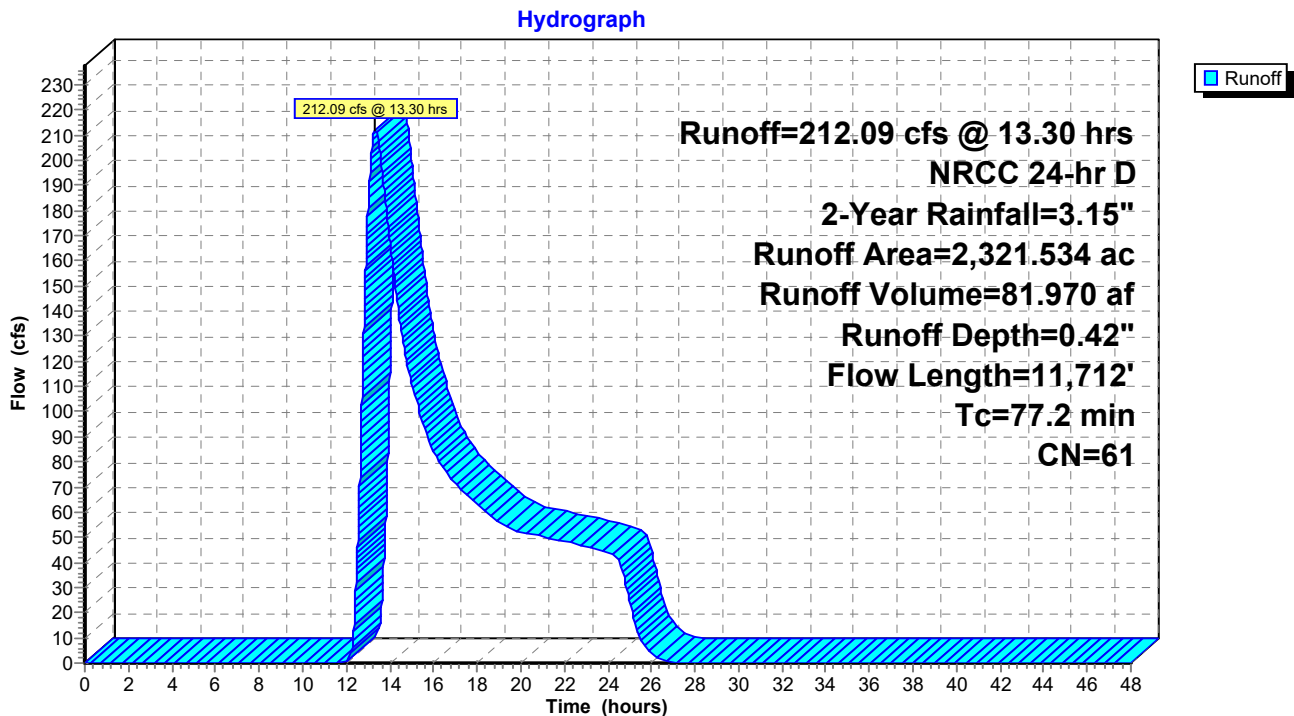
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 0.42" for 2-Year event
 Inflow = 212.06 cfs @ 13.35 hrs, Volume= 81.970 af
 Outflow = 212.05 cfs @ 13.37 hrs, Volume= 81.970 af, Atten= 0%, Lag= 0.9 min
 Primary = 212.05 cfs @ 13.37 hrs, Volume= 81.970 af
 Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 62.46' @ 13.37 hrs Surf.Area= 0.137 ac Storage= 0.166 af

Plug-Flow detention time= 0.5 min calculated for 81.953 af (100% of inflow)
 Center-of-Mass det. time= 0.5 min (1,030.0 - 1,029.4)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

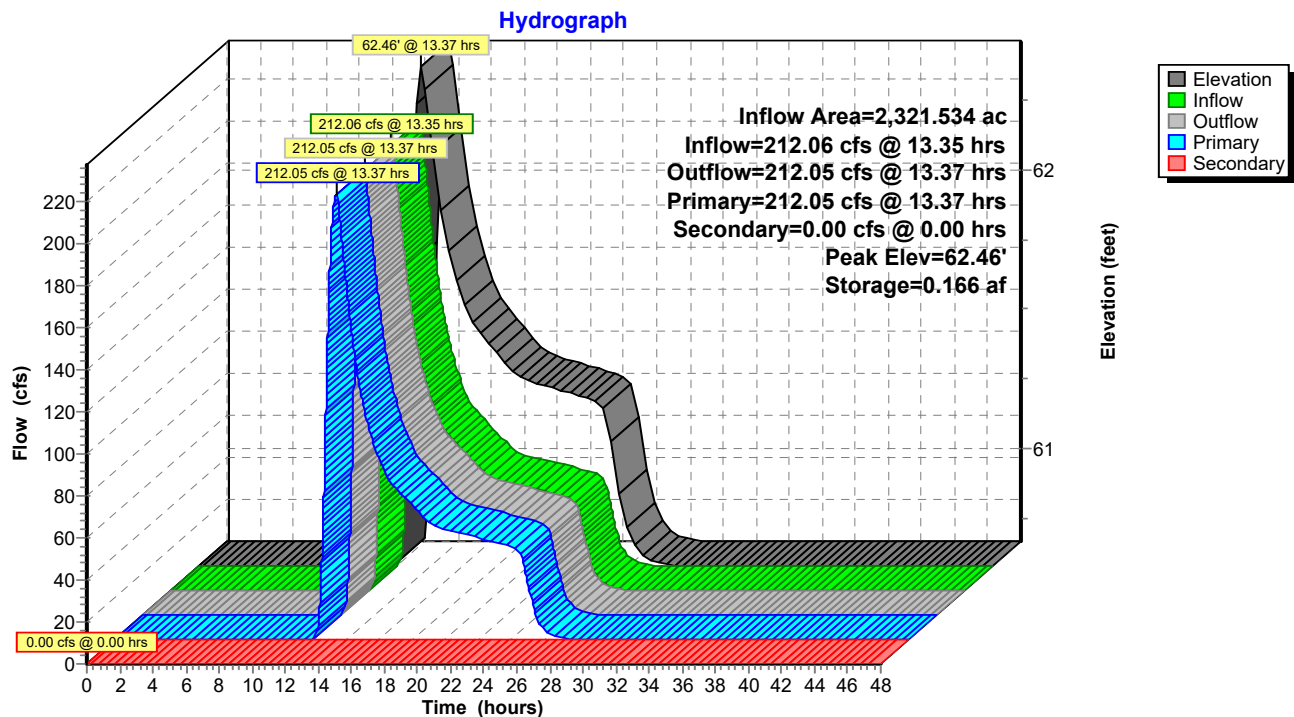
Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	408.0" W x 88.0" H Box Proposed Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 60.55' / 60.67' S= -0.0037 ' / Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 249.33 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00

71.00 72.00 73.00

Primary OutFlow Max=212.05 cfs @ 13.37 hrs HW=62.46' (Free Discharge)
 ↳ **1=Proposed Box Culvert** (Barrel Controls 212.05 cfs @ 4.36 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=60.67' (Free Discharge)
 ↳ **2=Overtopping Asymmetrical Weir** (Controls 0.00 cfs)

Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert*NRCC 24-hr D 2-Year Rainfall=3.15"*

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Stage-Discharge for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	3,258.73	2,789.08	469.65
60.87	9.76	9.76	0.00	71.07	3,577.41	2,880.95	696.46
61.07	26.57	26.57	0.00	71.27	3,939.21	2,969.98	969.23
61.27	45.55	45.55	0.00	71.47	4,339.03	3,056.42	1,282.61
61.47	67.68	67.68	0.00	71.67	4,774.99	3,140.48	1,634.51
61.67	92.54	92.54	0.00	71.87	5,246.15	3,222.35	2,023.80
61.87	119.83	119.83	0.00	72.07	5,751.96	3,302.18	2,449.78
62.07	149.36	149.36	0.00	72.27	6,261.15	3,350.03	2,911.11
62.27	180.95	180.95	0.00	72.47	6,800.04	3,393.61	3,406.43
62.47	214.47	214.47	0.00	72.67	7,371.54	3,436.59	3,934.95
62.67	249.83	249.83	0.00	72.87	7,975.12	3,479.00	4,496.12
62.87	286.92	286.92	0.00				
63.07	325.66	325.66	0.00				
63.27	366.00	366.00	0.00				
63.47	407.86	407.86	0.00				
63.67	451.20	451.20	0.00				
63.87	495.95	495.95	0.00				
64.07	542.09	542.09	0.00				
64.27	589.57	589.57	0.00				
64.47	638.36	638.36	0.00				
64.67	688.41	688.41	0.00				
64.87	739.70	739.70	0.00				
65.07	792.19	792.19	0.00				
65.27	845.87	845.87	0.00				
65.47	900.70	900.70	0.00				
65.67	956.67	956.67	0.00				
65.87	1,013.74	1,013.74	0.00				
66.07	1,071.90	1,071.90	0.00				
66.27	1,131.13	1,131.13	0.00				
66.47	1,191.40	1,191.40	0.00				
66.67	1,252.71	1,252.71	0.00				
66.87	1,315.03	1,315.03	0.00				
67.07	1,378.35	1,378.35	0.00				
67.27	1,442.65	1,442.65	0.00				
67.47	1,507.92	1,507.92	0.00				
67.67	1,574.14	1,574.14	0.00				
67.87	1,641.30	1,641.30	0.00				
68.07	1,709.39	1,709.39	0.00				
68.27	1,778.39	1,778.39	0.00				
68.47	1,848.30	1,848.30	0.00				
68.67	1,919.09	1,919.09	0.00				
68.87	1,990.76	1,990.76	0.00				
69.07	2,063.31	2,063.31	0.00				
69.27	2,136.71	2,136.71	0.00				
69.47	2,210.96	2,210.96	0.00				
69.67	2,286.05	2,286.05	0.00				
69.87	2,361.97	2,361.97	0.00				
70.07	2,456.47	2,438.71	17.76				
70.27	2,586.92	2,516.26	70.66				
70.47	2,756.30	2,595.60	160.71				
70.67	2,986.37	2,694.08	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 2-Year Rainfall=3.15"

Prepared by Greenman-Pedersen, Inc

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Stage-Area-Storage for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Summary for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 0.42" for 2-Year event
 Inflow = 212.09 cfs @ 13.30 hrs, Volume= 81.970 af
 Outflow = 212.06 cfs @ 13.35 hrs, Volume= 81.970 af, Atten= 0%, Lag= 3.2 min
 Primary = 212.06 cfs @ 13.35 hrs, Volume= 81.970 af
 Routed to Pond 6P : Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 67.93' @ 13.35 hrs Surf.Area= 0.357 ac Storage= 1.611 af (0.355 af above start)

Plug-Flow detention time= 13.9 min calculated for 80.714 af (98% of inflow)
 Center-of-Mass det. time= 1.7 min (1,029.4 - 1,027.7)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

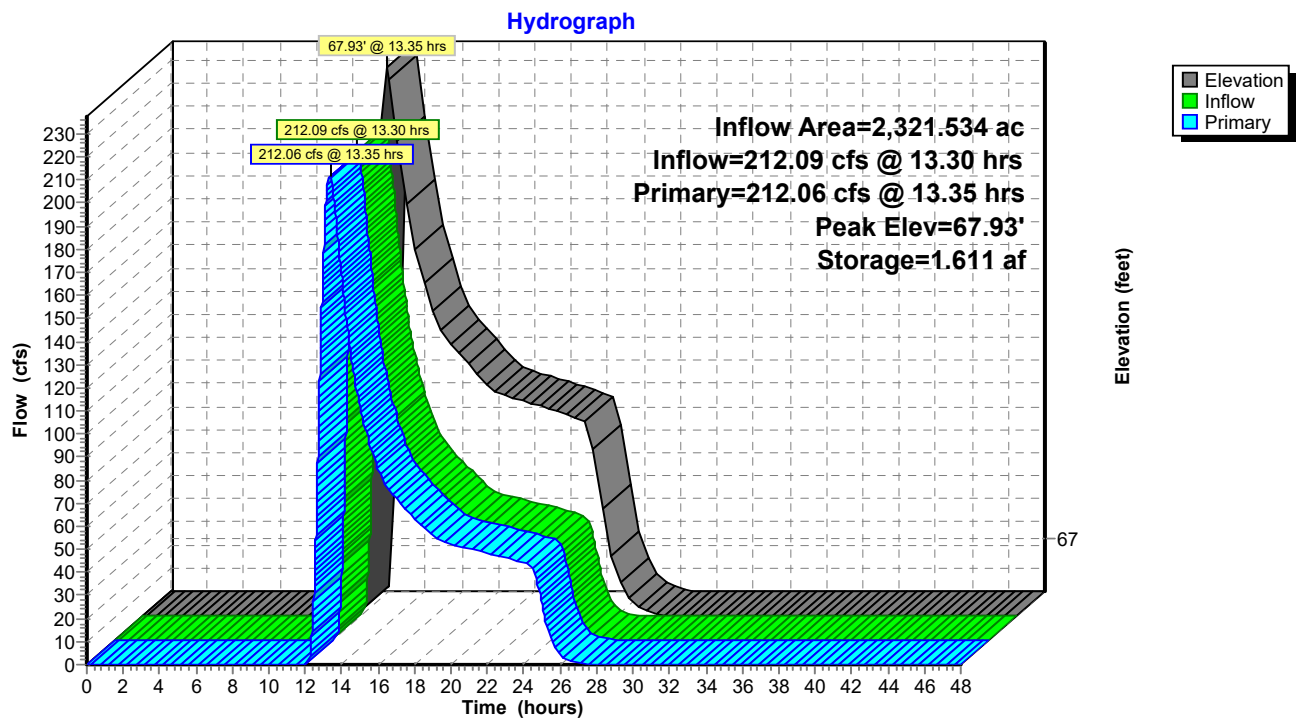
Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

125.83

Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00
 66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=212.05 cfs @ 13.35 hrs HW=67.93' TW=62.46' (Dynamic Tailwater)
 ↳1=Dam Asymmetrical Weir (Weir Controls 212.05 cfs @ 3.17 fps)

Pond 7P: Existing Brandy Brow Rd Beaver Dam



Haverhill Brandy Brow Culvert*NRCC 24-hr D 2-Year Rainfall=3.15"*

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Stage-Discharge for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert*NRCC 24-hr D 2-Year Rainfall=3.15"*

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Stage-Area-Storage for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment8S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=0.82"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=513.21 cfs 159.153 af

Pond 6P: Alternative2 - Proposed Peak Elev=63.94' Storage=0.402 af Inflow=513.02 cfs 159.153 af
Primary=512.93 cfs 159.153 af Secondary=0.00 cfs 0.000 af Outflow=512.93 cfs 159.153 af

Pond 7P: Existing Brandy Brow Rd Peak Elev=68.72' Storage=1.906 af Inflow=513.21 cfs 159.153 af
Outflow=513.02 cfs 159.153 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 159.153 af Average Runoff Depth = 0.82"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 513.21 cfs @ 13.21 hrs, Volume= 159.153 af, Depth= 0.82"
Routed to Pond 7P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 5-Year Rainfall=4.02"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Haverhill Brandy Brow Culvert

NRCC 24-hr D 5-Year Rainfall=4.02"

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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 5-Year Rainfall=4.02"

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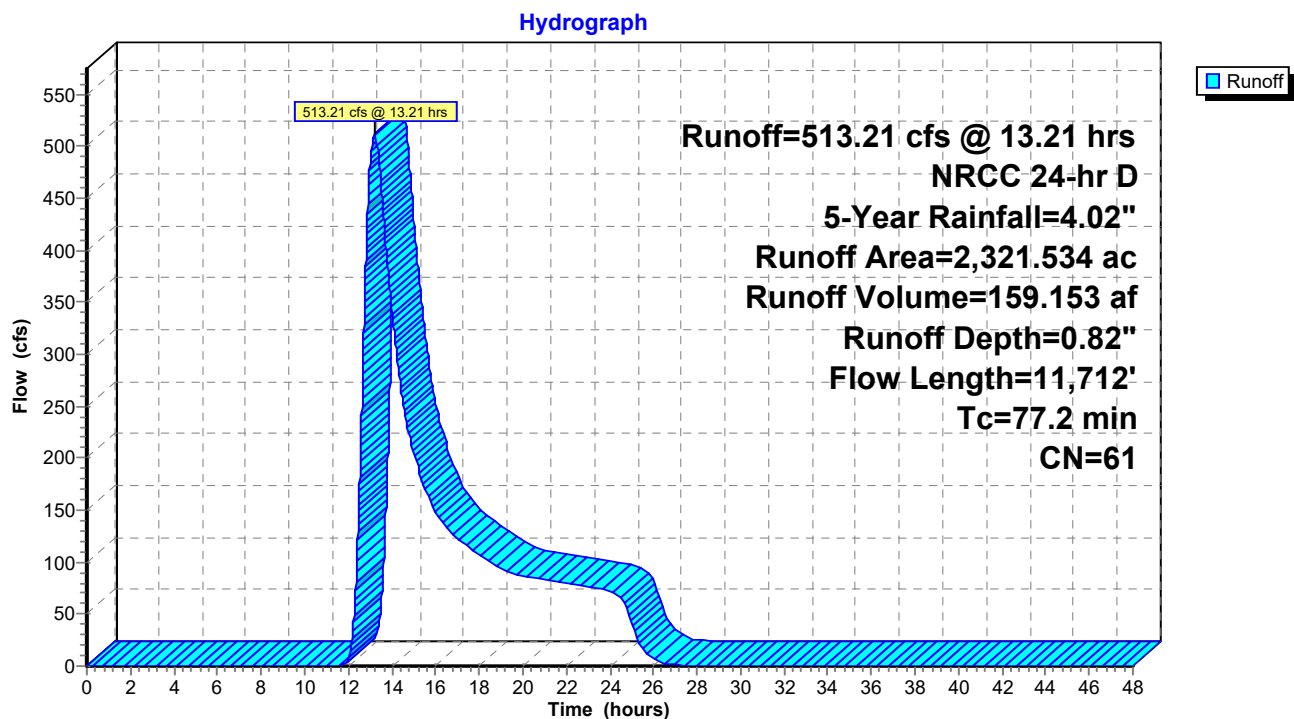
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 0.82" for 5-Year event
 Inflow = 513.02 cfs @ 13.22 hrs, Volume= 159.153 af
 Outflow = 512.93 cfs @ 13.22 hrs, Volume= 159.153 af, Atten= 0%, Lag= 0.4 min
 Primary = 512.93 cfs @ 13.22 hrs, Volume= 159.153 af
 Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 63.94' @ 13.22 hrs Surf.Area= 0.176 ac Storage= 0.402 af

Plug-Flow detention time= 0.6 min calculated for 159.119 af (100% of inflow)
 Center-of-Mass det. time= 0.6 min (997.3 - 996.7)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

