CT 11934
Access Road Drainage Report

SBA Bridgewater
Wewaka Brook Road
Bridgewater, CT 06752

CHA Project Number: 15363.1054.30000

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TABLE OF CONTENTS

APPENDICES

FIGURES

1.0 INTRODUCTION

The project site is located off Wewaka Brook Road in the town of Bridgewater, CT. The site spans two properties. The first parcel is owned by Edward R. and Cynthia S. Bennet. The second parcel is owned by Mary Allen. The subject parcels are bounded by Wewaka Brook Road to the East, and residential parcels to the North, South and West. Site access comes from an existing residential asphalt driveway off Wewaka Brook Road.

The proposed work includes the installation of a fenced gravel compound for a telecommunications tower, construction of a gravel access drive to the tower site (2,215 linear feet), and installation of a stormwater collection system consisting of rock lined drainage swales, and storm drain culverts. Replacement of the existing residential driveway and accompanying existing bridge is also associated with this project but has not been analyzed as part of this report.

This report addresses the design of drainage swales and storm drain culverts to protect the access road from washout, safely convey stormwater flows, and protect outfall locations from erosion. This report does not address the design of groundwater controls or slope stabilization, as site geotechnical information was not available at the time of this report.

Refer to the proposed Certificate Drawings submission, dated 10-27-10, under a separate cover, for specific site details.

2.0 HYDROLOGIC EVALUATION

Existing Watershed Characteristics

The Connecticut United States Geological Survey (USGS) Roxbury Quandrangle Map indicates that the project improvements are located between an existing topographic ridge to the west, and Wewaka Brook Road to the east. Topography is varied between these features and includes small topographic ridges, natural swales, flatlands, and wetlands in the surrounding area. Existing topography contributing to site drainage consists of elevations ranging from 670' above mean sea level (AMSL) along Stuart Road to the north to 482' AMSL at an existing culvert to be replaced. Existing slopes vary from flat to very steep ranging (+/- 25%) (See Figure 1 – USGS Map).

Aerial photography and a site field visit indicate that the existing land use at the site consists primarily of forested area, with the exception of the existing residential asphalt driveway off Wewaka Brook Road and adjacent lawn area (See Figure 2 – Aerial Map).

Project site soil characteristics were determined using the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey. The site is primarily comprised of soils belonging to Hydrologic Soil Groups (HSG) B and C, with small pockets of HSG D (See Appendix A). A summary of the soil composition is shown in Table 1 on the following page.

Below is a brief description of the hydrologic soil groups present within site drainage areas:

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

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

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

Table 1 - Soil Analysis Summary

Unit Symbol – Unit Name	Hydrologic Soil Group	Percent of Drainage Areas
2 – Ridgebury fine sandy loam	D	2.2
3 – Ridgebury, Leicester, and Whitman soils, extremely stony	D	4.9
34A – Merrimac sandy loam, 0 to 3 percent slopes	B	0.1
50B – Sutton fine sandy loam, 3 to 8 percent slopes	B	1.2
60C – Canton and Charlton soils, 8 to 15 percent slopes	B	0.4
73C – Charlton-Chatfield complex, 3 to 15 percent slopes, very rocky	B	48.7
75C – Hollis-Chatfield-Rock outcrop complex, 3 to 15 percent slopes	D	3.5
75E – Hollis-Chatfield-Rock Outcrop complex, 15 to 45 percent slopes	D	4.6
84B – Paxton and Montauk fine sandy loams, 3 to 8 percent slopes	C	20.9
84C – Paxton and Montauk fine sandy loams, 8 to 15 percent slopes	C	6.4
85B – Paxton and Montauk fine sandy loams, 3 to 8 percent slopes, extremely stony	C	3.1
86D – Paxton and Montauk fine sandy loams, 15 to 35 percent slopes, extremely stony	C	3.9

