SECTION 5.0

ENGINEERING REPORT

5.0 ENGINEERING REPORT

This Engineering Report for the Edge Moor Site II Ash Landfill was prepared by Golder Associates Inc. in connection with the design and permitting of the site closure.

APPENDIX 5-A

HYDROLOGIC ANALYSES

Channel Calculations

Date:	12/09/19 Revised March 2020 Revised April 2020	**Made by:** **Checked by:** **Reviewed by:**	ZEG JPG PAW
Project No.:	19129265	**Revised by:** **Checked by:** **Reviewed by:**	JPG ANO PAW
Site Name:	Edge Moor Site II Ash Landfill	**Revised by:** **Checked by:** **Reviewed by:**	JPG ANO PAW 4/7/2020

Subject: **CHANNEL CALCULATIONS**

1.0 OBJECTIVE

Evaluate the capacity of all channels at the Edge Moor Site II Ash Landfill (Site) in Wilmington, Delaware by calculating the contributing drainage subareas, the time of concentration for each drainage subarea, and the associated peak flow for the design storm.

2.0 REFERENCES

1) SCS Technical Release 55 (TR-55) Urban Hydrology for Small Watersheds, June 1986.

2) Rainfall Depths for Delaware, National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 2, Version 3, January 2014.

3) "Construction Site Stormwater Management Plan" drawing prepared by Golder Associates Inc., December 2019.

4) Delaware Department of Natural Resources and Environmental Control (DNREC) Division of Watershed Stewardship, "Delaware Erosion and Sediment Control Handbook," February 2019.

5) DNREC Division of Watershed Stewardship, "3.06.2 Post Construction Stormwater BMP Standards and Specifications," March 2013.

6) Bentley Systems Inc., Bentley FlowMaster V8i, November 2009.

7) HydroCAD Software Solutions LLC, HydroCAD 8.50, July 2011.

3.0 METHODOLOGY

Divide the landfill into drainage subareas for the plateau, which has a one (1) foot high diversion berm around its perimeter, and side slopes of the landfill based on the landfill grading and the perimeter channel slope direction (Reference 3). Determine the times of concentration and peak flows to be conveyed in the vertical channels, the plateau diversion berm channels and the perimeter channels. Use the flows and the proposed channel dimensioning to ensure the perimeter channels can adequately manage the peak flows based on a specified recurring storm event. Stormwater management software will be used to analyze the flows and channel capacity. Use shear stress method to evaluate channel linings.