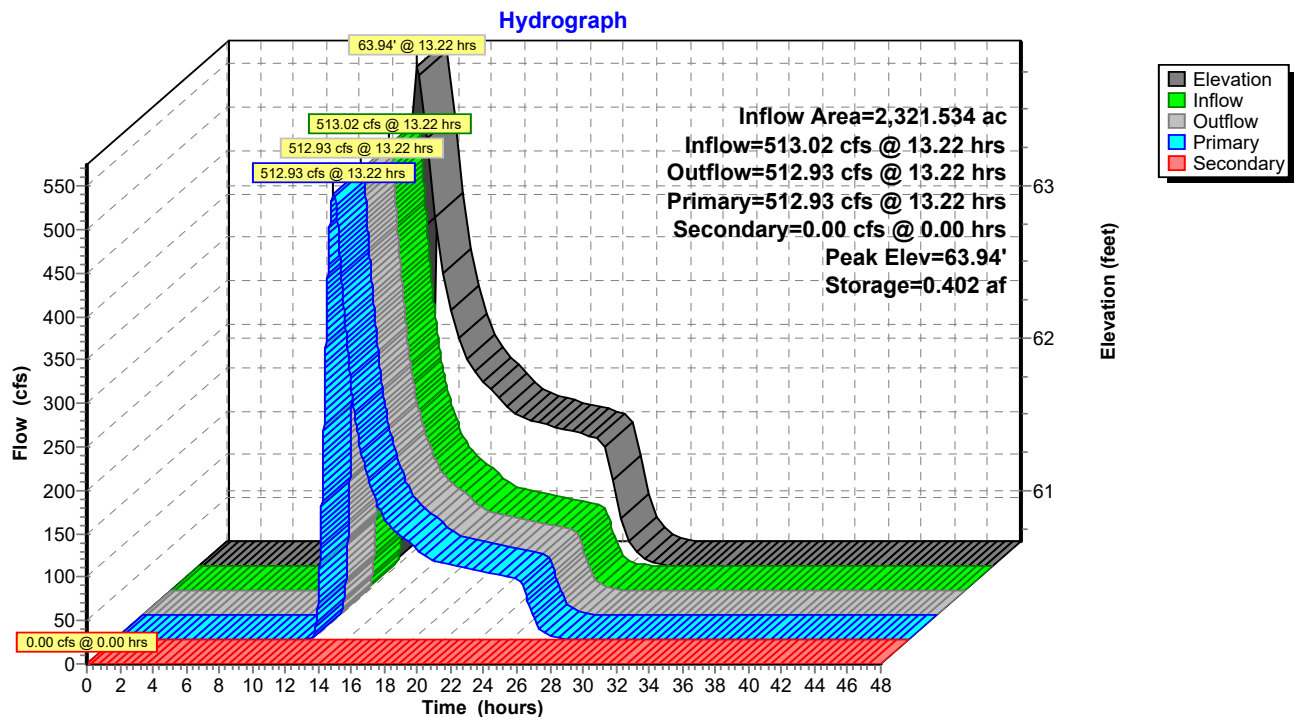
Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	408.0" W x 88.0" H Box Proposed Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 60.55' / 60.67' S= -0.0037 ' / ' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 249.33 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00

71.00 72.00 73.00

Primary OutFlow Max=512.91 cfs @ 13.22 hrs HW=63.94' (Free Discharge)
 ↳1=Proposed Box Culvert (Barrel Controls 512.91 cfs @ 5.93 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=60.67' (Free Discharge)
 ↳2=Overtopping Asymmetrical Weir(Controls 0.00 cfs)

Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert

NRCC 24-hr D 5-Year Rainfall=4.02"

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Stage-Discharge for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	3,258.73	2,789.08	469.65
60.87	9.76	9.76	0.00	71.07	3,577.41	2,880.95	696.46
61.07	26.57	26.57	0.00	71.27	3,939.21	2,969.98	969.23
61.27	45.55	45.55	0.00	71.47	4,339.03	3,056.42	1,282.61
61.47	67.68	67.68	0.00	71.67	4,774.99	3,140.48	1,634.51
61.67	92.54	92.54	0.00	71.87	5,246.15	3,222.35	2,023.80
61.87	119.83	119.83	0.00	72.07	5,751.96	3,302.18	2,449.78
62.07	149.36	149.36	0.00	72.27	6,261.15	3,350.03	2,911.11
62.27	180.95	180.95	0.00	72.47	6,800.04	3,393.61	3,406.43
62.47	214.47	214.47	0.00	72.67	7,371.54	3,436.59	3,934.95
62.67	249.83	249.83	0.00	72.87	7,975.12	3,479.00	4,496.12
62.87	286.92	286.92	0.00				
63.07	325.66	325.66	0.00				
63.27	366.00	366.00	0.00				
63.47	407.86	407.86	0.00				
63.67	451.20	451.20	0.00				
63.87	495.95	495.95	0.00				
64.07	542.09	542.09	0.00				
64.27	589.57	589.57	0.00				
64.47	638.36	638.36	0.00				
64.67	688.41	688.41	0.00				
64.87	739.70	739.70	0.00				
65.07	792.19	792.19	0.00				
65.27	845.87	845.87	0.00				
65.47	900.70	900.70	0.00				
65.67	956.67	956.67	0.00				
65.87	1,013.74	1,013.74	0.00				
66.07	1,071.90	1,071.90	0.00				
66.27	1,131.13	1,131.13	0.00				
66.47	1,191.40	1,191.40	0.00				
66.67	1,252.71	1,252.71	0.00				
66.87	1,315.03	1,315.03	0.00				
67.07	1,378.35	1,378.35	0.00				
67.27	1,442.65	1,442.65	0.00				
67.47	1,507.92	1,507.92	0.00				
67.67	1,574.14	1,574.14	0.00				
67.87	1,641.30	1,641.30	0.00				
68.07	1,709.39	1,709.39	0.00				
68.27	1,778.39	1,778.39	0.00				
68.47	1,848.30	1,848.30	0.00				
68.67	1,919.09	1,919.09	0.00				
68.87	1,990.76	1,990.76	0.00				
69.07	2,063.31	2,063.31	0.00				
69.27	2,136.71	2,136.71	0.00				
69.47	2,210.96	2,210.96	0.00				
69.67	2,286.05	2,286.05	0.00				
69.87	2,361.97	2,361.97	0.00				
70.07	2,456.47	2,438.71	17.76				
70.27	2,586.92	2,516.26	70.66				
70.47	2,756.30	2,595.60	160.71				
70.67	2,986.37	2,694.08	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 5-Year Rainfall=4.02"

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Stage-Area-Storage for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Summary for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 0.82" for 5-Year event
 Inflow = 513.21 cfs @ 13.21 hrs, Volume= 159.153 af
 Outflow = 513.02 cfs @ 13.22 hrs, Volume= 159.153 af, Atten= 0%, Lag= 0.4 min
 Primary = 513.02 cfs @ 13.22 hrs, Volume= 159.153 af
 Routed to Pond 6P : Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 68.72' @ 13.22 hrs Surf.Area= 0.389 ac Storage= 1.906 af (0.651 af above start)

Plug-Flow detention time= 7.8 min calculated for 157.897 af (99% of inflow)
 Center-of-Mass det. time= 1.3 min (996.7 - 995.4)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

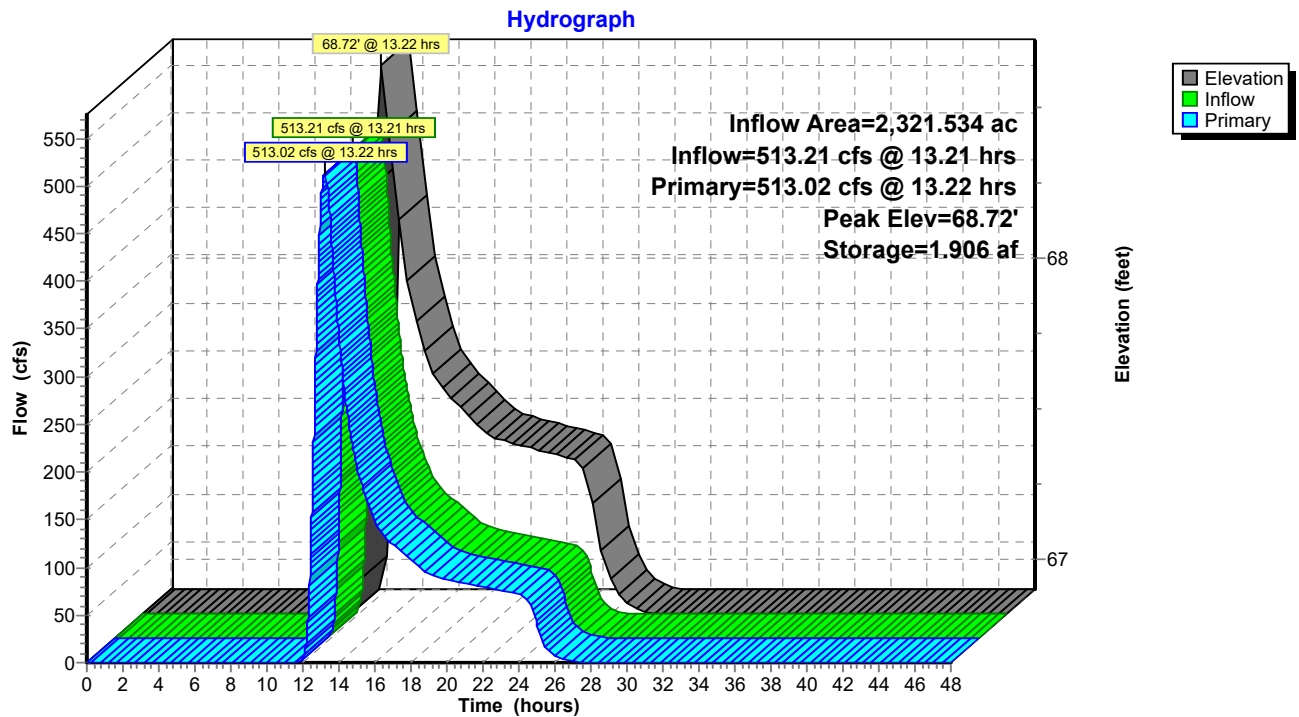
Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

125.83

Elev. (feet)	74.00	73.00	72.00	71.00	70.00	69.00	68.00	67.00
	66.90	66.90	67.00	68.00	69.00	70.00	71.00	72.00
								73.00
								74.00

Primary OutFlow Max=512.99 cfs @ 13.22 hrs HW=68.72' TW=63.94' (Dynamic Tailwater)
1=Dam Asymmetrical Weir (Weir Controls 512.99 cfs @ 4.20 fps)

Pond 7P: Existing Brandy Brow Rd Beaver Dam



Haverhill Brandy Brow Culvert*NRCC 24-hr D 5-Year Rainfall=4.02"*

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Stage-Discharge for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert*NRCC 24-hr D 5-Year Rainfall=4.02"*

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Stage-Area-Storage for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment8S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=1.27"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=870.09 cfs 245.345 af

Pond 6P: Alternative2 - Proposed Peak Elev=65.35' Storage=0.735 af Inflow=869.47 cfs 245.345 af
Primary=868.84 cfs 245.345 af Secondary=0.00 cfs 0.000 af Outflow=868.84 cfs 245.345 af

Pond 7P: Existing Brandy Brow Rd Peak Elev=69.45' Storage=2.207 af Inflow=870.09 cfs 245.345 af
Outflow=869.47 cfs 245.345 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 245.345 af Average Runoff Depth = 1.27"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 870.09 cfs @ 13.13 hrs, Volume= 245.345 af, Depth= 1.27"
Routed to Pond 7P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 10-Year Rainfall=4.83"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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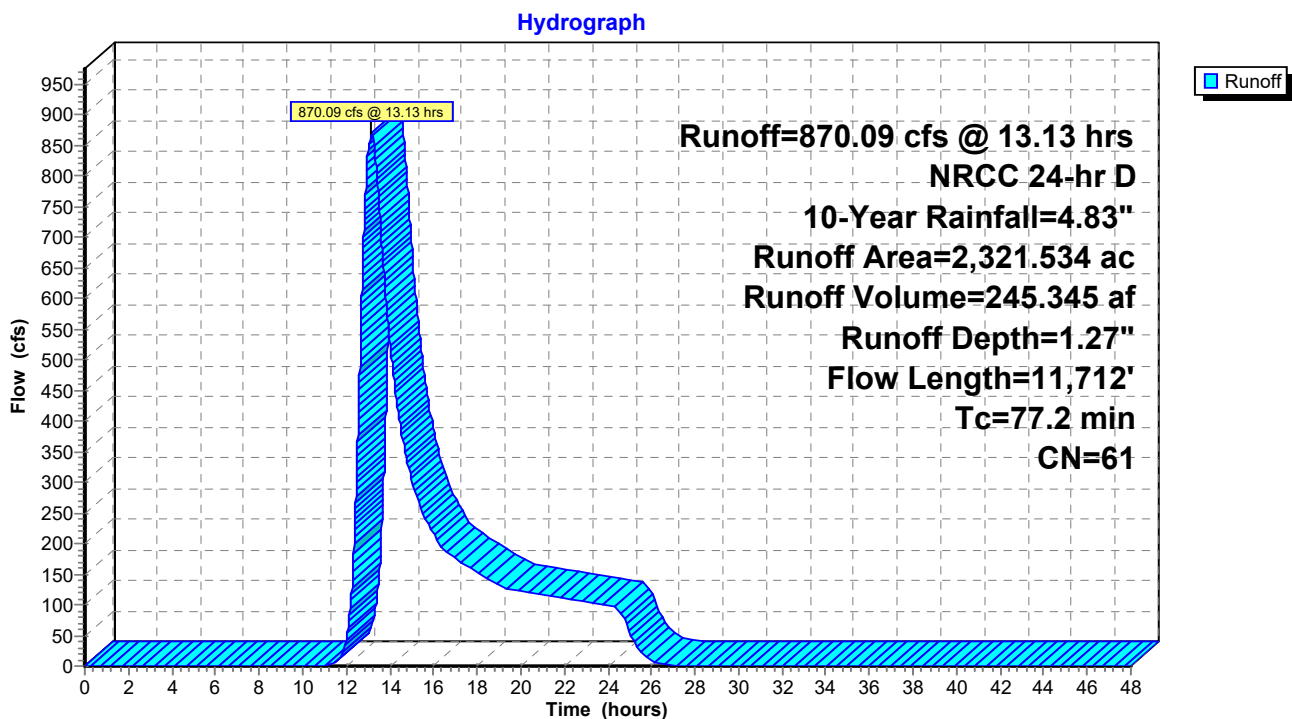
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 1.27" for 10-Year event
 Inflow = 869.47 cfs @ 13.14 hrs, Volume= 245.345 af
 Outflow = 868.84 cfs @ 13.15 hrs, Volume= 245.345 af, Atten= 0%, Lag= 0.9 min
 Primary = 868.84 cfs @ 13.15 hrs, Volume= 245.345 af
 Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 65.35' @ 13.15 hrs Surf.Area= 0.292 ac Storage= 0.735 af

Plug-Flow detention time= 0.6 min calculated for 245.294 af (100% of inflow)
 Center-of-Mass det. time= 0.6 min (978.6 - 978.0)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

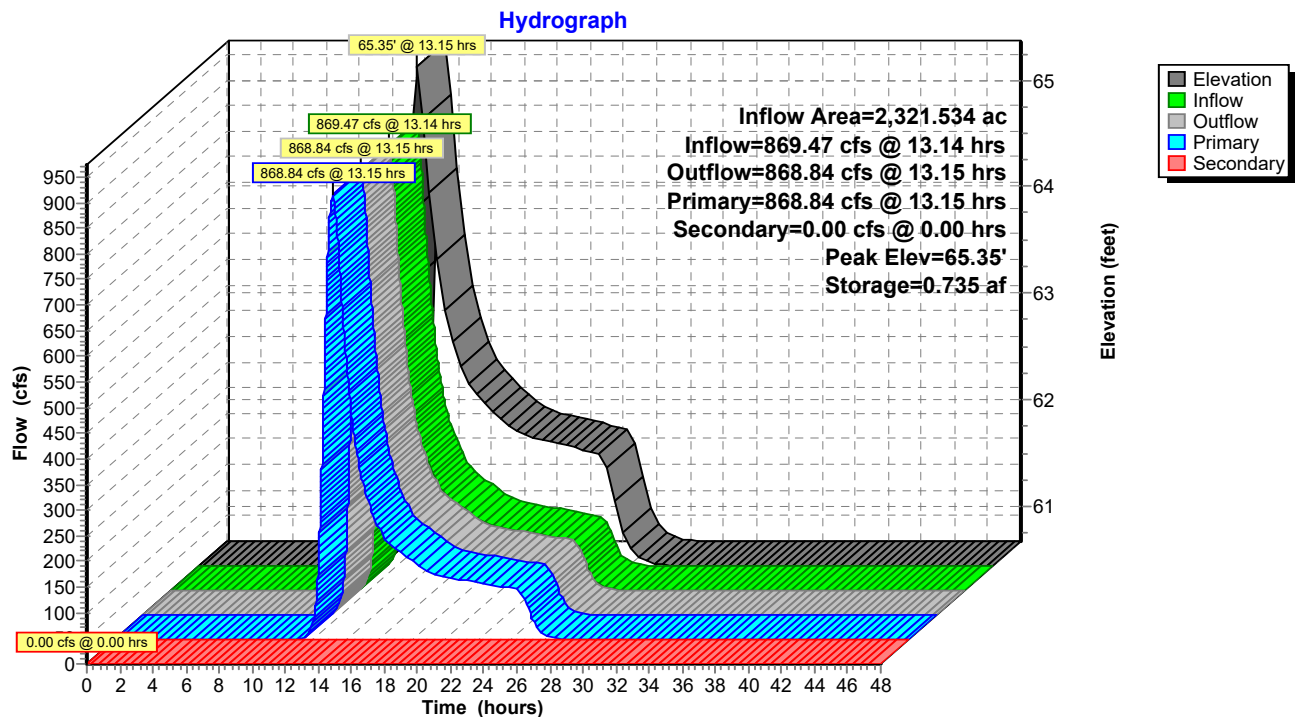
Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	408.0" W x 88.0" H Box Proposed Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 60.55' / 60.67' S= -0.0037 ' ' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 249.33 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00

71.00 72.00 73.00

Primary OutFlow Max=868.76 cfs @ 13.15 hrs HW=65.35' (Free Discharge)
 ↳ **1=Proposed Box Culvert** (Barrel Controls 868.76 cfs @ 7.09 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=60.67' (Free Discharge)
 ↳ **2=Overtopping Asymmetrical Weir**(Controls 0.00 cfs)

Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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Stage-Discharge for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	3,258.73	2,789.08	469.65
60.87	9.76	9.76	0.00	71.07	3,577.41	2,880.95	696.46
61.07	26.57	26.57	0.00	71.27	3,939.21	2,969.98	969.23
61.27	45.55	45.55	0.00	71.47	4,339.03	3,056.42	1,282.61
61.47	67.68	67.68	0.00	71.67	4,774.99	3,140.48	1,634.51
61.67	92.54	92.54	0.00	71.87	5,246.15	3,222.35	2,023.80
61.87	119.83	119.83	0.00	72.07	5,751.96	3,302.18	2,449.78
62.07	149.36	149.36	0.00	72.27	6,261.15	3,350.03	2,911.11
62.27	180.95	180.95	0.00	72.47	6,800.04	3,393.61	3,406.43
62.47	214.47	214.47	0.00	72.67	7,371.54	3,436.59	3,934.95
62.67	249.83	249.83	0.00	72.87	7,975.12	3,479.00	4,496.12
62.87	286.92	286.92	0.00				
63.07	325.66	325.66	0.00				
63.27	366.00	366.00	0.00				
63.47	407.86	407.86	0.00				
63.67	451.20	451.20	0.00				
63.87	495.95	495.95	0.00				
64.07	542.09	542.09	0.00				
64.27	589.57	589.57	0.00				
64.47	638.36	638.36	0.00				
64.67	688.41	688.41	0.00				
64.87	739.70	739.70	0.00				
65.07	792.19	792.19	0.00				
65.27	845.87	845.87	0.00				
65.47	900.70	900.70	0.00				
65.67	956.67	956.67	0.00				
65.87	1,013.74	1,013.74	0.00				
66.07	1,071.90	1,071.90	0.00				
66.27	1,131.13	1,131.13	0.00				
66.47	1,191.40	1,191.40	0.00				
66.67	1,252.71	1,252.71	0.00				
66.87	1,315.03	1,315.03	0.00				
67.07	1,378.35	1,378.35	0.00				
67.27	1,442.65	1,442.65	0.00				
67.47	1,507.92	1,507.92	0.00				
67.67	1,574.14	1,574.14	0.00				
67.87	1,641.30	1,641.30	0.00				
68.07	1,709.39	1,709.39	0.00				
68.27	1,778.39	1,778.39	0.00				
68.47	1,848.30	1,848.30	0.00				
68.67	1,919.09	1,919.09	0.00				
68.87	1,990.76	1,990.76	0.00				
69.07	2,063.31	2,063.31	0.00				
69.27	2,136.71	2,136.71	0.00				
69.47	2,210.96	2,210.96	0.00				
69.67	2,286.05	2,286.05	0.00				
69.87	2,361.97	2,361.97	0.00				
70.07	2,456.47	2,438.71	17.76				
70.27	2,586.92	2,516.26	70.66				
70.47	2,756.30	2,595.60	160.71				
70.67	2,986.37	2,694.08	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