Design Methodology

In order to design the proposed swales and culverts, peak flows (Q) for the 10-, 25-, and 50-year design storms were calculated using the Rational Method (Q=CIA). Composite runoff coefficients (C) were developed from an analysis of existing land use and typical C-values provided in Tables 6-3 and 6-5 of the Connecticut Department of Transportation (ConnDOT) Drainage Manual, dated October 2000 (See Appendix C). Times of concentration (T_c) were computed using standard NRCS TR-55 Methodology (See Appendix D). Rainfall intensities (I) were determined from Table B-2.1 of the ConnDOT Drainage Manual and the computed T_c values. A frequency factor (C_f) was used to refine the calculated peak flow for the 25- and 50-year design storms as prescribed in Table 6-2 in Section 6.9.5 of the ConnDOT Drainage Manual.

Proposed Condition Hydrology

For the purposes of the proposed condition analysis, eleven (11) drainage areas (DA) were developed to quantify the peak stormwater runoff rates to the proposed swales. Additionally, two separate design points (DP) were generated to quantify the peak stormwater runoff rates to the proposed culvert locations.

Drainage areas were determined through review of the existing topographic survey of the site (See Certificate Drawing submission) and the Connecticut USGS Roxbury Quadrangle Map.

A summary of the results for the proposed condition hydrologic analysis is shown in Table 2 and Table 3 below (See Figures 3A through 3D for site drainage areas).

Table 2 – Hydrologic Analysis Summary (Drainage Areas)

Drainage Area/ Design Point	Area (acres)	Runoff Coefficient (C)	Tc (min)[2]	Rainfall Intensity (I) (in/hr)			Peak Discharge (Q) (cfs)		
				10 year	25 year	50 year	10 year	25 year[1]	50 year[1]
DA 1	67.56	0.27	48	2.20	2.60	2.90	39.9	51.8	63.1
DA 1.1	0.36	0.30	10	4.80	5.50	6.00	0.5	0.6	0.8
DA 1.2	0.17	0.29	13	4.30	5.00	5.40	0.2	0.3	0.3
DA 2	0.22	0.27	17	3.80	4.40	4.90	0.2	0.3	0.4
DA 3	0.38	0.33	11	4.70	5.30	5.80	0.6	0.7	0.9
DA 4	0.40	0.33	10	4.80	5.50	6.00	0.6	0.8	1.0
DA 5	6.09	0.24	24	3.30	3.80	4.20	4.8	6.1	7.3
DA 5.1	0.25	0.40	10	4.80	5.50	6.00	0.5	0.6	0.7
DA 5.2	0.07	0.23	10	4.80	5.50	6.00	0.1	0.1	0.1
DA 6	0.05	0.45	10	4.80	5.50	6.00	0.1	0.1	0.1
DA 7	0.09	0.42	10	4.80	5.50	6.00	0.2	0.2	0.3

[1]Frequency Factor for 25-year recurrence interval is 1.1. Frequency factor for 50-year recurrence interval is 1.2 (Table 6-2 of ConnDOT Drainage Manual)
[2]Per section 6.9.6 of the ConnDOT Drainage Manual, the minimum T_C used for design purposes shall be 10 minutes for grass areas.

Table 3 – Hydrologic Analysis Summary (Design Points)

Drainage Area/ Design Point	Area (acres)	Runoff Coefficient (C)	Tc (min)[4]	Rainfall Intensity (I) (in/hr)			Peak Discharge (Q) (cfs)		
				10 year	25 year	50 year	10 year	25 year[3]	50 year[3]
DP 1[1]	68.09	0.27	48	2.20	2.60	2.90	40.2[5]	52.3[5]	63.6[5]
DP 5[2]	6.41	0.24	24	3.30	3.80	4.20	5.2[5]	6.5[5]	7.9[5]

[1]DP 1 consists of DA 1, DA 1.1 and DA 1.2
[2]DP5 consists of DA 5, DA 5.1 and DA 5.2
[3]Frequency Factor for 25-year recurrence interval is 1.1. Frequency factor for 50-year recurrence interval is 1.2 (Table 6-2 of ConnDOT Drainage Manual)
[4]Per section 6.9.6 of the ConnDOT Drainage Manual, the minimum T_C used for design purposes shall be 10 minutes for grass areas.
[5]Due to variable T_c, the sum of individual subarea peak flow rates may not necessarily equal the overall design point peak flow rate

3.0 HYDRAULIC EVALUATION

3.1 CULVERTS

Basis of Design

In accordance with the design criteria and procedures set forth in Section 8.3 of the ConnDOT Drainage Manual, the Connecticut Department of Environmental Protection Stream Crossing Guidelines and guidelines established by the Army Corps of Engineers, culverts shall be designed to:

- Allow for continuous flow and safe conveyance of the 50-year design storm peak flow.
- Have a HW/D ratio less than 1.5 (The hydraulic performance of a culvert is commonly expressed as a ratio of headwater depth (HW), which equals the depth of water measured from the invert of the culvert, to the culvert diameter (D) as HW/D).
- Have a minimum diameter of 18 inches.
- Have a gradient that is not steeper than the streambed gradient immediately upstream or downstream of the culvert.
- Have inverts that are set to greater than or equal to 12 inches below the elevation of the streambed.
- Be backfilled with natural substrate material matching the upstream and downstream steambed substrate.

Design Methodology

The proposed culverts were analyzed using Haestad Methods CulvertMaster Computer Software (Version 3.1). This program was utilized to compute the headwater elevation and discharge velocity of the culverts (evaluating both inlet and outlet control equations) (See Appendix E).

The pipe flow capacity was calculated using:

- Manning’s Equation for velocity (V) using equation 7.6 of the ConnDOT Drainage Manual.
- The Continuity Equation for flow capacity (Q) using equation 7.5 of the ConnDOT Drainage Manual.

See Appendix F for culvert capacity calculations.

Design Summary

The access road design required two (2) culvert locations (one at DP 1, the other at DP 5) for stormwater conveyance (See Figures 4A through 4D for locations). The culvert at DP 1 will be a 3-foot high x 6-foot wide x 42-foot long concrete box culvert set at a slope of approximately 2.4 percent, with an invert set 12 inches below the streambed elevation. The culverts at DP 5 will be 24-inch RCP culverts, 35 feet in length, set at a slope of approximately 8.5% (to match existing channel slope), with inverts set 12 inches below the streambed elevation. Three culverts have been utilized at this location in an attempt to maintain the existing drainage channel width and flow characteristics, and to minimize impact to wetlands. These culverts will be backfilled with free draining material to create a french mattress as recommended by the Wetland Impact Assessment prepared for this project by VHB, Inc., dated 11/11/2011 (See Figure 5 for drainage details).

See Table 4 below for a summary of the results of the culvert analysis

Table 4 – Culvert Analysis

Culvert	Length (ft)	Slope (%)	Size (ft)	Manning's n[1] (unitless)	50-year Peak Design Flow (cfs)	Provided Flow Capacity[2] (cfs)	Computed HW (ft)	HW/D Ratio (ft/ft)
DP 1	42	2.4	3 x 6	0.013	63.6	240.8	1.41	0.71
DP 5	35	7.9	2 (3x)	0.013	7.9	99.0	0.62	0.62

[1]Manning's n referenced from CulvertMaster.
[2]See Appendix E for culvert capacity calculations.

Based on the analysis, a 6 foot x 3 foot box culvert at DP 1will allow for continuous passage of the 50-year frequency design storm, with a calculated HW/D ratio less than 1.5. Additionally, three (3) 24" diameter RCP culverts at DP 5 will safely convey peak flows from the 50-year frequency design storm, with a calculated HW/D ratio less than 1.5.