Prepared by Greenman-Pedersen, Inc

Printed 7/24/2024

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Stage-Area-Storage for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Summary for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 1.27" for 10-Year event
 Inflow = 870.09 cfs @ 13.13 hrs, Volume= 245.345 af
 Outflow = 869.47 cfs @ 13.14 hrs, Volume= 245.345 af, Atten= 0%, Lag= 0.7 min
 Primary = 869.47 cfs @ 13.14 hrs, Volume= 245.345 af
 Routed to Pond 6P : Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 69.45' @ 13.14 hrs Surf.Area= 0.451 ac Storage= 2.207 af (0.951 af above start)

Plug-Flow detention time= 5.5 min calculated for 244.038 af (99% of inflow)
 Center-of-Mass det. time= 1.2 min (978.0 - 976.9)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

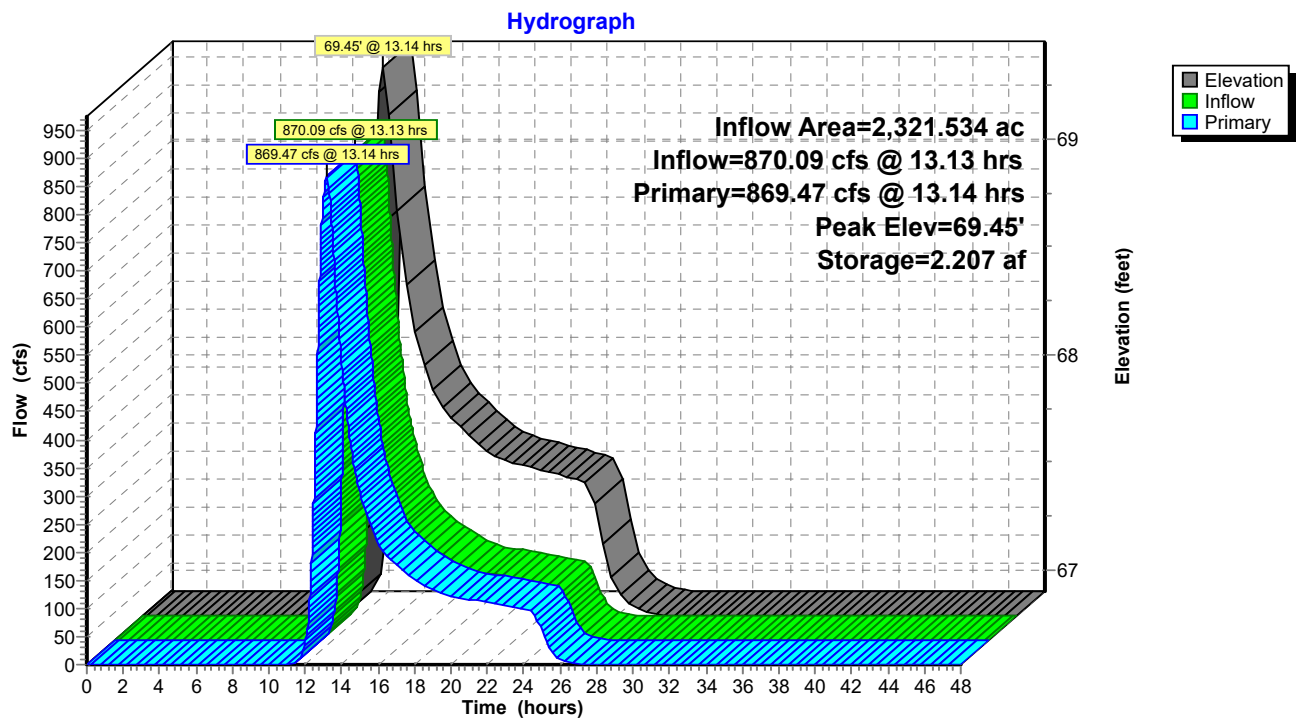
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

125.83
 Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00
 66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=869.46 cfs @ 13.14 hrs HW=69.45' TW=65.35' (Dynamic Tailwater)
 1=Dam Asymmetrical Weir (Weir Controls 869.46 cfs @ 4.94 fps)

Pond 7P: Existing Brandy Brow Rd Beaver Dam



Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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Stage-Discharge for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert

NRCC 24-hr D 10-Year Rainfall=4.83"

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Stage-Area-Storage for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment8S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=2.11"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=1,551.54 cfs 408.846 af

Pond 6P: Alternative2 - Proposed Peak Elev=67.14' Storage=10.153 af Inflow=1,550.52 cfs 408.846 af
Primary=1,399.83 cfs 408.846 af Secondary=0.00 cfs 0.000 af Outflow=1,399.83 cfs 408.846 af

Pond 7P: Existing Brandy Brow Rd Peak Elev=70.56' Storage=2.772 af Inflow=1,551.54 cfs 408.846 af
Outflow=1,550.52 cfs 408.846 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 408.846 af Average Runoff Depth = 2.11"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 1,551.54 cfs @ 13.12 hrs, Volume= 408.846 af, Depth= 2.11"
Routed to Pond 7P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 25-Year Rainfall=6.16"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

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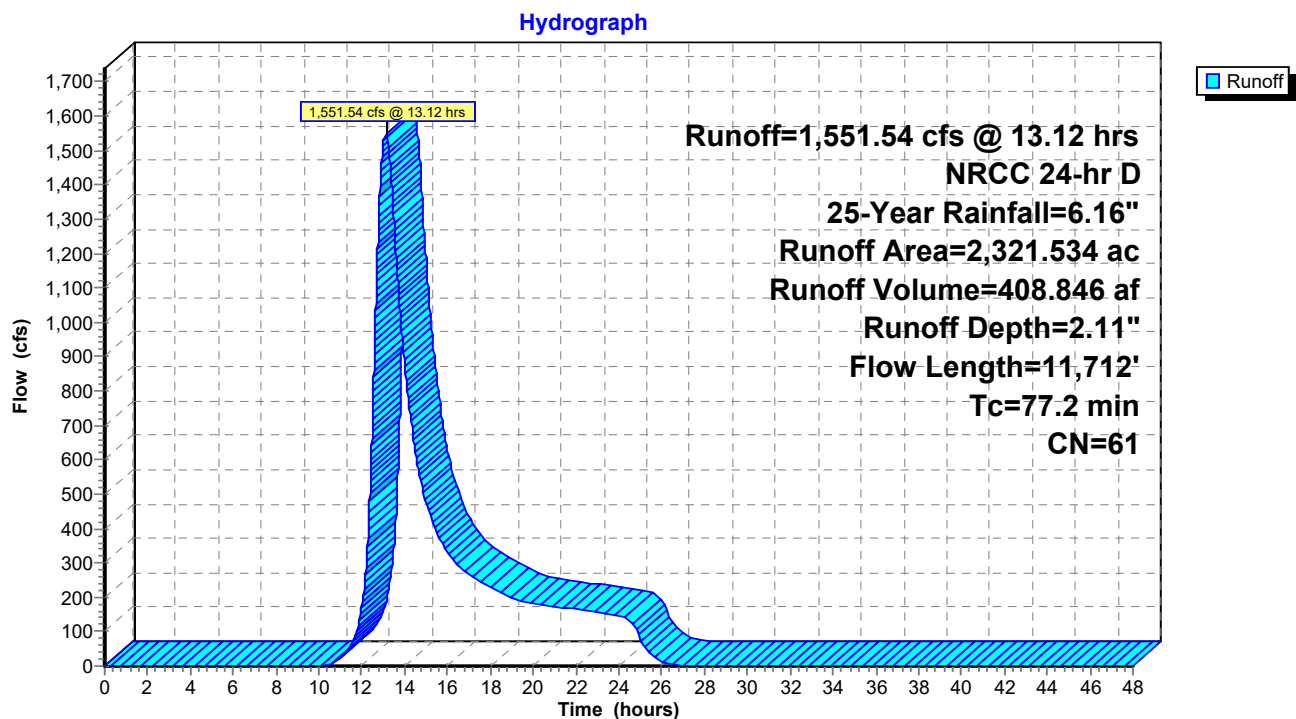
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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

0.4	199		8.02		Lake or Reservoir, 199 ft. Lake Flow - Water
					Mean Depth= 2.00'
0.2	135	0.0150	13.66	5,900.41	Parabolic Channel, 135 ft. Channel Flow - Woods
					W=81.00' D=8.00' Area=432.0 sf Perim=83.1'
					n= 0.040 Mountain streams
77.2	11,712	Total			

Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 2.11" for 25-Year event
 Inflow = 1,550.52 cfs @ 13.13 hrs, Volume= 408.846 af
 Outflow = 1,399.83 cfs @ 13.40 hrs, Volume= 408.846 af, Atten= 10%, Lag= 16.4 min
 Primary = 1,399.83 cfs @ 13.40 hrs, Volume= 408.846 af
 Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 67.14' @ 13.40 hrs Surf.Area= 14.673 ac Storage= 10.153 af

Plug-Flow detention time= 1.6 min calculated for 408.761 af (100% of inflow)
 Center-of-Mass det. time= 1.6 min (959.2 - 957.6)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

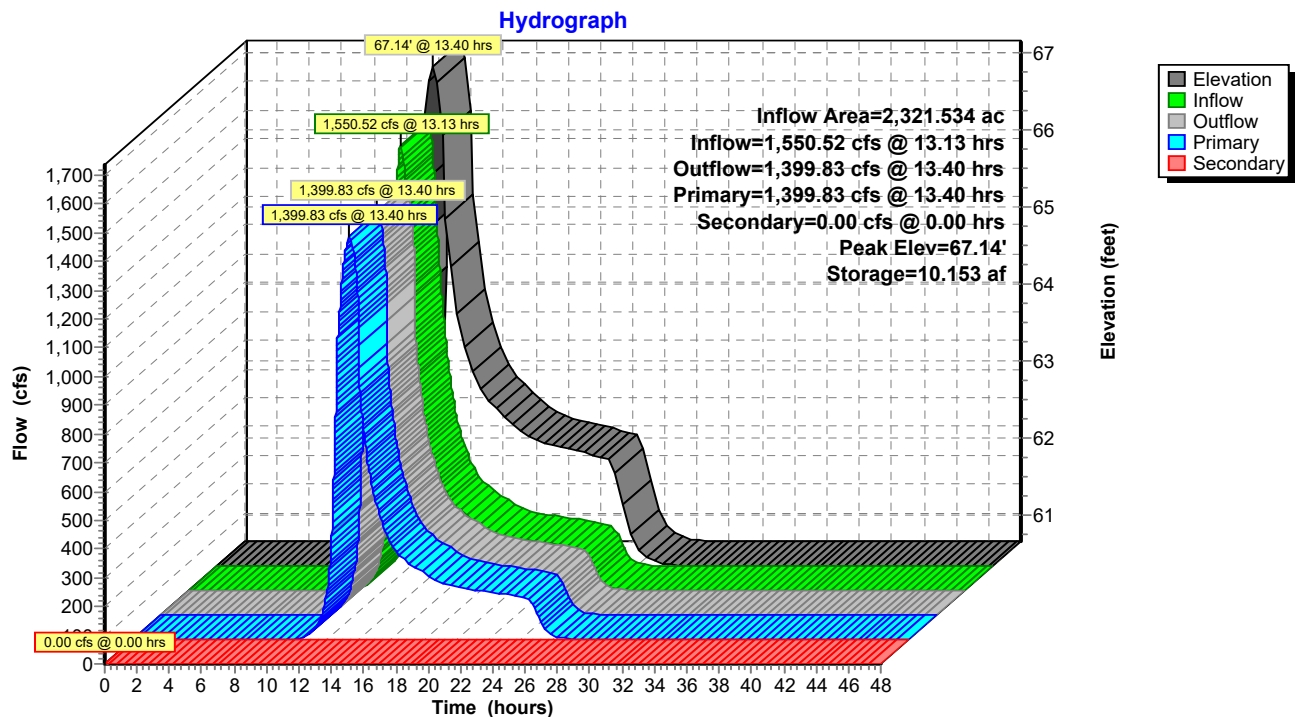
Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	408.0" W x 88.0" H Box Proposed Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 60.55' / 60.67' S= -0.0037 '/' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 249.33 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00

71.00 72.00 73.00

Primary OutFlow Max=1,399.81 cfs @ 13.40 hrs HW=67.14' (Free Discharge)
 ↳1=Proposed Box Culvert (Barrel Controls 1,399.81 cfs @ 8.33 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=60.67' (Free Discharge)
 ↳2=Overtopping Asymmetrical Weir(Controls 0.00 cfs)

Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

Prepared by Greenman-Pedersen, Inc

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Stage-Discharge for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	3,258.73	2,789.08	469.65
60.87	9.76	9.76	0.00	71.07	3,577.41	2,880.95	696.46
61.07	26.57	26.57	0.00	71.27	3,939.21	2,969.98	969.23
61.27	45.55	45.55	0.00	71.47	4,339.03	3,056.42	1,282.61
61.47	67.68	67.68	0.00	71.67	4,774.99	3,140.48	1,634.51
61.67	92.54	92.54	0.00	71.87	5,246.15	3,222.35	2,023.80
61.87	119.83	119.83	0.00	72.07	5,751.96	3,302.18	2,449.78
62.07	149.36	149.36	0.00	72.27	6,261.15	3,350.03	2,911.11
62.27	180.95	180.95	0.00	72.47	6,800.04	3,393.61	3,406.43
62.47	214.47	214.47	0.00	72.67	7,371.54	3,436.59	3,934.95
62.67	249.83	249.83	0.00	72.87	7,975.12	3,479.00	4,496.12
62.87	286.92	286.92	0.00				
63.07	325.66	325.66	0.00				
63.27	366.00	366.00	0.00				
63.47	407.86	407.86	0.00				
63.67	451.20	451.20	0.00				
63.87	495.95	495.95	0.00				
64.07	542.09	542.09	0.00				
64.27	589.57	589.57	0.00				
64.47	638.36	638.36	0.00				
64.67	688.41	688.41	0.00				
64.87	739.70	739.70	0.00				
65.07	792.19	792.19	0.00				
65.27	845.87	845.87	0.00				
65.47	900.70	900.70	0.00				
65.67	956.67	956.67	0.00				
65.87	1,013.74	1,013.74	0.00				
66.07	1,071.90	1,071.90	0.00				
66.27	1,131.13	1,131.13	0.00				
66.47	1,191.40	1,191.40	0.00				
66.67	1,252.71	1,252.71	0.00				
66.87	1,315.03	1,315.03	0.00				
67.07	1,378.35	1,378.35	0.00				
67.27	1,442.65	1,442.65	0.00				
67.47	1,507.92	1,507.92	0.00				
67.67	1,574.14	1,574.14	0.00				
67.87	1,641.30	1,641.30	0.00				
68.07	1,709.39	1,709.39	0.00				
68.27	1,778.39	1,778.39	0.00				
68.47	1,848.30	1,848.30	0.00				
68.67	1,919.09	1,919.09	0.00				
68.87	1,990.76	1,990.76	0.00				
69.07	2,063.31	2,063.31	0.00				
69.27	2,136.71	2,136.71	0.00				
69.47	2,210.96	2,210.96	0.00				
69.67	2,286.05	2,286.05	0.00				
69.87	2,361.97	2,361.97	0.00				
70.07	2,456.47	2,438.71	17.76				
70.27	2,586.92	2,516.26	70.66				
70.47	2,756.30	2,595.60	160.71				
70.67	2,986.37	2,694.08	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

Prepared by Greenman-Pedersen, Inc

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Stage-Area-Storage for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Summary for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 2.11" for 25-Year event
 Inflow = 1,551.54 cfs @ 13.12 hrs, Volume= 408.846 af
 Outflow = 1,550.52 cfs @ 13.13 hrs, Volume= 408.846 af, Atten= 0%, Lag= 0.5 min
 Primary = 1,550.52 cfs @ 13.13 hrs, Volume= 408.846 af
 Routed to Pond 6P : Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 70.56' @ 13.13 hrs Surf.Area= 0.556 ac Storage= 2.772 af (1.517 af above start)

Plug-Flow detention time= 3.9 min calculated for 407.590 af (100% of inflow)
 Center-of-Mass det. time= 1.0 min (957.6 - 956.6)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

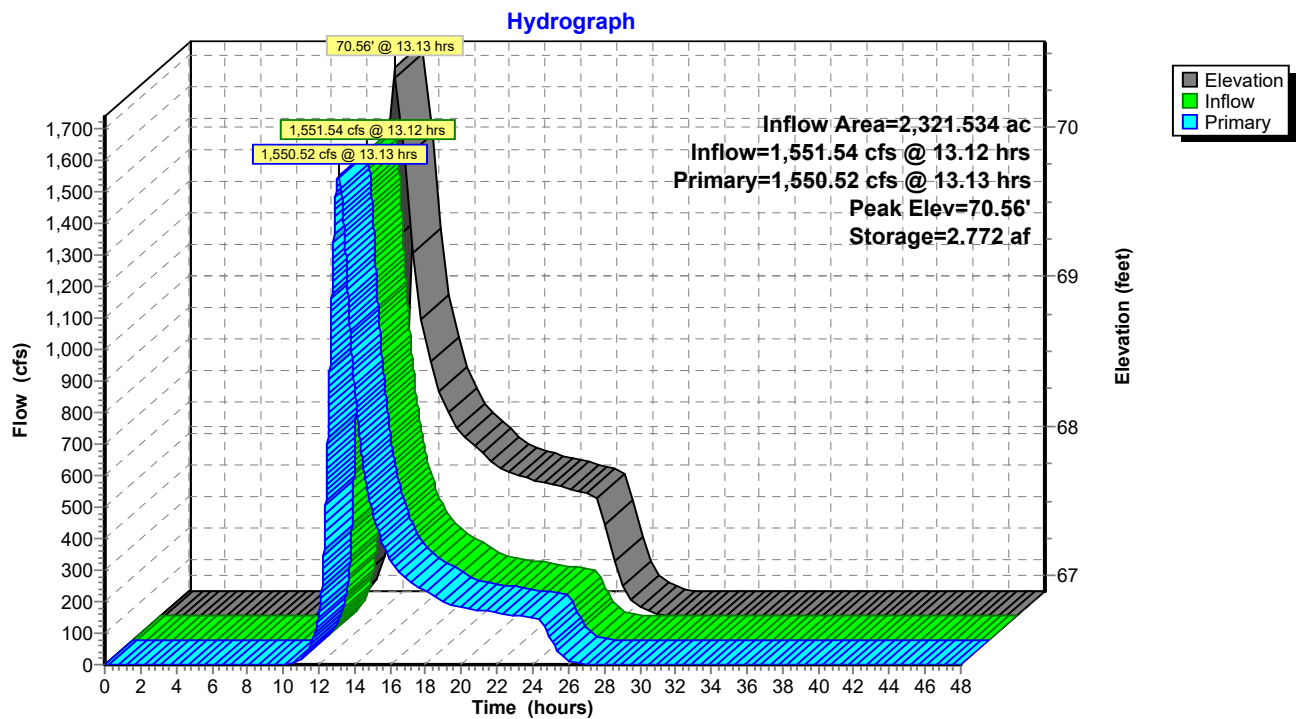
Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

125.83

Elev. (feet)	74.00	73.00	72.00	71.00	70.00	69.00	68.00	67.00
	66.90	66.90	67.00	68.00	69.00	70.00	71.00	72.00
							73.00	74.00

Primary OutFlow Max=1,550.41 cfs @ 13.13 hrs HW=70.56' TW=66.96' (Dynamic Tailwater)
 ↳1=Dam Asymmetrical Weir (Weir Controls 1,550.41 cfs @ 5.86 fps)

Pond 7P: Existing Brandy Brow Rd Beaver Dam



Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

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Stage-Discharge for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert

NRCC 24-hr D 25-Year Rainfall=6.16"

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Stage-Area-Storage for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment8S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=3.01"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=2,268.01 cfs 582.104 af