3.2 SWALES

Basis of Design

In accordance with the design criteria and procedures set forth in Sections 7.3 and 7.6 of the ConnDOT Drainage Manual, roadway swales shall be designed:

- To safely convey the 10-year frequency design storm peak flow without causing erosive damage.
- With a lining that is sufficient to resist the shear forces created from the transportation of storm flows (The permissible or critical shear stress in a swale defines the force required to initiate movement of the channel bed or lining).

Additionally, in accordance with Chapter 5, Section 6, Permanent Lined Waterway, of the 2002 Connecticut Guidelines for Soil Erosion and Sediment Control by The Connecticut Council on Soil and Water Conservation in Cooperation with the Connecticut Department of Environmental Protection (CTDEP), swales shall be designed with a minimum freeboard of 0.25 feet if no out-of-bank damage would be expected.

Design Methodology

Flow capacity of the swales was determined from the following:

- Velocity (V) – Equation 7.6 of the ConnDOT Drainage Manual (Manning's Equation)
- Flow capacity (Q) – Equation 7.5 of the ConnDOT Drainage Manual (The Continuity Equation).

See Appendix H for swale sizing calculations.

Swale lining was determined by the following:

- Average Shear Stress (τ) – Equation 7.11 of the ConnDOT Drainage Manual
- Maximum Shear Stress (τ_d) – Equation 7.12 of the ConnDOT Drainage Manual
- Lining Category (Material) and Type– Table 7-4 of the ConnDOT Drainage Manual

See Appendix I for shear stress calculations.

Design Summary

For ease of construction, one swale type (size) was designed which meets the dimensional requirements at all swale locations. (See Figures 4A through 4D for proposed swale locations and Figure 5 for drainage details). The swale selected is a 1-foot deep, 1-foot wide flat bottom swale with 2:1 side slopes.

See Table 5 on the following page for a summary of the results of the swale analysis.

Table 5 – Swale Hydraulic Analysis

Swale	Slope (ft/ft)	Manning's n[1] (unitless)	Velocity (ft/sec)	10-yr Peak Design Flow (cfs)	Provided Flow Capacity (cfs)	Provided Freeboard @ 10-yr Peak Flow (ft)
DA 1.1	0.20	0.078	2.24	0.51	9.11	0.82
DA 1. 2	0.01	0.088	0.52	0.21	1.65	0.72
DA 2	0.08	0.088	1.14	0.23	4.94	0.84
DA 3	0.17	0.079	2.15	0.59	8.27	0.80
DA 4	0.14	0.080	2.05	0.64	7.30	0.77
DA 5.1	0.16	0.083	1.94	0.49	7.66	0.81
DA 5.2	0.033	0.128	0.50	0.08	2.27	0.85
DA 6	0.10	0.104	0.85	0.10	4.83	0.90
DA 7	0.20	0.104	1.34	0.19	6.83	0.88

[1]Manning's n calculated using steep slope procedures in HEC-15, as prescribed in Section 7.6.9 of the ConnDOT Drainage Manual, as well as, the values listed in Table 7-4 of the ConnDOT Drainage Manual.

To determine the type of swale lining necessary to armor the swales and protect against erosive forces imparted by stormwater flows, shear stresses were calculated. Rock riprap lining was selected to armor the swales in order to withstand the calculated shear stresses. See Table 6 below for a summary of the results of the calculated shear stress and riprap sizing analysis.

Table 6 – Shear Stress and Riprap Sizing Analysis

Swale	Calculated Shear Stress (lb/ft^2)	Required ConnDOT Riprap[1]		
		Permissible Shear Stress[2] (lb/ft^2)	Classification	D_{50} Size (inches)
DA 1.1	2.25	2.68	Intermediate	8
DA 1. 2	0.15	1.68	Modified	5
DA 2	0.75	1.68	Modified	5
DA 3	2.11	2.68	Intermediate	8
DA 4	1.94	2.68	Intermediate	8
DA 5.1	1.90	2.68	Intermediate	8
DA 5.2	0.31	1.68	Modified	5
DA 6	0.62	1.68	Modified	5
DA 7	1.50	1.68	Modified	5

[1]Determined by selecting riprap with a higher permissible shear stress than the calculated shear stress
[2]Permissible shear stress for lining materials is taken from Table 7-4 of the ConnDOT Drainage Manual

Based on the analyses, each of these swales will be capable of safely conveying the 10-year peak storm flows calculated for their respective Drainage Area, provide the required 0.25 feet of freeboard, and withstand calculated shear stresses.