Pond 6P: Alternative2 - Proposed Peak Elev=68.50' Storage=34.895 af Inflow=2,264.79 cfs 582.104 af
Primary=1,859.97 cfs 582.104 af Secondary=0.00 cfs 0.000 af Outflow=1,859.97 cfs 582.104 af

Pond 7P: Existing Brandy Brow Rd Peak Elev=71.58' Storage=3.373 af Inflow=2,268.01 cfs 582.104 af
Outflow=2,264.79 cfs 582.104 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 582.104 af Average Runoff Depth = 3.01"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 2,268.01 cfs @ 13.12 hrs, Volume= 582.104 af, Depth= 3.01"
Routed to Pond 7P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 50-Year Rainfall=7.42"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

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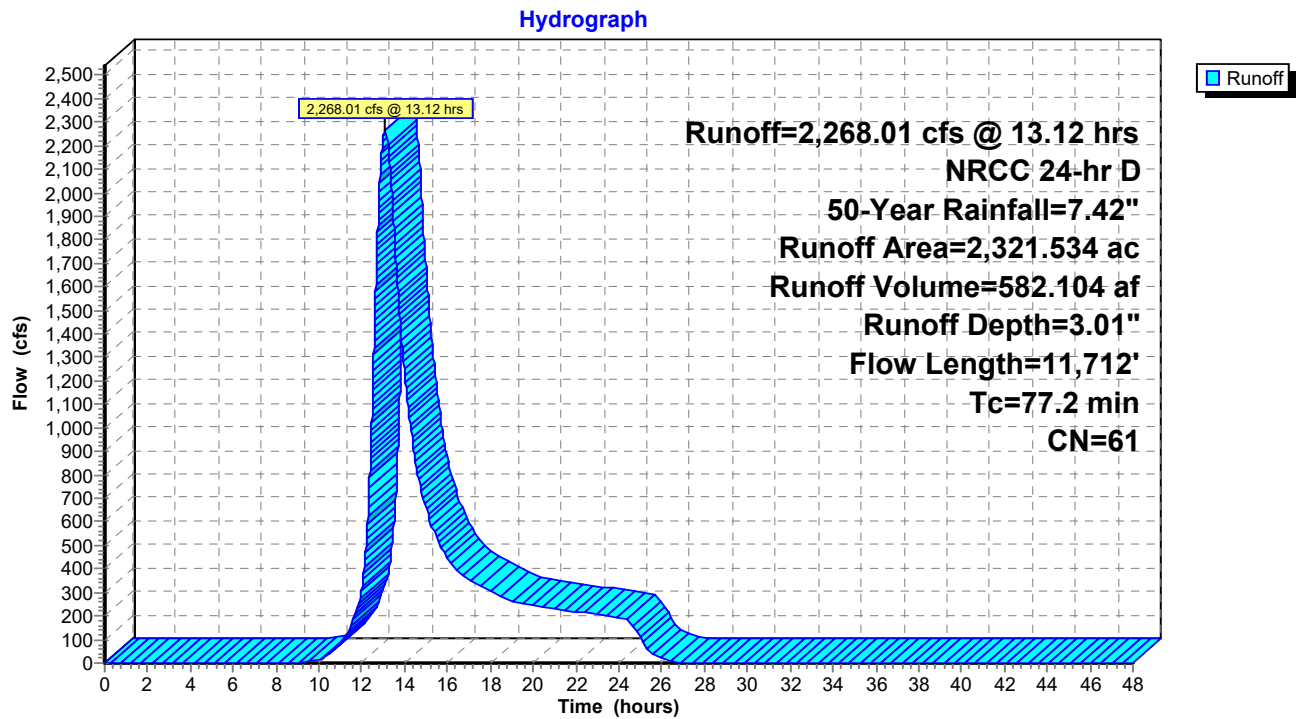
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 3.01" for 50-Year event
 Inflow = 2,264.79 cfs @ 13.12 hrs, Volume= 582.104 af
 Outflow = 1,859.97 cfs @ 13.51 hrs, Volume= 582.104 af, Atten= 18%, Lag= 23.1 min
 Primary = 1,859.97 cfs @ 13.51 hrs, Volume= 582.104 af
 Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 68.50' @ 13.51 hrs Surf.Area= 24.415 ac Storage= 34.895 af

Plug-Flow detention time= 4.6 min calculated for 581.982 af (100% of inflow)
 Center-of-Mass det. time= 4.6 min (948.7 - 944.1)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

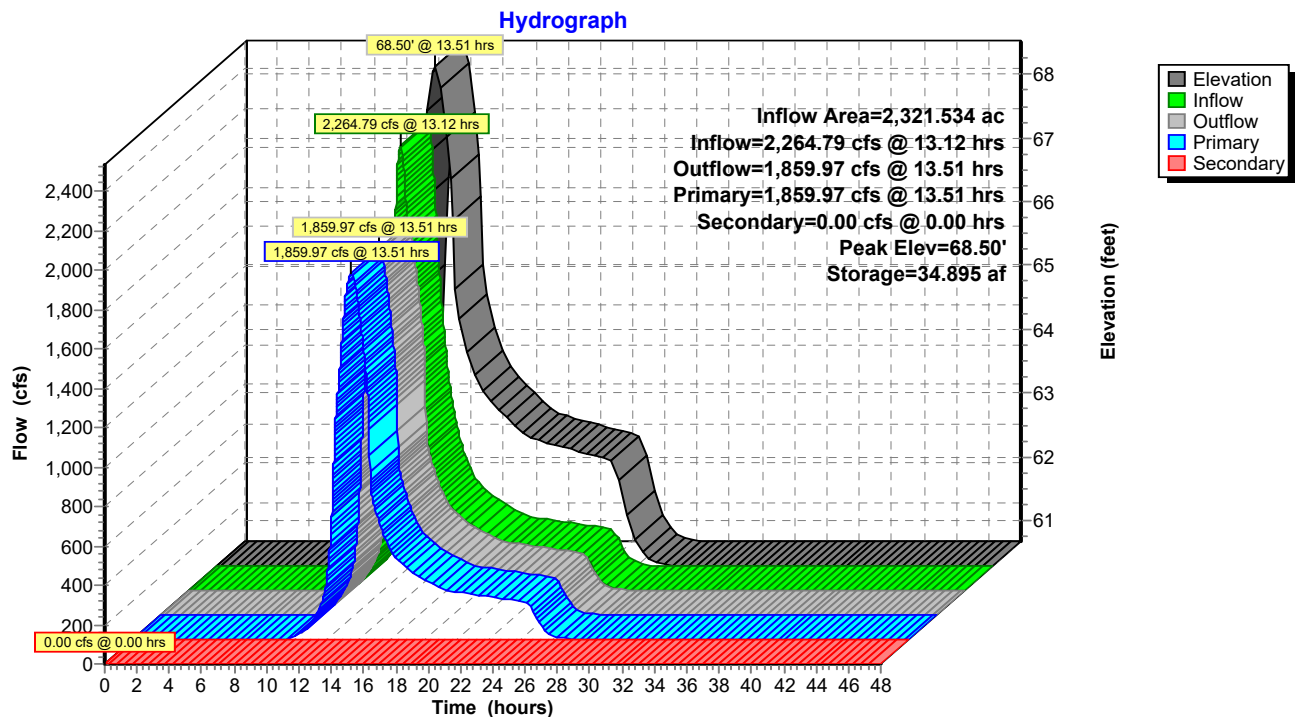
Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	408.0" W x 88.0" H Box Proposed Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 60.55' / 60.67' S= -0.0037 '/' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 249.33 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00

71.00 72.00 73.00

Primary OutFlow Max=1,859.95 cfs @ 13.51 hrs HW=68.50' (Free Discharge)
 ↳1=Proposed Box Culvert (Barrel Controls 1,859.95 cfs @ 9.17 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=60.67' (Free Discharge)
 ↳2=Overtopping Asymmetrical Weir(Controls 0.00 cfs)

Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River



Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

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Stage-Discharge for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	3,258.73	2,789.08	469.65
60.87	9.76	9.76	0.00	71.07	3,577.41	2,880.95	696.46
61.07	26.57	26.57	0.00	71.27	3,939.21	2,969.98	969.23
61.27	45.55	45.55	0.00	71.47	4,339.03	3,056.42	1,282.61
61.47	67.68	67.68	0.00	71.67	4,774.99	3,140.48	1,634.51
61.67	92.54	92.54	0.00	71.87	5,246.15	3,222.35	2,023.80
61.87	119.83	119.83	0.00	72.07	5,751.96	3,302.18	2,449.78
62.07	149.36	149.36	0.00	72.27	6,261.15	3,350.03	2,911.11
62.27	180.95	180.95	0.00	72.47	6,800.04	3,393.61	3,406.43
62.47	214.47	214.47	0.00	72.67	7,371.54	3,436.59	3,934.95
62.67	249.83	249.83	0.00	72.87	7,975.12	3,479.00	4,496.12
62.87	286.92	286.92	0.00				
63.07	325.66	325.66	0.00				
63.27	366.00	366.00	0.00				
63.47	407.86	407.86	0.00				
63.67	451.20	451.20	0.00				
63.87	495.95	495.95	0.00				
64.07	542.09	542.09	0.00				
64.27	589.57	589.57	0.00				
64.47	638.36	638.36	0.00				
64.67	688.41	688.41	0.00				
64.87	739.70	739.70	0.00				
65.07	792.19	792.19	0.00				
65.27	845.87	845.87	0.00				
65.47	900.70	900.70	0.00				
65.67	956.67	956.67	0.00				
65.87	1,013.74	1,013.74	0.00				
66.07	1,071.90	1,071.90	0.00				
66.27	1,131.13	1,131.13	0.00				
66.47	1,191.40	1,191.40	0.00				
66.67	1,252.71	1,252.71	0.00				
66.87	1,315.03	1,315.03	0.00				
67.07	1,378.35	1,378.35	0.00				
67.27	1,442.65	1,442.65	0.00				
67.47	1,507.92	1,507.92	0.00				
67.67	1,574.14	1,574.14	0.00				
67.87	1,641.30	1,641.30	0.00				
68.07	1,709.39	1,709.39	0.00				
68.27	1,778.39	1,778.39	0.00				
68.47	1,848.30	1,848.30	0.00				
68.67	1,919.09	1,919.09	0.00				
68.87	1,990.76	1,990.76	0.00				
69.07	2,063.31	2,063.31	0.00				
69.27	2,136.71	2,136.71	0.00				
69.47	2,210.96	2,210.96	0.00				
69.67	2,286.05	2,286.05	0.00				
69.87	2,361.97	2,361.97	0.00				
70.07	2,456.47	2,438.71	17.76				
70.27	2,586.92	2,516.26	70.66				
70.47	2,756.30	2,595.60	160.71				
70.67	2,986.37	2,694.08	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

Prepared by Greenman-Pedersen, Inc

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Stage-Area-Storage for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Summary for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 3.01" for 50-Year event
 Inflow = 2,268.01 cfs @ 13.12 hrs, Volume= 582.104 af
 Outflow = 2,264.79 cfs @ 13.12 hrs, Volume= 582.104 af, Atten= 0%, Lag= 0.3 min
 Primary = 2,264.79 cfs @ 13.12 hrs, Volume= 582.104 af
 Routed to Pond 6P : Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 71.58' @ 13.13 hrs Surf.Area= 0.619 ac Storage= 3.373 af (2.118 af above start)

Plug-Flow detention time= 3.1 min calculated for 580.848 af (100% of inflow)
 Center-of-Mass det. time= 0.9 min (944.1 - 943.2)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

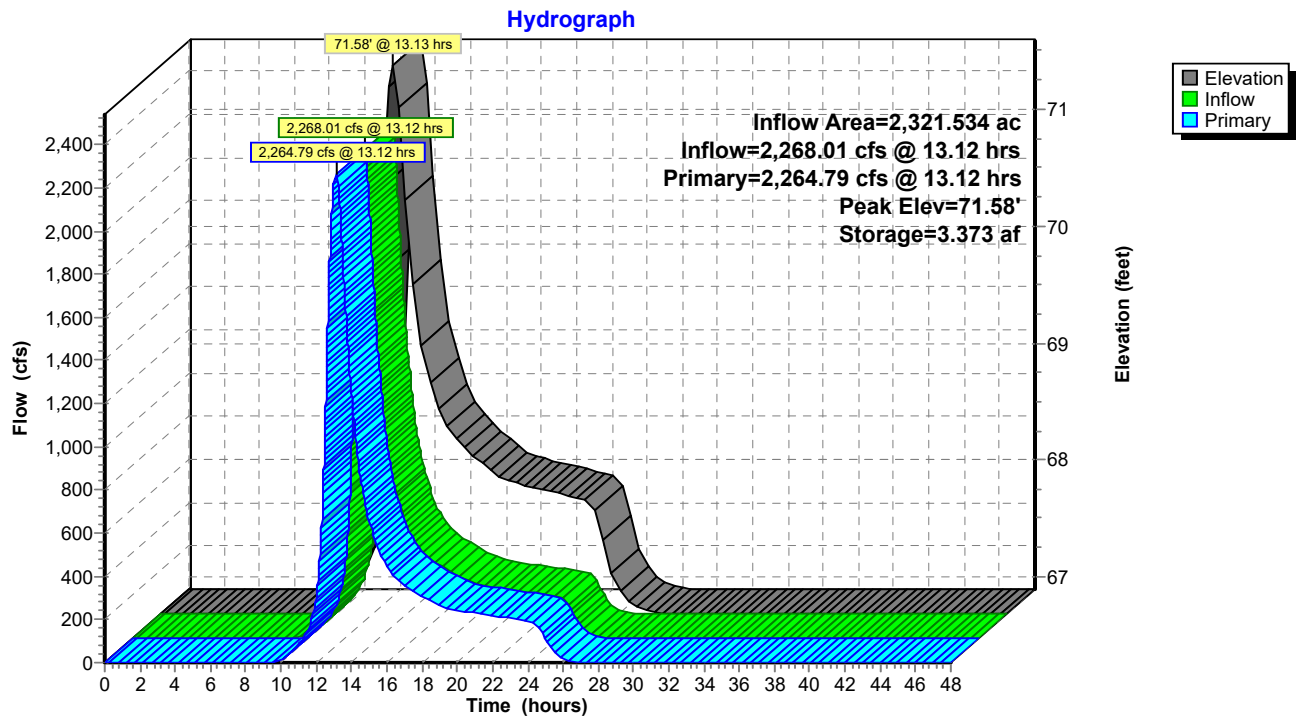
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

125.83
 Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00
 66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=2,264.65 cfs @ 13.12 hrs HW=71.58' TW=68.08' (Dynamic Tailwater)
 1=Dam Asymmetrical Weir (Weir Controls 2,264.65 cfs @ 6.40 fps)

Pond 7P: Existing Brandy Brow Rd Beaver Dam



Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

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Stage-Discharge for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert

NRCC 24-hr D 50-Year Rainfall=7.42"

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Stage-Area-Storage for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment8S: Brandy Brow Rd Runoff Area=2,321.534 ac 9.32% Impervious Runoff Depth=4.18"
Flow Length=11,712' Tc=77.2 min CN=61 Runoff=3,191.97 cfs 807.936 af

Pond 6P: Alternative2 - Proposed Peak Elev=69.88' Storage=77.111 af Inflow=3,187.54 cfs 807.936 af
Primary=2,366.11 cfs 807.936 af Secondary=0.00 cfs 0.000 af Outflow=2,366.11 cfs 807.936 af

Pond 7P: Existing Brandy Brow Rd Peak Elev=72.75' Storage=4.134 af Inflow=3,191.97 cfs 807.936 af
Outflow=3,187.54 cfs 807.936 af

Total Runoff Area = 2,321.534 ac Runoff Volume = 807.936 af Average Runoff Depth = 4.18"
90.68% Pervious = 2,105.067 ac 9.32% Impervious = 216.467 ac

Summary for Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area

Land use and Tc Path were obtained using 1 ft contours. Backup can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Land Use Data from Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MA Executive Office of Energy and Environmental Affairs' Land Cover / Land Use Source: MassGIS.
(<https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/datasets/Mass-EOEEA::land-cover-land-use-source-mass>)

Land Use Data from New Hampshire Geodata Portal by NH GRANIT LandCover / Land Use Source:
(https://www.nhgeodata.unh.edu/datasets/794284cc673e4507b9529804cf86aa4e_0/about)

Runoff = 3,191.97 cfs @ 13.12 hrs, Volume= 807.936 af, Depth= 4.18"
Routed to Pond 7P : Existing Brandy Brow Rd Beaver Dam

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 100-Year Rainfall=8.94"

Area (ac)	CN	Description
31.735	30	Brush, Good, HSG A
3.405	48	Brush, Good, HSG B
0.037	65	Brush, Good, HSG C
40.968	73	Brush, Good, HSG D
47.515	89	Urban commercial, 85% imp, HSG A
2.752	92	Urban commercial, 85% imp, HSG B
1.200	94	Urban commercial, 85% imp, HSG C
5.614	95	Urban commercial, 85% imp, HSG D
0.875	74	Farmsteads, HSG B
0.831	82	Farmsteads, HSG C
0.344	86	Farmsteads, HSG D
73.989	98	Paved parking, HSG A
98.365	39	>75% Grass cover, Good, HSG A
42.619	61	>75% Grass cover, Good, HSG B
29.535	74	>75% Grass cover, Good, HSG C
85.688	80	>75% Grass cover, Good, HSG D
89.074	61	1/4 acre lots, 38% imp, HSG A
54.055	75	1/4 acre lots, 38% imp, HSG B
22.582	83	1/4 acre lots, 38% imp, HSG C
45.584	87	1/4 acre lots, 38% imp, HSG D
13.667	98	Water Surface, HSG A
606.768	30	Woods, Good, HSG A
150.824	55	Woods, Good, HSG B
223.499	70	Woods, Good, HSG C
650.009	77	Woods, Good, HSG D
2,321.534	61	Weighted Average
2,105.067		90.68% Pervious Area
216.467		9.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
35.0	100	0.0060	0.05		Sheet Flow, 100 ft. Sheet Flow - Woods Woods: Light underbrush n= 0.400 P2= 3.15"
5.5	254	0.0240	0.77		Shallow Concentrated Flow, 254 ft. Shallow Conc. Flow - Woods Woodland Kv= 5.0 fps
10.2	1,611	0.0020	2.64	6,529.90	Parabolic Channel, 1611 ft. Channel Flow - Woods W=1,238.00' D=3.00' Area=2,476.0 sf Perim=1,238.0' n= 0.040 Mountain streams
4.1	1,099	0.0040	4.52	8,517.88	Parabolic Channel, 1099 ft. Channel Flow - Woods W=707.00' D=4.00' Area=1,885.3 sf Perim=707.1' n= 0.040 Mountain streams
0.7	592	0.0150	15.02	66,326.28	Parabolic Channel, 592 ft. Channel Flow - Woods W=736.00' D=9.00' Area=4,416.0 sf Perim=736.3' n= 0.040 Mountain streams
0.4	142		5.67		Lake or Reservoir, 142 ft. Lake Flow - Water Mean Depth= 1.00'
1.6	1,004	0.0080	10.14	79,301.12	Parabolic Channel, 1004 ft. Channel Flow - Woods W=1,466.00' D=8.00' Area=7,818.7 sf Perim=1,466.1' n= 0.040 Mountain streams
0.4	369	0.0054	17.33444	686.55	Parabolic Channel, 369 ft. Channel Flow - Woods W=1,604.00' D=24.00' Area=25,664.0 sf Perim=1,605.0' n= 0.040 Mountain streams
1.0	713	0.0028	12.48321	409.66	Parabolic Channel, 713 ft. Channel Flow - Brush W=1,610.00' D=24.00' Area=25,760.0 sf Perim=1,611.0' n= 0.040 Mountain streams
0.9	559	0.0040	9.89	29,050.00	Parabolic Channel, 559 ft. Channel Flow - Woods W=339.00' D=13.00' Area=2,938.0 sf Perim=340.3' n= 0.040 Mountain streams
2.5	974	0.0021	6.42	17,219.62	Parabolic Channel, 974 ft. Channel Flow - Brush W=366.00' D=11.00' Area=2,684.0 sf Perim=366.9' n= 0.040 Mountain streams
1.2	396		5.67		Lake or Reservoir, 396 ft. Lake Flow - Water Mean Depth= 1.00'
1.7	464	0.0060	4.57	9,884.90	Parabolic Channel, 464 ft. Channel Flow - Brush W=1,082.00' D=3.00' Area=2,164.0 sf Perim=1,082.0' n= 0.040 Mountain streams
6.5	730	0.0010	1.86	3,934.79	Parabolic Channel, 730 ft. Channel Flow - Woods W=1,055.00' D=3.00' Area=2,110.0 sf Perim=1,055.0' n= 0.040 Mountain streams
0.5	261		8.02		Lake or Reservoir, 261 ft. Lake Flow - Water Mean Depth= 2.00'
1.4	964	0.0093	11.82	31,135.77	Parabolic Channel, 964 ft. Channel Flow - Woods W=439.00' D=9.00' Area=2,634.0 sf Perim=439.5' n= 0.040 Mountain streams
2.6	944	0.0053	6.03	20,981.08	Parabolic Channel, 944 ft. Channel Flow - Woods W=1,043.00' D=5.00' Area=3,476.7 sf Perim=1,043.1' n= 0.040 Mountain streams
0.4	202	0.0050	8.02	35,234.07	Parabolic Channel, 202 ft Channel Flow - Brush W=824.00' D=8.00' Area=4,394.7 sf Perim=824.2' n= 0.040 Mountain streams

Haverhill Brandy Brow Culvert

NRCC 24-hr D 100-Year Rainfall=8.94"

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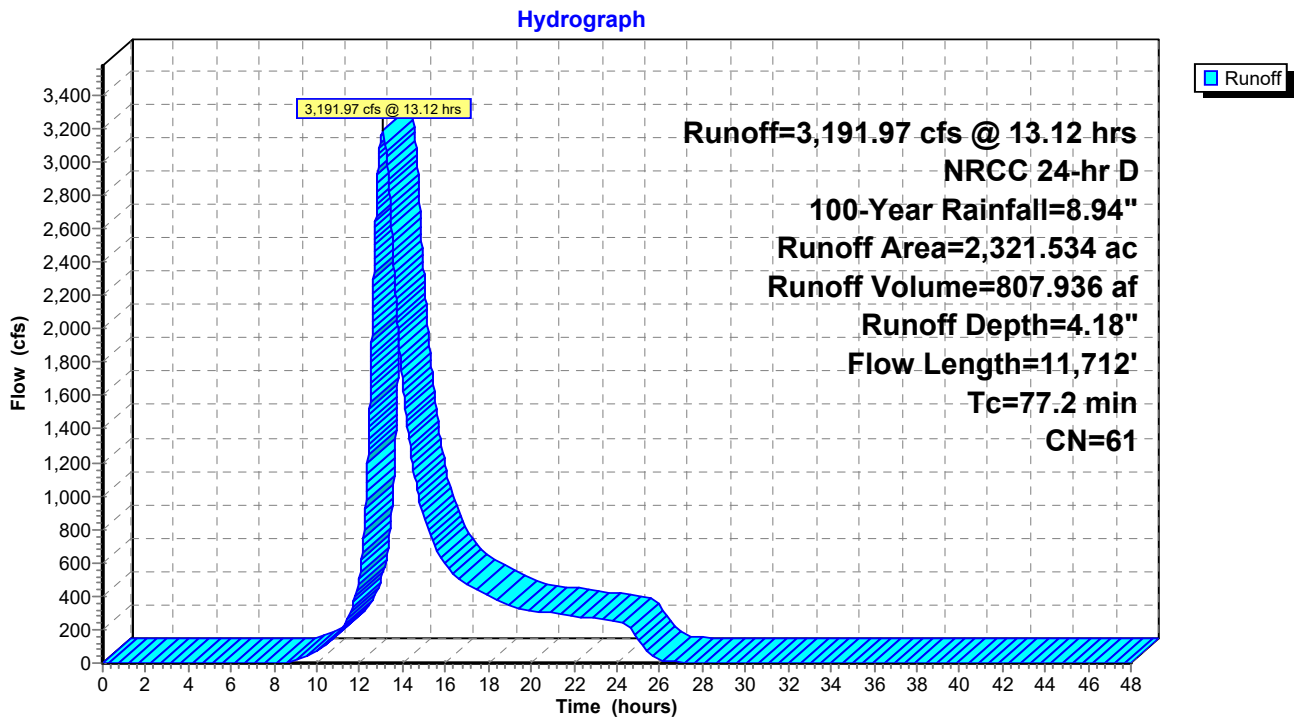
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0.4	199	8.02	Lake or Reservoir, 199 ft. Lake Flow - Water	
			Mean Depth= 2.00'	
0.2	135	0.0150	13.66	5,900.41
			Parabolic Channel, 135 ft. Channel Flow - Woods	
			W=81.00' D=8.00' Area=432.0 sf Perim=83.1'	
			n= 0.040 Mountain streams	

77.2 11,712 Total

Subcatchment 8S: Brandy Brow Rd Culvert Over East Meadow River Drainage Area



Summary for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 4.18" for 100-Year event
 Inflow = 3,187.54 cfs @ 13.12 hrs, Volume= 807.936 af
 Outflow = 2,366.11 cfs @ 13.60 hrs, Volume= 807.936 af, Atten= 26%, Lag= 28.8 min
 Primary = 2,366.11 cfs @ 13.60 hrs, Volume= 807.936 af
 Secondary = 0.00 cfs @ 13.60 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Peak Elev= 69.88' @ 13.60 hrs Surf.Area= 33.930 ac Storage= 77.111 af

Plug-Flow detention time= 9.1 min calculated for 807.767 af (100% of inflow)
 Center-of-Mass det. time= 9.1 min (941.0 - 931.8)

Volume	Invert	Avail.Storage	Storage Description
#1	60.67'	217.781 af	Haverhill Brandy Brow Culvert Storage (Prismatic) listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
60.67	0.000	0.000	0.000
61.00	0.069	0.011	0.011
62.00	0.122	0.095	0.107
63.00	0.155	0.138	0.245
64.00	0.177	0.166	0.411
65.00	0.271	0.224	0.635
66.00	0.331	0.301	0.936
67.00	14.150	7.240	8.177
68.00	17.964	16.057	24.234
69.00	30.785	24.374	48.608
70.00	34.355	32.570	81.178
71.00	43.931	39.143	120.321
72.00	48.399	46.165	166.486
73.00	54.190	51.294	217.781

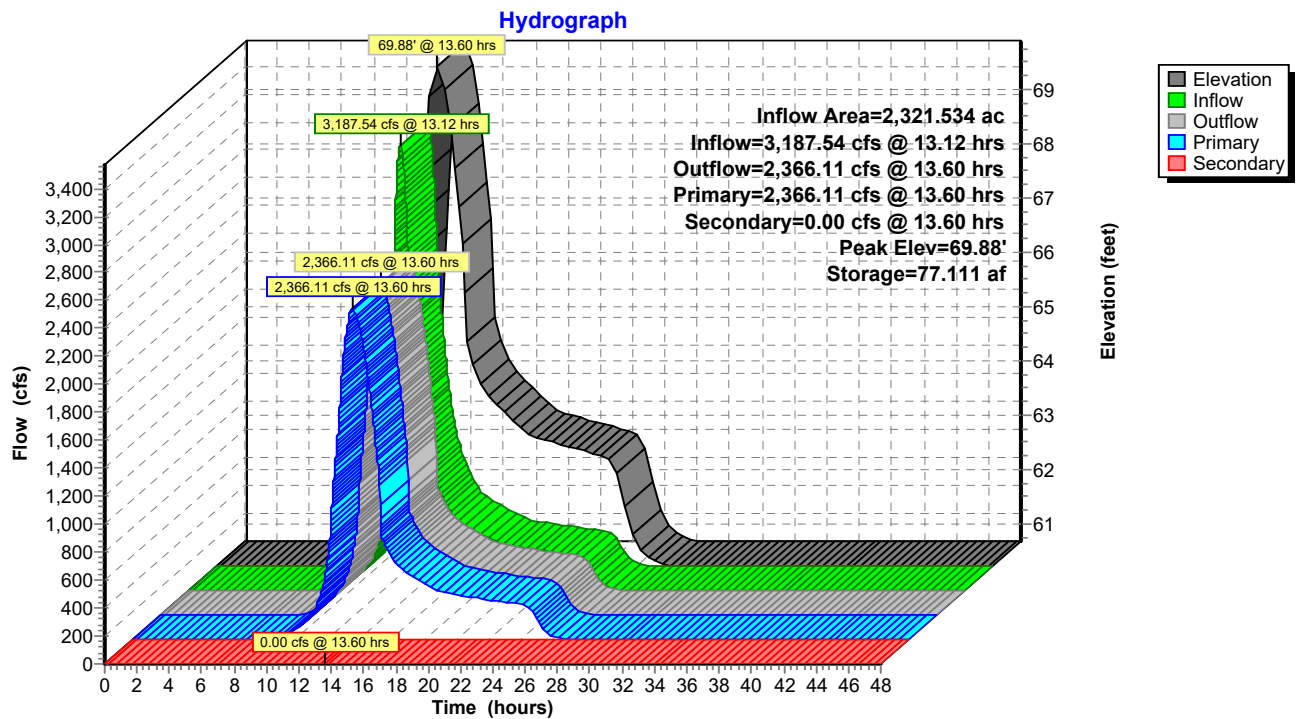
Device	Routing	Invert	Outlet Devices
#1	Primary	60.67'	408.0" W x 88.0" H Box Proposed Box Culvert L= 32.7' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 60.55' / 60.67' S= -0.0037 '/' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 249.33 sf
#2	Secondary	69.88'	Overtopping Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 19.91 58.84 194.40 211.85 227.08 268.53 280.33 369.44 393.41 414.91 Elev. (feet) 73.00 72.00 71.00 70.00 69.91 69.88 69.91 70.00

71.00 72.00 73.00

Primary OutFlow Max=2,366.11 cfs @ 13.60 hrs HW=69.88' (Free Discharge)
 ↳1=Proposed Box Culvert (Barrel Controls 2,366.11 cfs @ 9.94 fps)

Secondary OutFlow Max=0.00 cfs @ 13.60 hrs HW=69.88' (Free Discharge)
 ↳2=Overtopping Asymmetrical Weir(Weir Controls 0.00 cfs @ 0.04 fps)

Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River



Stage-Discharge for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)	Elevation (feet)	Discharge (cfs)	Primary (cfs)	Secondary (cfs)
60.67	0.00	0.00	0.00	70.87	3,258.73	2,789.08	469.65
60.87	9.76	9.76	0.00	71.07	3,577.41	2,880.95	696.46
61.07	26.57	26.57	0.00	71.27	3,939.21	2,969.98	969.23
61.27	45.55	45.55	0.00	71.47	4,339.03	3,056.42	1,282.61
61.47	67.68	67.68	0.00	71.67	4,774.99	3,140.48	1,634.51
61.67	92.54	92.54	0.00	71.87	5,246.15	3,222.35	2,023.80
61.87	119.83	119.83	0.00	72.07	5,751.96	3,302.18	2,449.78
62.07	149.36	149.36	0.00	72.27	6,261.15	3,350.03	2,911.11
62.27	180.95	180.95	0.00	72.47	6,800.04	3,393.61	3,406.43
62.47	214.47	214.47	0.00	72.67	7,371.54	3,436.59	3,934.95
62.67	249.83	249.83	0.00	72.87	7,975.12	3,479.00	4,496.12
62.87	286.92	286.92	0.00				
63.07	325.66	325.66	0.00				
63.27	366.00	366.00	0.00				
63.47	407.86	407.86	0.00				
63.67	451.20	451.20	0.00				
63.87	495.95	495.95	0.00				
64.07	542.09	542.09	0.00				
64.27	589.57	589.57	0.00				
64.47	638.36	638.36	0.00				
64.67	688.41	688.41	0.00				
64.87	739.70	739.70	0.00				
65.07	792.19	792.19	0.00				
65.27	845.87	845.87	0.00				
65.47	900.70	900.70	0.00				
65.67	956.67	956.67	0.00				
65.87	1,013.74	1,013.74	0.00				
66.07	1,071.90	1,071.90	0.00				
66.27	1,131.13	1,131.13	0.00				
66.47	1,191.40	1,191.40	0.00				
66.67	1,252.71	1,252.71	0.00				
66.87	1,315.03	1,315.03	0.00				
67.07	1,378.35	1,378.35	0.00				
67.27	1,442.65	1,442.65	0.00				
67.47	1,507.92	1,507.92	0.00				
67.67	1,574.14	1,574.14	0.00				
67.87	1,641.30	1,641.30	0.00				
68.07	1,709.39	1,709.39	0.00				
68.27	1,778.39	1,778.39	0.00				
68.47	1,848.30	1,848.30	0.00				
68.67	1,919.09	1,919.09	0.00				
68.87	1,990.76	1,990.76	0.00				
69.07	2,063.31	2,063.31	0.00				
69.27	2,136.71	2,136.71	0.00				
69.47	2,210.96	2,210.96	0.00				
69.67	2,286.05	2,286.05	0.00				
69.87	2,361.97	2,361.97	0.00				
70.07	2,456.47	2,438.71	17.76				
70.27	2,586.92	2,516.26	70.66				
70.47	2,756.30	2,595.60	160.71				
70.67	2,986.37	2,694.08	292.29				

Haverhill Brandy Brow Culvert

NRCC 24-hr D 100-Year Rainfall=8.94"

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Stage-Area-Storage for Pond 6P: Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
60.67	0.000	0.000	70.87	42.686	114.691
60.87	0.042	0.004	71.07	44.244	123.408
61.07	0.073	0.016	71.27	45.137	132.346
61.27	0.083	0.032	71.47	46.031	141.462
61.47	0.094	0.050	71.67	46.925	150.758
61.67	0.105	0.070	71.87	47.818	160.232
61.87	0.115	0.091	72.07	48.804	169.889
62.07	0.124	0.116	72.27	49.963	179.765
62.27	0.131	0.141	72.47	51.121	189.874
62.47	0.138	0.168	72.67	52.279	200.214
62.67	0.144	0.196	72.87	53.437	210.785
62.87	0.151	0.226			
63.07	0.157	0.256			
63.27	0.161	0.288			
63.47	0.165	0.321			
63.67	0.170	0.354			
63.87	0.174	0.389			
64.07	0.184	0.424			
64.27	0.202	0.463			
64.47	0.221	0.505			
64.67	0.240	0.551			
64.87	0.259	0.601			
65.07	0.275	0.655			
65.27	0.287	0.711			
65.47	0.299	0.769			
65.67	0.311	0.830			
65.87	0.323	0.894			
66.07	1.298	0.993			
66.27	4.062	1.529			
66.47	6.826	2.618			
66.67	9.590	4.260			
66.87	12.354	6.454			
67.07	14.417	9.177			
67.27	15.180	12.136			
67.47	15.943	15.249			
67.67	16.705	18.513			
67.87	17.468	21.931			
68.07	18.861	25.523			
68.27	21.426	29.551			
68.47	23.990	34.093			
68.67	26.554	39.147			
68.87	29.118	44.715			
69.07	31.035	50.772			
69.27	31.749	57.050			
69.47	32.463	63.472			
69.67	33.177	70.036			
69.87	33.891	76.742			
70.07	35.025	83.607			
70.27	36.941	90.803			
70.47	38.856	98.383			
70.67	40.771	106.346			

Summary for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Haverhill Brandy Brow Culvert

Culvert does overtop and therefore an overtopping weir was modeled.

Culvert dimensions and invert data from GPI MA survey.

Storage curve backups can be found in "I:\MAX Haverhill Brandy Brow culvert\CAD"

Inflow Area = 2,321.534 ac, 9.32% Impervious, Inflow Depth = 4.18" for 100-Year event
 Inflow = 3,191.97 cfs @ 13.12 hrs, Volume= 807.936 af
 Outflow = 3,187.54 cfs @ 13.12 hrs, Volume= 807.936 af, Atten= 0%, Lag= 0.0 min
 Primary = 3,187.54 cfs @ 13.12 hrs, Volume= 807.936 af
 Routed to Pond 6P : Alternative 2 - Proposed Brandy Brow Rd Culvert Over East Meadow River

Routing by Dyn-Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
 Starting Elev= 66.90' Surf.Area= 0.333 ac Storage= 1.256 af
 Peak Elev= 72.75' @ 13.13 hrs Surf.Area= 0.678 ac Storage= 4.134 af (2.878 af above start)

Plug-Flow detention time= 2.6 min calculated for 806.680 af (100% of inflow)
 Center-of-Mass det. time= 0.9 min (931.8 - 931.0)

Volume	Invert	Avail.Storage	Storage Description
#1	59.81'	5.757 af	Brandy Brow Rd Culvert Over East Meadow River (Prismatic) listed below (

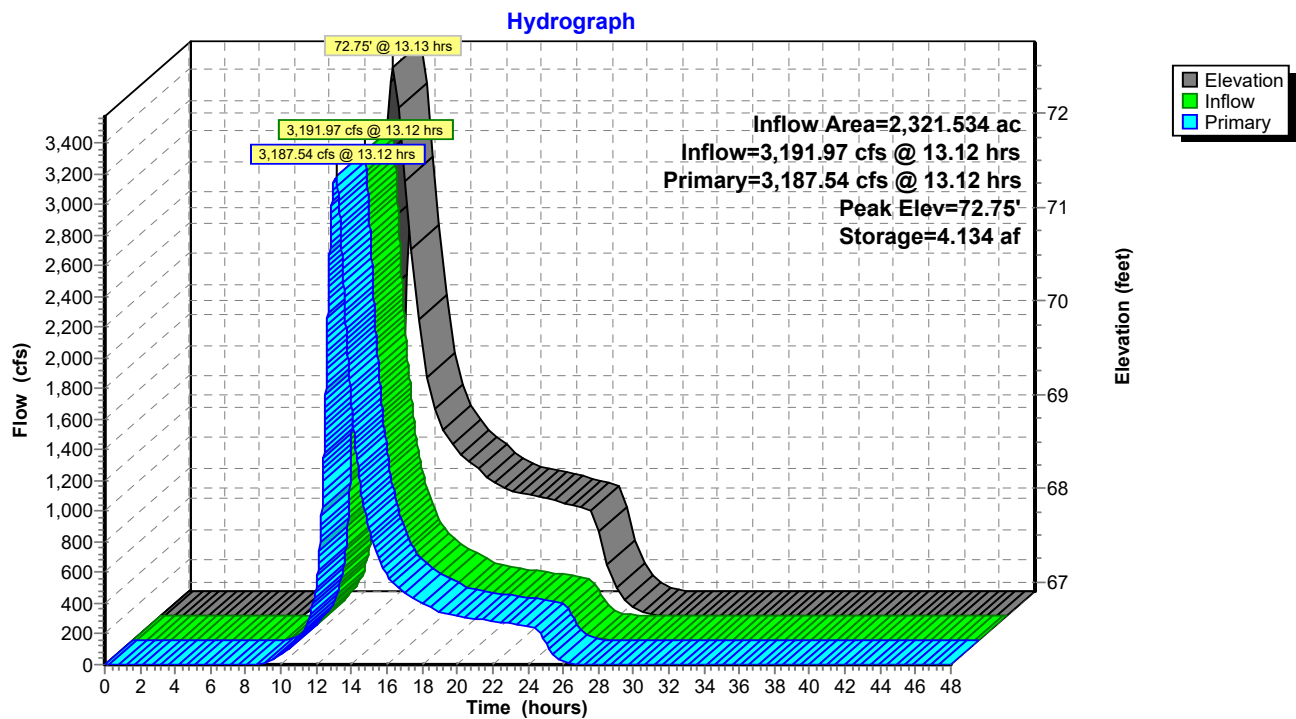
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
59.81	0.000	0.000	0.000
60.00	0.028	0.003	0.003
61.00	0.069	0.048	0.051
62.00	0.122	0.095	0.147
63.00	0.155	0.138	0.285
64.00	0.177	0.166	0.451
65.00	0.271	0.224	0.675
66.00	0.311	0.291	0.966
67.00	0.335	0.323	1.289
68.00	0.359	0.347	1.636
69.00	0.400	0.379	2.016
70.00	0.514	0.457	2.473
71.00	0.589	0.551	3.024
72.00	0.640	0.615	3.639
73.00	0.690	0.665	4.304
74.00	0.727	0.709	5.012
75.00	0.762	0.744	5.757