3.3 OUTLET PROTECTION

Basis of Design

In accordance with the design criteria and procedures set forth in Section 11.13.3 of the ConnDOT Drainage Manual, riprap outlet protection shall be designed to reduce the erosive potential at all discharge points.

Design Methodology

The type and dimensions of rip rap protection was determined by the guidelines established in Sections 11.13.2 and 11.13.5 of the ConnDOT Drainage Manual, and the following:

- Length (L_a) – Tables 11-12.1 and 11-13.1 of the ConnDOT Drainage Manual
- Width of apron at pipe outlet (W_1) and width of apron at terminus (W_2) – Equation 11.33 of the ConnDOT Drainage Manual, as well as, Section 11.13.5 of the ConnDOT Drainage Manual.
- Riprap Specification – Table 11.11 of the ConnDOT Drainage Manual

See Appendix J for outlet protection calculations.

Design Summary

Based on recommended design procedures in Section 11.13.2 of the ConnDOT Drainage Manual, a Type A riprap apron shall be used at all of the swale discharge points. The selected riprap apron shall have a length (L_a) of 10 feet, a width of apron at outlet (W_1) of 5 feet, and a width of apron at terminus (W_2) of 10 feet . Type A riprap aprons shall utilize modified riprap for erosion protection. A Type C riprap apron shall be used at both culvert discharge locations. The culvert at DP 1 and culverts at DP 5 shall have a L_a of 24 feet and 12 feet, respectively. The width of the Type C riprap aprons shall match the width of the downstream channel. Type C riprap aprons shall utilize intermediate riprap for erosion protection (See Figure 5 for drainage details).

Table 7 on the following page summarizes the minimum outlet protection requirements.

Table 7 – Outlet Protection Requirements

Design Point	Structure	Diameter or Span (ft)	Outlet Velocity (ft/sec)	10-year Peak Discharge (ft^3/sec)	Outlet Type	Calculated Dimensions[6]			
						L_a[1] (ft)	W_1[2] (ft)	W_2[3] (ft)	Riprap Specification[4]
DA 1.1	Swale[5]	1.00	2.24	0.5	Type A Riprap Apron	10	3	10	Modified
DA 1.2	Swale[5]	1.00	0.52	0.2		10	3	10	Modified
DA 2	Swale[5]	1.00	1.14	0.2		10	3	10	Modified
DA 3	Swale[5]	1.00	2.15	0.6		10	3	10	Modified
DA 4	Swale[5]	1.00	2.05	0.6		10	3	10	Modified
DA 5.1	Swale[5]	1.00	1.94	0.5		10	3	10	Modified
DA 5.2	Swale[5]	1.00	0.50	0.1		10	3	10	Modified
DA 6	Swale[5]	1.00	0.85	0.1		10	3	10	Modified
DA 7	Swale[5]	1.00	1.34	0.2		10	3	10	Modified
DP 1	Culvert	6.00	9.92	40.2	Type C Riprap Apron	24	Match Downstream Channel		Intermediate
DP 5	Culverts	8.00	7.44	5.2		12			Intermediate

[1]L_a values determined using Table 11-12.1 and 11-13.1 of the ConnDOT Drainage Manual.
[2]W_1 = width of apron at pipe outlet
[3]W_2 = width of apron at terminus
[4]Riprap specification selected from Table 11.11 of the ConnDOT Drainage Manual
[5]Diameter used for swales is the bottom channel width
[6]Dimensions represent minimum acceptable parameters based on calculations. Actual dimensions selected for use may differ