Device	Routing	Invert	Outlet Devices
#1	Primary	66.90'	Dam Asymmetrical Weir, C= 3.27 Offset (feet) 0.00 11.79 27.62 33.23 37.09 40.32 43.00 45.63 48.19 103.82 106.38 108.81 111.25 113.80 116.50 119.38 122.50

125.83
 Elev. (feet) 74.00 73.00 72.00 71.00 70.00 69.00 68.00 67.00
 66.90 66.90 67.00 68.00 69.00 70.00 71.00 72.00 73.00 74.00

Primary OutFlow Max=3,187.55 cfs @ 13.12 hrs HW=72.75' TW=69.20' (Dynamic Tailwater)
 ↳1=Dam Asymmetrical Weir (Weir Controls 3,187.55 cfs @ 6.73 fps)

Pond 7P: Existing Brandy Brow Rd Beaver Dam



Haverhill Brandy Brow Culvert*NRCC 24-hr D 100-Year Rainfall=8.94"*

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Stage-Discharge for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)	Elevation (feet)	Primary (cfs)
59.81	0.00	64.91	0.00	70.01	1,192.68
59.91	0.00	65.01	0.00	70.11	1,254.77
60.01	0.00	65.11	0.00	70.21	1,318.18
60.11	0.00	65.21	0.00	70.31	1,382.91
60.21	0.00	65.31	0.00	70.41	1,448.97
60.31	0.00	65.41	0.00	70.51	1,516.34
60.41	0.00	65.51	0.00	70.61	1,585.04
60.51	0.00	65.61	0.00	70.71	1,655.05
60.61	0.00	65.71	0.00	70.81	1,726.39
60.71	0.00	65.81	0.00	70.91	1,799.05
60.81	0.00	65.91	0.00	71.01	1,873.03
60.91	0.00	66.01	0.00	71.11	1,948.34
61.01	0.00	66.11	0.00	71.21	2,025.01
61.11	0.00	66.21	0.00	71.31	2,103.04
61.21	0.00	66.31	0.00	71.41	2,182.45
61.31	0.00	66.41	0.00	71.51	2,263.24
61.41	0.00	66.51	0.00	71.61	2,345.42
61.51	0.00	66.61	0.00	71.71	2,429.01
61.61	0.00	66.71	0.00	71.81	2,514.00
61.71	0.00	66.81	0.00	71.91	2,600.41
61.81	0.00	66.91	0.18	72.01	2,688.23
61.91	0.00	67.01	6.90	72.11	2,777.54
62.01	0.00	67.11	18.62	72.21	2,868.45
62.11	0.00	67.21	33.76	72.31	2,961.03
62.21	0.00	67.31	51.74	72.41	3,055.33
62.31	0.00	67.41	72.20	72.51	3,151.42
62.41	0.00	67.51	94.92	72.61	3,249.33
62.51	0.00	67.61	119.74	72.71	3,349.10
62.61	0.00	67.71	146.52	72.81	3,450.76
62.71	0.00	67.81	175.18	72.91	3,554.37
62.81	0.00	67.91	205.63	73.01	3,659.94
62.91	0.00	68.01	237.80	73.11	3,767.49
63.01	0.00	68.11	271.64	73.21	3,877.00
63.11	0.00	68.21	307.09	73.31	3,988.49
63.21	0.00	68.31	344.13	73.41	4,101.96
63.31	0.00	68.41	382.71	73.51	4,217.43
63.41	0.00	68.51	422.80	73.61	4,334.90
63.51	0.00	68.61	464.38	73.71	4,454.40
63.61	0.00	68.71	507.41	73.81	4,575.92
63.71	0.00	68.81	551.87	73.91	4,699.49
63.81	0.00	68.91	597.76	74.01	4,824.72
63.91	0.00	69.01	645.04	74.11	4,937.75
64.01	0.00	69.11	693.71	74.21	5,042.64
64.11	0.00	69.21	743.75	74.31	5,142.46
64.21	0.00	69.31	795.17	74.41	5,238.41
64.31	0.00	69.41	847.94	74.51	5,331.17
64.41	0.00	69.51	902.06	74.61	5,421.22
64.51	0.00	69.61	957.53	74.71	5,508.89
64.61	0.00	69.71	1,014.33	74.81	5,594.44
64.71	0.00	69.81	1,072.46	74.91	5,678.08
64.81	0.00	69.91	1,131.91		

Haverhill Brandy Brow Culvert*NRCC 24-hr D 100-Year Rainfall=8.94"*

Prepared by Greenman-Pedersen, Inc

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Stage-Area-Storage for Pond 7P: Existing Brandy Brow Rd Beaver Dam

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
59.81	0.000	0.000	70.01	0.515	2.478
60.01	0.028	0.003	70.21	0.530	2.582
60.21	0.037	0.009	70.41	0.545	2.690
60.41	0.045	0.018	70.61	0.560	2.800
60.61	0.053	0.027	70.81	0.575	2.914
60.81	0.061	0.039	71.01	0.590	3.030
61.01	0.070	0.052	71.21	0.600	3.149
61.21	0.080	0.067	71.41	0.610	3.270
61.41	0.091	0.084	71.61	0.620	3.393
61.61	0.101	0.103	71.81	0.630	3.518
61.81	0.112	0.124	72.01	0.641	3.645
62.01	0.122	0.148	72.21	0.651	3.774
62.21	0.129	0.173	72.41	0.660	3.905
62.41	0.136	0.199	72.61	0.670	4.038
62.61	0.142	0.227	72.81	0.681	4.173
62.81	0.149	0.256	73.01	0.690	4.311
63.01	0.155	0.287	73.21	0.698	4.449
63.21	0.160	0.318	73.41	0.705	4.590
63.41	0.164	0.351	73.61	0.713	4.731
63.61	0.168	0.384	73.81	0.720	4.875
63.81	0.173	0.418	74.01	0.727	5.019
64.01	0.178	0.453	74.21	0.734	5.166
64.21	0.197	0.490	74.41	0.741	5.313
64.41	0.216	0.532	74.61	0.748	5.462
64.61	0.234	0.577	74.81	0.755	5.613
64.81	0.253	0.625			
65.01	0.271	0.678			
65.21	0.279	0.733			
65.41	0.287	0.790			
65.61	0.295	0.848			
65.81	0.303	0.908			
66.01	0.311	0.969			
66.21	0.316	1.032			
66.41	0.321	1.096			
66.61	0.326	1.160			
66.81	0.330	1.226			
67.01	0.335	1.293			
67.21	0.340	1.360			
67.41	0.345	1.429			
67.61	0.350	1.498			
67.81	0.354	1.568			
68.01	0.359	1.640			
68.21	0.368	1.712			
68.41	0.376	1.787			
68.61	0.384	1.863			
68.81	0.392	1.940			
69.01	0.401	2.020			
69.21	0.424	2.102			
69.41	0.447	2.189			
69.61	0.470	2.281			
69.81	0.492	2.377			

APPENDIX E

FlowMaster Downstream Normal Depth Calculations



Existing Conditions: 2-Year 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	211.65 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	15.6 in
Roughness Coefficient	0.045

Existing Conditions: 2-Year 50 ft Downstream

Results

Elevation	62.30 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	18.3 ft ²
Wetted Perimeter	23.1 ft
Hydraulic Radius	9.5 in
Top Width	22.70 ft
Normal Depth	15.6 in
Critical Depth	22.7 in
Critical Slope	0.028 ft/ft
Velocity	11.54 ft/s
Velocity Head	2.07 ft
Specific Energy	3.37 ft
Froude Number	2.264
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	15.6 in
Critical Depth	22.7 in
Channel Slope	0.167 ft/ft
Critical Slope	0.028 ft/ft

Worksheet for 5-Year 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	379.70 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	19.9 in
Roughness Coefficient	0.045

Worksheet for 5-Year 50 ft Downstream

Results

Elevation	62.65 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	26.5 ft ²
Wetted Perimeter	24.1 ft
Hydraulic Radius	13.2 in
Top Width	23.39 ft
Normal Depth	19.9 in
Critical Depth	32.4 in
Critical Slope	0.028 ft/ft
Velocity	14.34 ft/s
Velocity Head	3.19 ft
Specific Energy	4.85 ft
Froude Number	2.375
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	19.9 in
Critical Depth	32.4 in
Channel Slope	0.167 ft/ft
Critical Slope	0.028 ft/ft

Existing Conditions: 10-Year 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	494.49 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	22.3 in
Roughness Coefficient	0.045

Existing Conditions: 10-Year 50 ft Downstream

Results

Elevation	62.86 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	31.3 ft ²
Wetted Perimeter	24.7 ft
Hydraulic Radius	15.2 in
Top Width	23.80 ft
Normal Depth	22.3 in
Critical Depth	36.2 in
Critical Slope	0.028 ft/ft
Velocity	15.78 ft/s
Velocity Head	3.87 ft
Specific Energy	5.73 ft
Froude Number	2.425
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	22.3 in
Critical Depth	36.2 in
Channel Slope	0.167 ft/ft
Critical Slope	0.028 ft/ft

Existing Conditions: 25-Year 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	715.12 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	28.6 in
Roughness Coefficient	0.045

Existing Conditions: 25-Year 50 ft Downstream

Results

Elevation	63.38 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	46.3 ft ²
Wetted Perimeter	37.7 ft
Hydraulic Radius	14.7 in
Top Width	36.57 ft
Normal Depth	28.6 in
Critical Depth	41.8 in
Critical Slope	0.027 ft/ft
Velocity	15.46 ft/s
Velocity Head	3.71 ft
Specific Energy	6.09 ft
Froude Number	2.422
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	28.6 in
Critical Depth	41.8 in
Channel Slope	0.167 ft/ft
Critical Slope	0.027 ft/ft

Existing Conditions: 50-Year 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	1,429.96 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	38.8 in
Roughness Coefficient	0.045

Existing Conditions: 50-Year 50 ft Downstream

Results

Elevation	64.23 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	89.4 ft ²
Wetted Perimeter	69.1 ft
Hydraulic Radius	15.5 in
Top Width	67.94 ft
Normal Depth	38.8 in
Critical Depth	51.8 in
Critical Slope	0.025 ft/ft
Velocity	15.99 ft/s
Velocity Head	3.98 ft
Specific Energy	7.20 ft
Froude Number	2.458
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	38.8 in
Critical Depth	51.8 in
Channel Slope	0.167 ft/ft
Critical Slope	0.025 ft/ft

Existing Conditions: 100-Year 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	2,456.21 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	46.6 in
Roughness Coefficient	0.045

Existing Conditions: 100-Year 50 ft Downstream

Results

Elevation	64.88 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	143.8 ft ²
Wetted Perimeter	100.8 ft
Hydraulic Radius	17.1 in
Top Width	99.59 ft
Normal Depth	46.6 in
Critical Depth	62.1 in
Critical Slope	0.023 ft/ft
Velocity	17.08 ft/s
Velocity Head	4.53 ft
Specific Energy	8.41 ft
Froude Number	2.505
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	46.6 in
Critical Depth	62.1 in
Channel Slope	0.167 ft/ft
Critical Slope	0.023 ft/ft

Existing Conditions: 2-Year 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	211.65 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	15.0 in
Roughness Coefficient	0.045

Existing Conditions: 2-Year 200 ft Downstream

Results

Elevation	60.25 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	35.0 ft ²
Wetted Perimeter	44.2 ft
Hydraulic Radius	9.5 in
Top Width	44.00 ft
Normal Depth	15.0 in
Critical Depth	16.3 in
Critical Slope	0.031 ft/ft
Velocity	6.05 ft/s
Velocity Head	0.57 ft
Specific Energy	1.82 ft
Froude Number	1.195
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	15.0 in
Critical Depth	16.3 in
Channel Slope	0.046 ft/ft
Critical Slope	0.031 ft/ft

Worksheet for 5-Year 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	379.70 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	19.3 in
Roughness Coefficient	0.045

Worksheet for 5-Year 200 ft Downstream

Results

Elevation	60.61 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	51.3 ft ²
Wetted Perimeter	47.7 ft
Hydraulic Radius	12.9 in
Top Width	47.40 ft
Normal Depth	19.3 in
Critical Depth	21.5 in
Critical Slope	0.028 ft/ft
Velocity	7.41 ft/s
Velocity Head	0.85 ft
Specific Energy	2.46 ft
Froude Number	1.256
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	19.3 in
Critical Depth	21.5 in
Channel Slope	0.046 ft/ft
Critical Slope	0.028 ft/ft

Existing Conditions: 10-Year 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	494.49 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	21.7 in
Roughness Coefficient	0.045

Existing Conditions: 10-Year 200 ft Downstream

Results

Elevation	60.81 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	61.1 ft ²
Wetted Perimeter	49.7 ft
Hydraulic Radius	14.7 in
Top Width	49.34 ft
Normal Depth	21.7 in
Critical Depth	25.4 in
Critical Slope	0.028 ft/ft
Velocity	8.10 ft/s
Velocity Head	1.02 ft
Specific Energy	2.83 ft
Froude Number	1.283
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	21.7 in
Critical Depth	25.4 in
Channel Slope	0.046 ft/ft
Critical Slope	0.028 ft/ft

Existing Conditions: 25-Year 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	715.12 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	27.8 in
Roughness Coefficient	0.045

Existing Conditions: 25-Year 200 ft Downstream

Results

Elevation	61.32 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	91.2 ft ²
Wetted Perimeter	77.8 ft
Hydraulic Radius	14.1 in
Top Width	77.30 ft
Normal Depth	27.8 in
Critical Depth	31.3 in
Critical Slope	0.028 ft/ft
Velocity	7.84 ft/s
Velocity Head	0.96 ft
Specific Energy	3.28 ft
Froude Number	1.273
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	27.8 in
Critical Depth	31.3 in
Channel Slope	0.046 ft/ft
Critical Slope	0.028 ft/ft

Existing Conditions: 50-Year 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	1,429.96 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	37.3 in
Roughness Coefficient	0.045

Existing Conditions: 50-Year 200 ft Downstream

Results

Elevation	62.11 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	178.5 ft ²
Wetted Perimeter	147.7 ft
Hydraulic Radius	14.5 in
Top Width	147.04 ft
Normal Depth	37.3 in
Critical Depth	40.8 in
Critical Slope	0.028 ft/ft
Velocity	8.01 ft/s
Velocity Head	1.00 ft
Specific Energy	4.11 ft
Froude Number	1.281
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	37.3 in
Critical Depth	40.8 in
Channel Slope	0.046 ft/ft
Critical Slope	0.028 ft/ft

Existing Conditions: 100-Year 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	2,456.21 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	44.7 in
Roughness Coefficient	0.045

Existing Conditions: 100-Year 200 ft Downstream

Results

Elevation	62.72 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	291.5 ft ²
Wetted Perimeter	223.5 ft
Hydraulic Radius	15.6 in
Top Width	222.87 ft
Normal Depth	44.7 in
Critical Depth	48.3 in
Critical Slope	0.026 ft/ft
Velocity	8.43 ft/s
Velocity Head	1.10 ft
Specific Energy	4.83 ft
Froude Number	1.299
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	44.7 in
Critical Depth	48.3 in
Channel Slope	0.046 ft/ft
Critical Slope	0.026 ft/ft

Alt2_ 2-Year Storm 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	212.05 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	15.6 in
Roughness Coefficient	0.045

Alt2_ 2-Year Storm 50 ft Downstream

Results

Elevation	62.30 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	18.4 ft ²
Wetted Perimeter	23.1 ft
Hydraulic Radius	9.5 in
Top Width	22.70 ft
Normal Depth	15.6 in
Critical Depth	22.8 in
Critical Slope	0.028 ft/ft
Velocity	11.55 ft/s
Velocity Head	2.07 ft
Specific Energy	3.37 ft
Froude Number	2.264
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	15.6 in
Critical Depth	22.8 in
Channel Slope	0.167 ft/ft
Critical Slope	0.028 ft/ft

Worksheet for 5-Year 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	512.93 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	22.7 in
Roughness Coefficient	0.045

Worksheet for 5-Year 50 ft Downstream

Results

Elevation	62.89 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	32.1 ft ²
Wetted Perimeter	24.8 ft
Hydraulic Radius	15.5 in
Top Width	23.86 ft
Normal Depth	22.7 in
Critical Depth	36.8 in
Critical Slope	0.028 ft/ft
Velocity	15.99 ft/s
Velocity Head	3.97 ft
Specific Energy	5.87 ft
Froude Number	2.432
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	22.7 in
Critical Depth	36.8 in
Channel Slope	0.167 ft/ft
Critical Slope	0.028 ft/ft

Alt2_ 10-Year Storm 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	868.84 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	31.5 in
Roughness Coefficient	0.045

Alt2_ 10-Year Storm 50 ft Downstream

Results

Elevation	63.63 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	56.2 ft ²
Wetted Perimeter	45.7 ft
Hydraulic Radius	14.8 in
Top Width	44.56 ft
Normal Depth	31.5 in
Critical Depth	44.7 in
Critical Slope	0.027 ft/ft
Velocity	15.47 ft/s
Velocity Head	3.72 ft
Specific Energy	6.34 ft
Froude Number	2.428
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	31.5 in
Critical Depth	44.7 in
Channel Slope	0.167 ft/ft
Critical Slope	0.027 ft/ft

Alt2_ 25-Year Storm 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	1,399.83 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	38.4 in
Roughness Coefficient	0.045

Alt2_ 25-Year Storm 50 ft Downstream

Results

Elevation	64.20 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	87.6 ft ²
Wetted Perimeter	67.8 ft
Hydraulic Radius	15.5 in
Top Width	66.64 ft
Normal Depth	38.4 in
Critical Depth	51.5 in
Critical Slope	0.025 ft/ft
Velocity	15.98 ft/s
Velocity Head	3.97 ft
Specific Energy	7.17 ft
Froude Number	2.457
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	38.4 in
Critical Depth	51.5 in
Channel Slope	0.167 ft/ft
Critical Slope	0.025 ft/ft

Alt2_ 50-Year Storm 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	1,859.97 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	42.6 in
Roughness Coefficient	0.045

Alt2_ 50-Year Storm 50 ft Downstream

Results

Elevation	64.55 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	113.5 ft ²
Wetted Perimeter	84.7 ft
Hydraulic Radius	16.1 in
Top Width	83.46 ft
Normal Depth	42.6 in
Critical Depth	55.9 in
Critical Slope	0.024 ft/ft
Velocity	16.38 ft/s
Velocity Head	4.17 ft
Specific Energy	7.72 ft
Froude Number	2.477
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	42.6 in
Critical Depth	55.9 in
Channel Slope	0.167 ft/ft
Critical Slope	0.024 ft/ft

Alt2_ 100-Year Storm 50 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.167 ft/ft
Discharge	2,366.11 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	70.00
0+72	69.00
0+88	68.00
0+94	67.00
1+60	66.00
1+62	65.00
1+73	64.00
1+77	63.00
1+78	62.00
1+96	61.00
1+97	61.00
2+00	62.00
2+01	63.00
2+29	64.00
2+68	65.00
2+71	66.00
2+76	67.00
2+77	68.00
2+78	69.00
2+79	70.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 70.00)	(2+79, 70.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	46.0 in
Roughness Coefficient	0.045

Alt2_ 100-Year Storm 50 ft Downstream

Results

Elevation	64.83 ft
Elevation Range	61.0 to 70.0 ft
Flow Area	139.4 ft ²
Wetted Perimeter	98.6 ft
Hydraulic Radius	17.0 in
Top Width	97.40 ft
Normal Depth	46.0 in
Critical Depth	60.8 in
Critical Slope	0.023 ft/ft
Velocity	16.97 ft/s
Velocity Head	4.48 ft
Specific Energy	8.31 ft
Froude Number	2.501
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	46.0 in
Critical Depth	60.8 in
Channel Slope	0.167 ft/ft
Critical Slope	0.023 ft/ft

Alt2_ 2-Year Storm 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	212.05 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	15.1 in
Roughness Coefficient	0.045

Alt2_ 2-Year Storm 200 ft Downstream

Results

Elevation	60.26 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	34.8 ft ²
Wetted Perimeter	43.7 ft
Hydraulic Radius	9.6 in
Top Width	43.56 ft
Normal Depth	15.1 in
Critical Depth	16.4 in
Critical Slope	0.031 ft/ft
Velocity	6.09 ft/s
Velocity Head	0.58 ft
Specific Energy	1.83 ft
Froude Number	1.200
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	15.1 in
Critical Depth	16.4 in
Channel Slope	0.046 ft/ft
Critical Slope	0.031 ft/ft

Worksheet for 5-Year 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	512.93 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	22.2 in
Roughness Coefficient	0.045

Worksheet for 5-Year 200 ft Downstream

Results

Elevation	60.85 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	62.3 ft ²
Wetted Perimeter	49.8 ft
Hydraulic Radius	15.0 in
Top Width	49.48 ft
Normal Depth	22.2 in
Critical Depth	26.5 in
Critical Slope	0.028 ft/ft
Velocity	8.23 ft/s
Velocity Head	1.05 ft
Specific Energy	2.90 ft
Froude Number	1.292
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	22.2 in
Critical Depth	26.5 in
Channel Slope	0.046 ft/ft
Critical Slope	0.028 ft/ft

Alt2_ 10-Year Storm 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	868.84 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	30.8 in
Roughness Coefficient	0.045

Alt2_ 10-Year Storm 200 ft Downstream

Results

Elevation	61.57 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	112.1 ft ²
Wetted Perimeter	98.0 ft
Hydraulic Radius	13.7 in
Top Width	97.54 ft
Normal Depth	30.8 in
Critical Depth	34.0 in
Critical Slope	0.028 ft/ft
Velocity	7.75 ft/s
Velocity Head	0.93 ft
Specific Energy	3.50 ft
Froude Number	1.274
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	30.8 in
Critical Depth	34.0 in
Channel Slope	0.046 ft/ft
Critical Slope	0.028 ft/ft

Alt2_ 25-Year Storm 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	1,399.83 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	37.1 in
Roughness Coefficient	0.045

Alt2_ 25-Year Storm 200 ft Downstream

Results

Elevation	62.09 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	174.5 ft ²
Wetted Perimeter	144.8 ft
Hydraulic Radius	14.5 in
Top Width	144.22 ft
Normal Depth	37.1 in
Critical Depth	40.6 in
Critical Slope	0.028 ft/ft
Velocity	8.02 ft/s
Velocity Head	1.00 ft
Specific Energy	4.09 ft
Froude Number	1.285
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	37.1 in
Critical Depth	40.6 in
Channel Slope	0.046 ft/ft
Critical Slope	0.028 ft/ft

Alt2_ 50-Year Storm 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	1,859.97 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	41.0 in
Roughness Coefficient	0.045

Alt2_ 50-Year Storm 200 ft Downstream

Results

Elevation	62.42 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	228.5 ft ²
Wetted Perimeter	185.5 ft
Hydraulic Radius	14.8 in
Top Width	184.91 ft
Normal Depth	41.0 in
Critical Depth	44.5 in
Critical Slope	0.027 ft/ft
Velocity	8.14 ft/s
Velocity Head	1.03 ft
Specific Energy	4.45 ft
Froude Number	1.291
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	41.0 in
Critical Depth	44.5 in
Channel Slope	0.046 ft/ft
Critical Slope	0.027 ft/ft

Alt2_ 100-Year Storm 200 ft Downstream

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.046 ft/ft
Discharge	2,366.11 cfs

Section Definitions

Station (ft)	Elevation (ft)
0+00	68.00
0+21	67.00
0+30	66.00
0+36	65.00
0+42	64.00
0+60	63.00
1+64	62.00
1+66	61.00
1+68	60.00
1+83	59.00
1+90	59.00
2+09	60.00
2+17	61.00
2+97	62.00
3+17	63.00
3+74	64.00
4+06	65.00
4+11	66.00
4+14	67.00
4+19	68.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 68.00)	(4+19, 68.00)	0.045

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	44.2 in
Roughness Coefficient	0.045

Alt2_ 100-Year Storm 200 ft Downstream

Results

Elevation	62.68 ft
Elevation Range	59.0 to 68.0 ft
Flow Area	281.8 ft ²
Wetted Perimeter	218.4 ft
Hydraulic Radius	15.5 in
Top Width	217.73 ft
Normal Depth	44.2 in
Critical Depth	47.9 in
Critical Slope	0.027 ft/ft
Velocity	8.40 ft/s
Velocity Head	1.10 ft
Specific Energy	4.78 ft
Froude Number	1.301
Flow Type	Supercritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	44.2 in
Critical Depth	47.9 in
Channel Slope	0.046 ft/ft
Critical Slope	0.027 ft/ft

APPENDIX F

Sediment Sample Test Results, Scour Hole Results and Riprap Abutment Protection Calculations

Consulting
Engineers and
Scientists

February 12, 2024
Project 2400197

Ms. Kim Armstrong, P.E.
Greenman-Pedersen, Inc.
181 Ballardvale Street, Suite 202
Wilmington, MA 01887

Dear Ms. Armstrong:

Re: **Sediment Sample Test Results**
Culvert Replacement – Brandy Brow Road over East Meadow River
Haverhill, Massachusetts

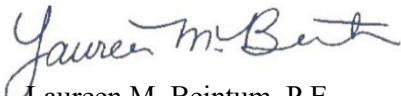
This letter presents the results of our laboratory testing on the two sediment samples collected on January 23, 2024, from the riverbed upstream and downstream of the culvert located near 284 Brandy Brow Road in Haverhill, MA. The approximate locations of the samples are shown on the attached Figure.

Samples were tested by GEI in our Woburn geotechnical laboratory for particle size analyses in accordance with ASTM D6913. The test results are attached. We understand that these test results will be used in the preparation of the Hydraulic Study Report for this project.

Please call Laureen at 781-721-4022 or Rich at 781-721-4084 if you have any questions.

Sincerely,

GEI CONSULTANTS, INC.


Laureen M. Beintum, P.E.

Senior Project Manager



Rich F. Tobin, P.E.
Senior Project Manager

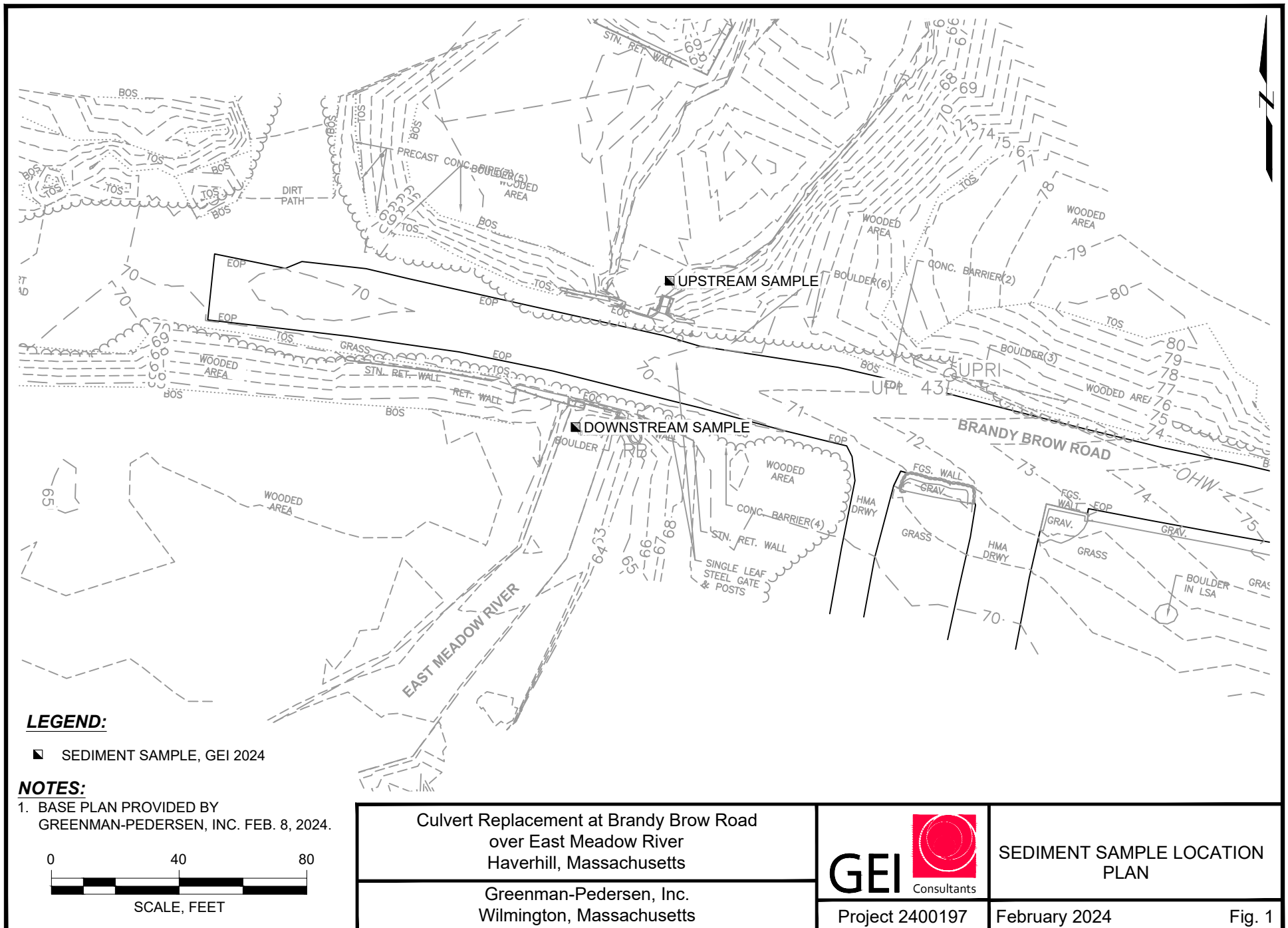
SP:LMB/RFT:jam

c: Ryan Melchionno, Greenman-Pedersen, Inc.

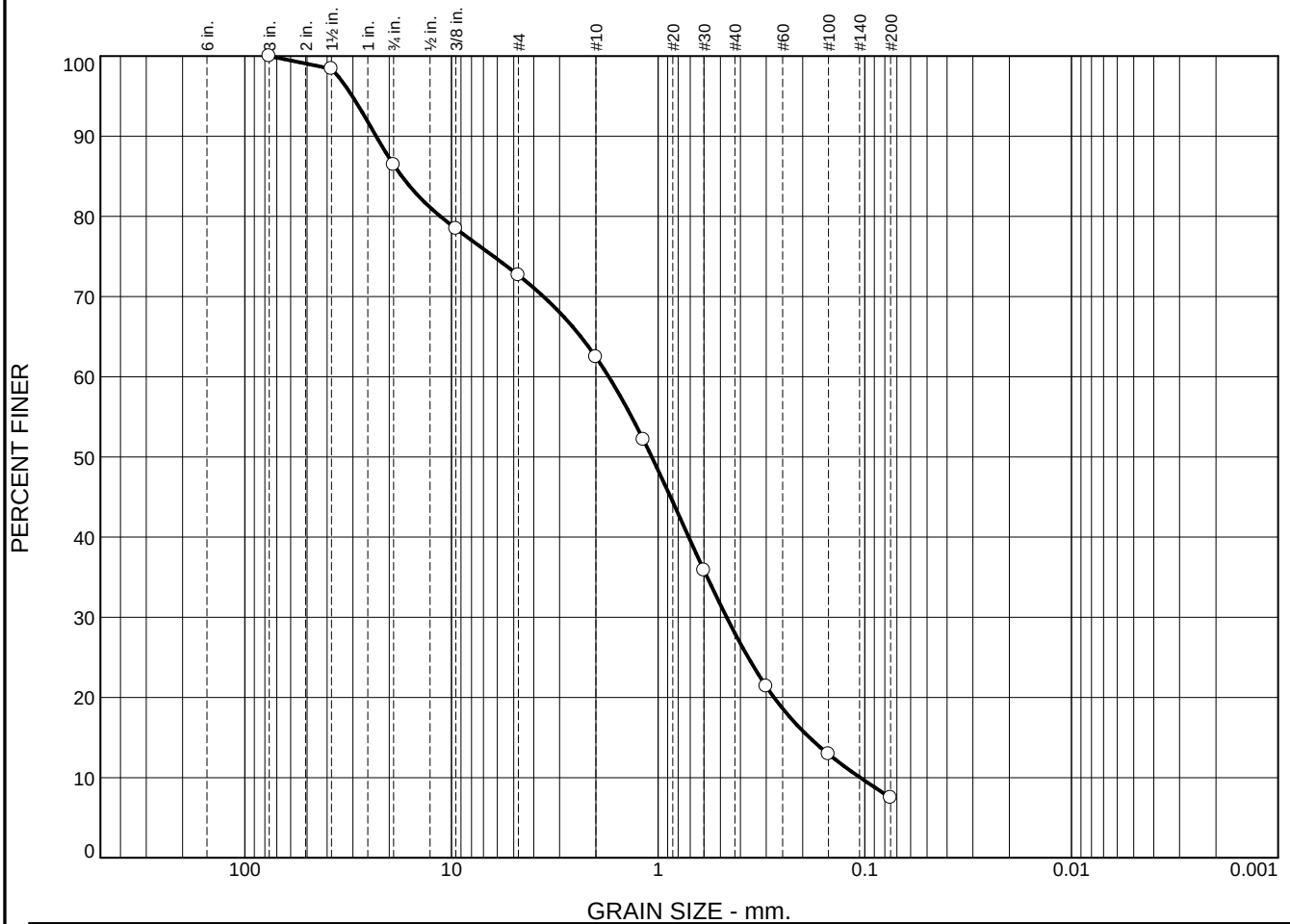
Attachments: Fig.1 – Sediment Sample Location Plan
Particle Size Distribution Reports (4 pages)

B:\Working\GREENMAN PEDERSEN\2400197 Brandy Brow Rd over E Meadow R_Haverhill\10_Sediment Transmittal\Brandy Brow Rd over E Meadow R_Haverhill Sediment Sample Test Results.docx

Attachments



Particle Size Distribution Report



	% Boulders	% +3"	% Gravel			% Sand		% Fines		
			Coarse	Medium	Fine	Coarse	Fine			
☐	0.0	0.0	8.2	13.3	16.0	34.5	20.5	7.5		
☐										
☒	LL	PL	D ₈₅	D ₆₀	D ₅₀	D ₃₀	D ₁₅	D ₁₀	C _c	C _u
☐			17.3833	1.7337	1.0734	0.4661	0.1852	0.1052	1.19	16.48
Material Description								USCS	AASHTO	
☐ FINE TO COARSE SAND, some fine to coarse gravel, trace inorganic silt.								SW-SM		
Project No. 2400197 Client: Greenman Pedersen Project: Culvert Replacement - Brandy Brow Road over East Meadow River ☐ Source of Sample: Upstream Sample Depth: - Sample Number: -								Remarks: ☐ As Received WC=17.5% Fines classified visually.		
GEI Consultants, Inc. 400 Unicorn Park Drive Woburn, MA 01801 										

Figure

Tested By: M. Alstede 2/1/24

Checked By: W. Lukas 2/1/24

GRAIN SIZE DISTRIBUTION TEST DATA

2/2/2024

Client: Greenman Pedersen**Project:** Culvert Replacement - Brandy Brow Road over East Meadow River**Project Number:** 2400197**Location:** Upstream Sample**Depth:** -**Sample Number:** -**Material Description:** FINE TO COARSE SAND, some fine to coarse gravel, trace inorganic silt.**USCS Classification:** SW-SM**Testing Remarks:** As Received WC=17.5%

Fines classified visually.

Tested by: M. Alstede 2/1/24**Checked by:** W. Lukas 2/1/24**Sieve Test Data**

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
4379.38	0.00	412.08	3.0	412.08	100.0
			1.5	481.52	98.4
			3/4	1005.80	86.4
			3/8	1354.63	78.5
365.72	0.00	198.46	#4	225.50	72.7
			#10	273.14	62.5
			#16	321.06	52.2
			#30	397.12	35.8
			#50	464.55	21.4
			#100	503.85	12.9
			#200	529.26	7.5

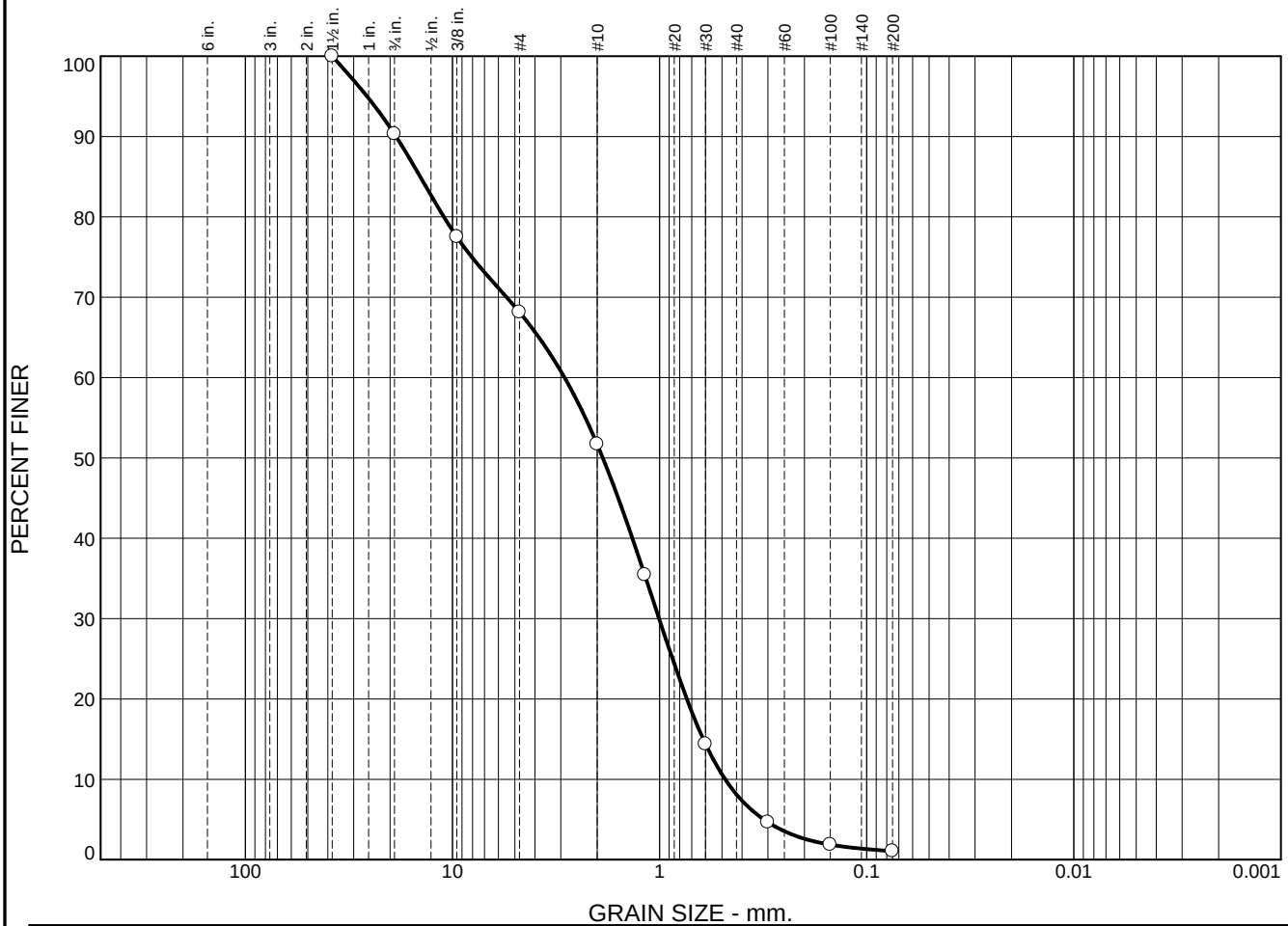
Fractional Components

Boulders	Cobbles	Gravel				Sand			Fines
		Coarse	Medium	Fine	Total	Coarse	Fine	Total	
0.0	0.0	8.2	13.3	16.0	37.5	34.5	20.5	55.0	7.5