Based on analysis of proposed outfall locations, discharge velocities meet the ConnDOT requirements for use of riprap aprons (outlet velocities are less than 14 fps). A Type A riprap aprong with dimensions of 10’ (L_a) x 5’ (W_1) x 10’ (W_2) is sufficient to reduce the erosive potential at swale discharge points. Type C riprap aprons with widths matching the downstream channel and an L_a value of 24 feet (DP 1) and 12 feet (DP 5) are sufficient to reduce the erosive potential at the culvert discharge points.

4.0 INSPECTION AND MAINTENANCE

Inspection and maintenance of the stormwater collection system (riprap lined swales, storm drain culverts, and riprap aprons) is critical to maintaining proper function. Normally, a visual inspection of all components should be completed annually and after major storm events. Due to steep gradients which produce high shear stresses in the proposed swales, an increased inspection and maintenance schedule is required. A visual inspection of the swale riprap lining should be completed semi-annually and after major storm events.

The following maintenance tasks should be completed during the inspection process:

- Removal of any organic matter, trash/debris, or obstructions found in swales or riprap aprons
- Removal of any accumulated sediment found in culvert, swales or riprap aprons
- Removal of any potential obstructions at culvert inlet/outlet points
- Replacement of any riprap material that may have washed away during large storm events

Careful inspection and proper maintenance on a regular basis will enable the system to safely convey stormwater flows and reduce the risk of system backup or overflow during major storm events.

5.0 CONCLUSION

All proposed drainage improvements (swales, culverts, outlet protection) have been designed in accordance with the engineering guidelines established in the ConnDOT Drainage Manual, the Connecticut Department of Environmental Protection Stream Crossing Guidelines and guidelines established by the Army Corps of Engineers. Based on the analysis, the following design parameters are recommended:

- The wetland crossing at DP 1 shall be constructed using a 3-foot high x 6-foot wide concrete box culvert, with an invert set 12 inches below the adjacent streambed elevation. The crossing shall be 42 feet in length and set at a slope to match the gradient immediately upstream and downstream of the culvert. The culvert will meet the Army Corps of Engineers requirements of safely conveying the 50-year design storm peak flows.

- The wetland crossing at DP 5 shall be constructed using three (3) 24-inch diameter RCP with inverts set 12-inches below the adjacent streambed elevation. The crossing shall be 35-feet in length and set at a slope to match the gradient immediately upstream and downstream of the culvert. The culvert will meet the Army Corps of Engineers requirements of safely conveying the 50-year design storm peak flows.

- Swales shall be at minimum 1-foot wide flat bottom, 1-foot deep, riprap lined trapezoidal swales with 2:1 side slopes. The designed swales will meet the ConnDOT requirements for conveying the 10-year design storm peak flows while withstanding the calculated shear stresses. They will also meet the DEEP requirement of providing 0.25 feet of freeboard.

- Outlet protection for swales shall be Type A riprap aprons with the following minimum parameters:
  - Length (L_a) – 10 feet
  - Width of apron at pipe outlet (W_1) – 5 feet
  - Width of apron at terminus (W_2) – 10 feet
  - Utilize modified riprap for armoring.

  This will meet the ConnDOT requirements for use of riprap aprons (discharge velocities < 14 fps) to provide erosion protection at outfall locations.

- Outlet protection for culverts shall be Type C riprap aprons with the following minimum parameters:
    - Length (L_a) – 24-feet at Culvert DP 1, 12-feet at Culvert DP 5
    - Width of apron at pipe outlet (W_1) – Match width at outlet
    - Width of apron at terminus (W_2) – Match downstream width
    - Utilize intermediate riprap for armoring.

  This will meet the ConnDOT requirements for use of riprap aprons (discharge velocities < 14fps) to provide erosion protection at outfall locations.