D ₁₀	D ₁₅	D ₂₀	D ₃₀	D ₅₀	D ₆₀	D ₈₀	D ₈₅	D ₉₀	D ₉₅
0.1052	0.1852	0.2750	0.4661	1.0734	1.7337	11.3195	17.3833	23.1520	30.1760

Fineness Modulus	C _u	C _c
3.77	16.48	1.19

Particle Size Distribution Report



GRAIN SIZE - mm.										
% Boulders	% +3"	% Gravel			% Sand		% Fines			
		Coarse	Medium	Fine	Coarse	Fine				
0.0	0.0	5.2	17.3	25.8	43.6	7.0	1.1			
LL	PL	D ₈₅	D ₆₀	D ₅₀	D ₃₀	D ₁₅	D ₁₀	C _c	C _u	
		14.3141	2.8758	1.8788	1.0057	0.6158	0.4825	0.73	5.96	

Material Description	USCS	AASHTO
○ FINE TO COARSE SAND AND FINE TO COARSE GRAVEL, trace inorganic silt.	SP	

Project No. 2400197 Client: Greenman Pedersen Project: Culvert Replacement - Brandy Brow Road over East Meadow River ○ Source of Sample: Downstream Sample Depth: - Sample Number: -	Remarks: ○ As Received WC=12.1% Fines classified visually
GEI Consultants, Inc. 400 Unicorn Park Drive Woburn, MA 01801 	

Figure

Tested By: S. Larson 2/1/24 Checked By: W. Lukas 2/1/24

GRAIN SIZE DISTRIBUTION TEST DATA

2/2/2024

Client: Greenman Pedersen**Project:** Culvert Replacement - Brandy Brow Road over East Meadow River**Project Number:** 2400197**Location:** Downstream Sample**Depth:** -**Sample Number:** -**Material Description:** FINE TO COARSE SAND AND FINE TO COARSE GRAVEL, trace inorganic silt.**USCS Classification:** SP**Testing Remarks:** As Received WC=12.1%

Fines classified visually

Tested by: S. Larson 2/1/24**Checked by:** W. Lukas 2/1/24**Sieve Test Data**

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
3184.81	0.00	412.80	1.5	412.80	100.0
			3/4	721.55	90.3
			3/8	1129.45	77.5
610.99	0.00	229.63	#4	303.37	68.1
			#10	433.06	51.7
			#16	561.19	35.4
			#30	727.31	14.4
			#50	803.87	4.7
			#100	825.85	1.9
			#200	832.24	1.1

Fractional Components

Boulders	Cobbles	Gravel				Sand			Fines
		Coarse	Medium	Fine	Total	Coarse	Fine	Total	
0.0	0.0	5.2	17.3	25.8	48.3	43.6	7.0	50.6	1.1

D ₁₀	D ₁₅	D ₂₀	D ₃₀	D ₅₀	D ₆₀	D ₈₀	D ₈₅	D ₉₀	D ₉₅
0.4825	0.6158	0.7389	1.0057	1.8788	2.8758	11.0059	14.3141	18.7165	25.8495

Fineness Modulus	C _u	C _c
4.52	5.96	0.73

Greenman - Pedersen, Inc

520 U.S. Highway 22, Suite 200
Bridgewater, NJ 08807
(908) 236-9001

Job	MAX Brandy Brow Culvert	
Calculated By	TCL	Date 6/19/2024
Checked By	SCS	Date 6/19/2024

All formulas are based on the *HEC-18, Evaluating Scour at Bridges 5th Edition, 2012*

Scour Calculation for Brandy Brow Culvert: 25-Year Design Storm

Q 1400 CFS
Ku 0.57 for English Units
Q_{BI} 150 CFS
Wc 34 ft
D50 0.0088 ft - 2.67 mm to ft

Upstream Inv. 60.55 ft
ymax 9.2 ft
yo 6.47 ft
ys 2.7 ft **Scour depth at culvert entrance**

Scour Elevation at Culvert Entrance: 57.8 ft

Note: Scour calculations were performed using equation "without wing wall case" although the scour depths are using for curtain wall to ensure the wingwall footings are low enough. This was done because the "with wing wall case" assumes wing walls flared at 45 degrees, which is not the case here for this culvert. Results using equation "without wing wall case" are more conservative.

Cross Section Output

File Type Options Help

River: EastMeadowRiver Profile: 25-Year

Reach: Reach 1 RS: 404 Plan: Proposed Box Culvert

Plan: Proposed Box Culvert EastMeadowRiver Reach 1 RS: 404 Profile: 25-Year					
E.G. Elev (ft)	70.57	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.21	Wt. n-Val.	0.080	0.045	0.080
W.S. Elev (ft)	70.35	Reach Len. (ft)	9.61	9.61	9.61
Crit W.S. (ft)	67.06	Flow Area (sq ft)	64.39	209.47	425.59
E.G. Slope (ft/ft)	0.001311	Area (sq ft)	64.39	209.47	425.59
Q Total (cfs)	1552.00	Flow (cfs)	48.92	964.28	538.80
Top Width (ft)	248.65	Top Width (ft)	52.68	26.50	169.47
Vel Total (ft/s)	2.22	Avg. Vel. (ft/s)	0.76	4.60	1.27
Max Chl Dpth (ft)	8.85	Hydr. Depth (ft)	1.22	7.90	2.51
Conv. Total (cfs)	42865.6	Conv. (cfs)	1351.1	26633.1	14881.5
Length Wtd. (ft)	9.61	Wetted Per. (ft)	53.62	27.72	170.54
Min Ch El (ft)	61.50	Shear (lb/sq ft)	0.10	0.62	0.20
Alpha	2.79	Stream Power (lb/ft s)	0.07	2.85	0.26
Frctn Loss (ft)	0.03	Cum Volume (acre-ft)	0.09	0.42	1.00
C & E Loss (ft)	0.35	Cum SA (acres)	0.04	0.05	0.35

Errors, Warnings and Notes

Warning: Divided flow computed for this cross-section.

Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.

Note: Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Enter to move to next upstream river station location

Greenman - Pedersen, Inc
520 U.S. Highway 22, Suite 200
Bridgewater, NJ 08807
(908) 236-9001

Job	MAX Brandy Brow Culvert	
Calculated By	TCL	Date 6/19/2024
Checked By	SCS	Date 6/19/2024

All formulas are based on the HEC-18, Evaluating Scour at Bridges 5th Edition, 2012

Scour Calculation for Brandy Brow Culvert: 50-Year Check Storm

Q	1860 CFS	
Ku	0.57 for English Units	
Q _{BI}	405 CFS	
Wc	34 ft	
D50	0.0088 ft - 2.67 mm to ft	
Upstream Inv.	60.55 ft	
y _{max}	13.1 ft	
y _o	7.33 ft	
y _s	5.7 ft	Scour depth at culvert entrance
Scour Elevation at Culvert Entrance:		54.8 ft

Note: Scour calculations were performed using equation "without wing wall case" although the scour depths are using for curtain wall to ensure the wingwall footings are low enough. This was done because the "with wing wall case" assumes wing walls flared at 45 degrees, which is not the case here for this culvert. Results using equation "without wing wall case" are more conservative.

River:	EastMeadowRiver	Profile:	50-Year		
Reach	Reach 1	RS:	404		Plan: Proposed Box Culvert
Plan: Proposed Box Culvert EastMeadowRiver Reach 1 RS: 404 Profile: 50-Year					
E.G. Elev (ft)	71.90	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.19	Wt. n-Val.	0.080	0.045	0.080
W.S. Elev (ft)	71.72	Reach Len. (ft)	9.61	9.61	9.61
Crit W.S. (ft)	68.07	Flow Area (sq ft)	142.15	245.62	689.46
E.G. Slope (ft/ft)	0.001107	Area (sq ft)	142.15	245.62	689.46
Q Total (cfs)	2268.00	Flow (cfs)	152.65	1155.26	960.09
Top Width (ft)	289.93	Top Width (ft)	61.00	26.50	202.44
Vel Total (ft/s)	2.11	Avg. Vel. (ft/s)	1.07	4.70	1.39
Max Chl Dpth (ft)	10.22	Hydr. Depth (ft)	2.33	9.27	3.41
Conv. Total (cfs)	68173.6	Conv. (cfs)	4588.5	34725.8	28859.2
Length Wtd. (ft)	9.61	Wetted Per. (ft)	62.05	27.72	203.80
Min Ch El (ft)	61.50	Shear (lb/sq ft)	0.16	0.61	0.23
Alpha	2.74	Stream Power (lb/ft s)	0.17	2.88	0.33
Frctn Loss (ft)	0.03	Cum Volume (acre-ft)	0.18	0.51	1.54
C & E Loss (ft)	0.17	Cum SA (acres)	0.08	0.06	0.43

Riprap Protection Calculations for Brandy Brow Culvert - 25 Year Design Storm

Peak Discharge, Q	1400 cfs
Culvert Width, Wc	34 ft
Flow Depth of Design Discharge, Yo	6.6 ft
Average Velocity in Culvert, V _{AC}	6.2 ft/s

Acceleration of Gravity, g	32.2 sfs
Sizing Coefficient, Kr	0.7
Riprap Specific Gravity, Sg	2.7
Median Stone Diameter, D ₅₀	1.6 ft

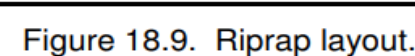
Average Contraction Scour, Ys	3.2 ft
Long-term Degradation	0 ft
Invert Elevation	60.6 ft
Total Scour, Ysc	3.2 ft
Top of Footing Elevation	57.4 ft

Riprap Layer thickness (Y_{sc} +difference between invert and bed at culvert wall +1), Y_{tot}	4.2 ft	<i>This value is less than $3*D_{50}=4.8ft$, therefore use 4.8 ft as Y_{tot}</i>
Riprap Layer thickness ($3*D_{50}$), Y_{tot}	4.8 ft	

3*d ₅₀	4.8 ft	
Riprap top width, W _t	5 ft	3*D ₅₀ < 5, thus top width will be 5 ft

Riprap top width, W_t	5 ft
Riprap layer thickness, Y_{tot}	4.8 ft
Riprap Bottom Width, W_b	19.4 ft

RIPRAP SUMMARY TABLE	
Component	Measurement (ft)
Riprap Size (D50) *Minimum*	1.6
Top of Footing Elevation	58.8
Riprap Layer Thickness, Y_{tot}	4.8
Riprap Top Width, W_t	4.8
Riprap Bottom Width, W_b	19.4



Greenman - Pedersen, Inc 520 U.S. Highway 22, Suite 200 Bridgewater, NJ 08807 (908) 236-9001	Job		MAX Haverhill Brandy Brow Culvert
	Calculated By	TCL	Date 6/19/2024
	Checked By	SCS	Date 6/19/2024

All formulas are based on the *HEC-23, Bridge Scour and Stream Instability Countermeasures: Experience, Selectionm and Design Guidance 3rd Edition, 2009*
Section 6 - Special Applications Design Guideline 18 - Riprap Protection for Bottomless Culverts

Riprap Protection Calculations for Brandy Brow Culvert - 50 Year Check Storm

1. Calculate the average velocity in the culvert

Peak Discharge, Q	1860 cfs
Culvert Width, Wc	34 ft
Flow Depth of Design Discharge, Yo	8.0 ft
Average Velocity in Culvert, V _{Ac}	
	6.9 ft/s

2. Calculate the median stone diameter *d*₅₀

Acceleration of Gravity, g	32.2 sfs
Sizing Coefficient, Kr	0.7
Riprap Specific Gravity, Sg	2.7
Median Stone Diameter, D ₅₀	
	1.9 ft

3. Calculate the top of footing elevation

Average Contraction Scour, Ys	5.7 ft
Long-term Degradation	0 ft
Invert Elevation	60.6 ft
Total Scour, Ysc	5.7 ft
Top of Footing Elevation	
	54.9 ft

4. Calculate the riprap layer thickness, *Y*_{tot}

Channel Bed Elevation at Culvert Wall	60.6 ft
Difference Between Invert and Bed at C	0.0 ft
Riprap Layer thickness (3*D50), Y _{tot}	5.7 ft
Riprap Layer thickness (Y _{sc} +difference between invert and bed at culvert wall +1), Y _{tot}	6.7 ft
	<i>This value is greater than 3*D₅₀=5.7, therefore use 6.7 ft as Y_{tot}</i>

5. Calculate the riprap top width, *W*_t

*W_t is 3 *D₅₀ or 5 ft, whichever is greater*

3*d ₅₀	5.7 ft
Riprap top width, W _t	5.7 ft
	<i>3*D₅₀ > 5, thus top width will be 5.7 ft</i>

6. Calculate the riprap bottom width, *W*_b

Riprap top width, W _t	5.7 ft
Riprap layer thickness, Y _{tot}	6.7 ft
Riprap Bottom Width, W _b	
	25.8 ft

RIPRAP PROTECTION DESIGN SUMMARY

RIPRAP SUMMARY TABLE	
Component	Measurement (ft)
Riprap Size (D50) *Minimum*	1.9
Top of Footing Elevation	56.8
Riprap Layer Thickness, Y _{tot}	5.7
Riprap Top Width, W _t	5.7
Riprap Bottom Width, W _b	25.8

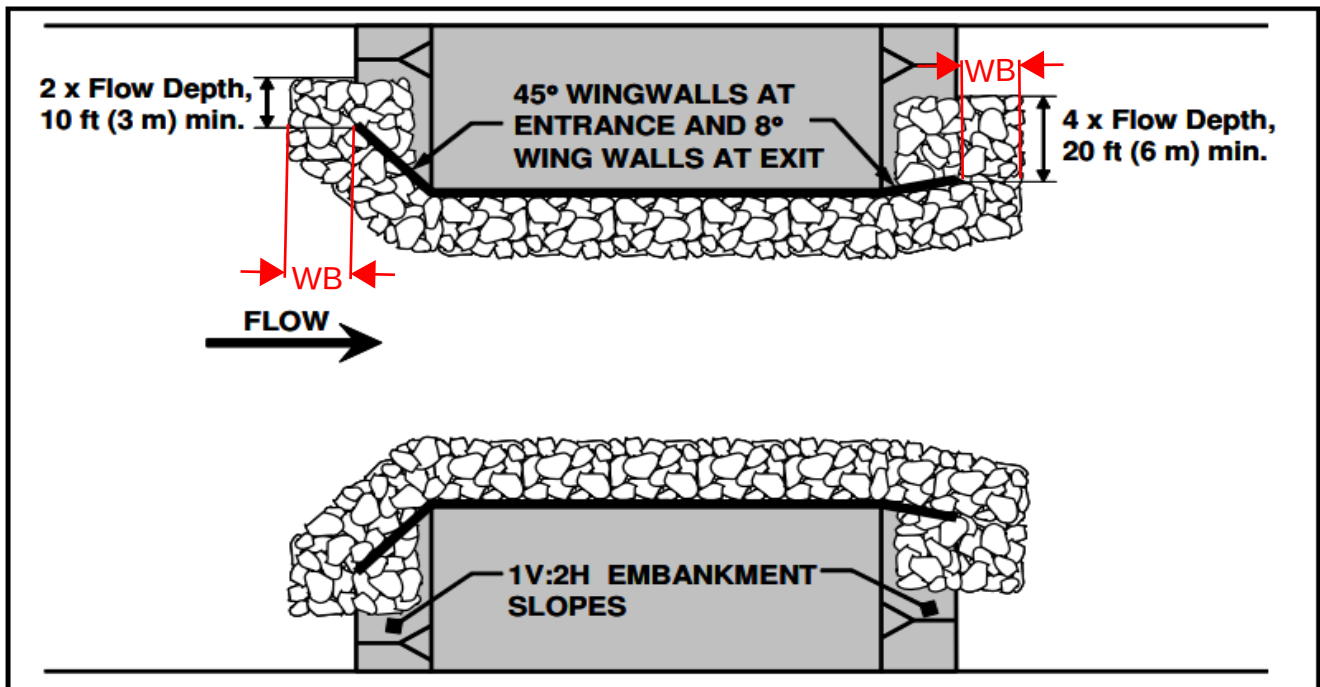


Figure 18.9. Riprap layout.

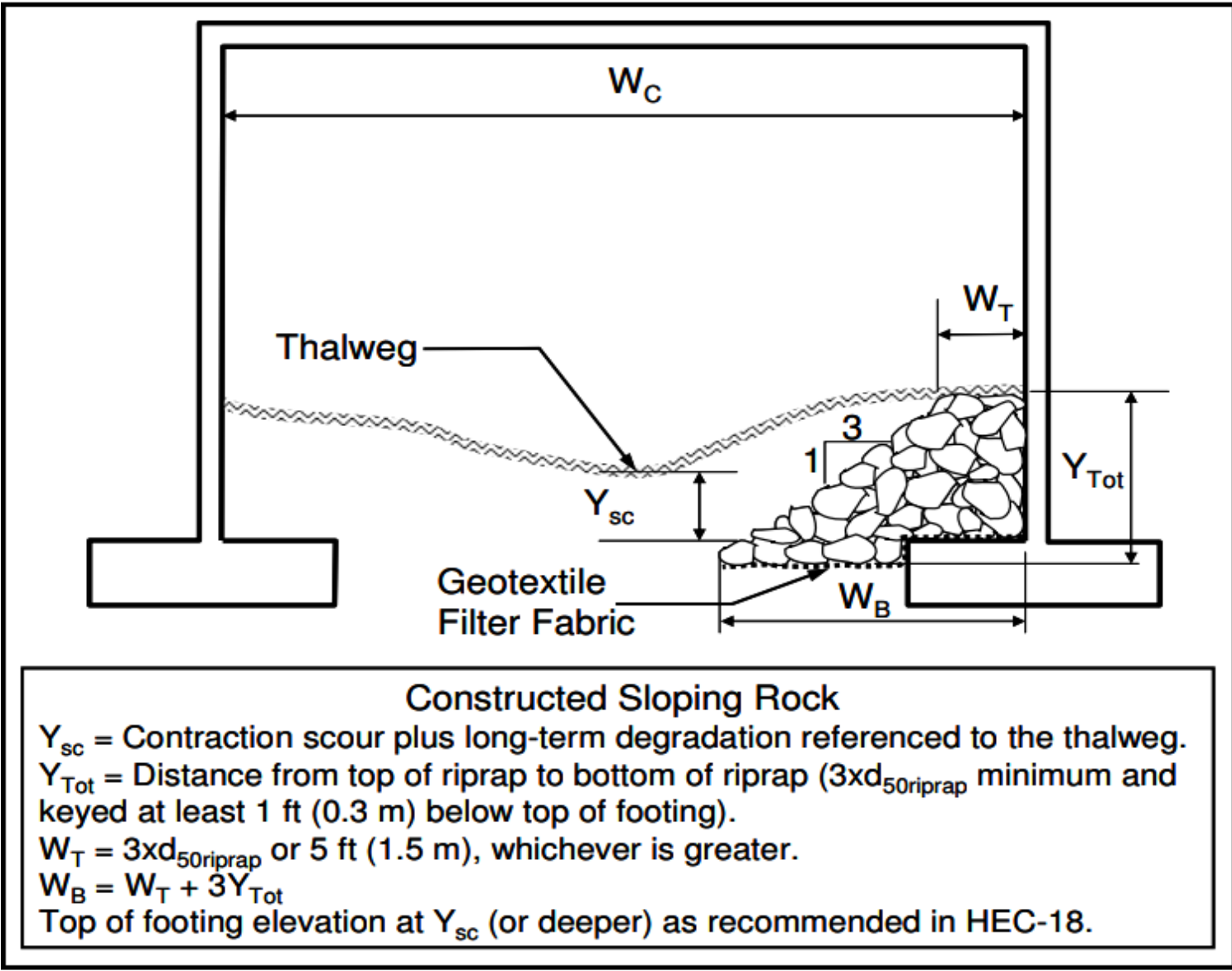


Figure 18.10. Cross Section for Sloping Rock.