4.0 ASSUMPTIONS

1. The soil type is assumed to be a Hydrologic Soil Group (HSG) C and the channels will be vegetated. The estimated Curve Number (CN) for the landfill is 86.
2. The stormwater on the plateau of the landfill is directed, via grading, to plateau diversion berm channels and/or vertical channels along the steep slopes. The plateau areas do not discharge directly onto the steep slope areas and thus, they are broken into different drainage subareas (Reference 3).
3. The landfill side slopes range from 4H:1V to 7H:1V, with a small bench at a 5% slope at the southeast toe.
4. The 25-year, 24-hour storm event is 6.0 inches for New Castle County, Delaware (Reference 2) and is used to calculate the flow capacity necessary for all channels, as specified by Delaware's Regulations Governing Solid Waste (DRGSW) § 6.6.2.2.
5. All flow is assumed to be sheet flow for the first 150 feet, it will then be considered shallow concentrated flow. Flow within the channels is not continuous from the slopes and is evaluated separately.
6. Each perimeter channel will be analyzed separately using stormwater management software (References 6 & 7) and all channels are designed to withstand the maximum peak flow from the contributing drainage subareas.
7. The perimeter channel is a 2-foot deep V-ditch with 4H:1V sideslope on the landfill side and 3H:1V sideslope on the opposing side. The channel slope is 0.25%. The landfill side is lined with aggregate and the opposing side is vegetated with erosion control blanket (ECB) lining.
8. The vertical channels are 6-inch deep V-ditches with 10H:1V sideslopes. The vertical channel slope varies with the side slopes. These channels are vegetated with turf reinforcement mat (TRM) lining.
9. The plateau diversion berm channel side slopes are 3H:1V with varying channel slopes. These channels are vegetated.
10. Manning's roughness coefficient for the perimeter channel is assumed to be 0.035 for aggregate, riprap, reno mattress, etc. and 0.03 for vegetated channels (References 4 & 5). The perimeter channels will be lined with reno mattresses at each intersection with a vertical channel. The reno mattress lining will begin ten (10) feet upstream, continue the length of the vertical channel (ten feet) and extend twenty (20) feet downstream resulting in a 40-foot long reno mattress zone at each vertical channel.
11. For the time of concentration calculations, the Manning's roughness coefficient on the slope of the landfill is assumed to be 0.3 (References 4).
12. A freeboard of 0.25 feet, or three (3) inches, is required for a 10-year, 24-hour storm event for lined channels, but no freeboard is necessary for properly vegetated areas (Reference 4). All vertical channels are intended to grow good vegetation and be maintained during post construction, thus requiring no freeboard.
13. The plateau diversion berm channel is a one-foot deep trapezoidal channel with a 3-foot base width.
14. The plateau diversion berm channels are only found along subareas A2, A3, B2, B3, and C2.
15. The minimum time of concentration will be 0.05 hours.

5.0 CALCULATION

1) The drainage area, time of concentration and the peak discharge for each subarea is shown in Table 1. Drainage subareas were identified and measured for the four perimeter channels, five vertical channels, and five plateau diversion berm channels (Reference 3).

Vertical Channels	
Assigned Model Designation (1)	**Channel ID**
A4	VC -1
B4	VC-5
C3	VC-2
C6	VC-3
D3	VC-4

(1) Note that A4, B4, C3, C6, and D3 were assigned designations for the HydroCad input model for the corresponding vertical channels and do not represent the upstream drainage areas.

2) The contributing drainage subareas with peak channel flows are shown in Table 2.

3) Using the peak flows for each subarea from HydroCAD, the channels can be sized using the FlowMaster software (Reference 6 & 7). FlowMaster allows the user to solve for the required normal depth of a channel based on the roughness coefficient, channel slope, side slopes, and peak flows (see Table 3 for channel designs). Attached are the HydroCAD and FlowMaster outputs.

Table 1: Post-Construction Drainage Areas, Tc, and Peak Discharge

Channel Location	Subarea ID	Drainage Area (ac)	Time of Concentration (Tc) (hr)	25-Year, 24-Hour Peak Discharge (cfs)
Southwest	A1	0.110	0.055	0.87
	A2	0.629	0.123	4.41
	A3	0.144	0.128	1.00
	A5	0.231	0.105	1.65
Southeast	B1	1.11	0.135	7.62
	B2	1.11	0.195	6.76
	B3	0.204	0.187	1.26
	B5	0.258	0.207	1.85
Northwest	C1	0.895	0.087	6.69
	C2	0.332	0.252	1.82
	C4	1.770	0.148	11.83
	C5	0.434	0.323	2.11
	C7	0.418	0.390	1.83
Northeast	D1	0.417	0.090	3.09
	D2	0.763	0.327	3.69
	D4	0.552	0.193	3.37

4) Based on the modeling all channels can adequately convey the peak flow from the 25-year, 24-hour storm without overtopping. The modeled minimum freeboard for any lined perimeter channel is 0.34 feet, or 4 inches. Table 4 displays a summary of each channel based on a 25-year, 24-hour storm.

5) The perimeter channels were analyzed in FlowMaster using a composite cross section incorporating the varying sideslopes and Manning's coefficients applicable to each side of the channel. More detail can be found in the attached outputs.

6) Shear stresses were calculated to determine necessary channel lining. The shear stress and the appropriate lining for each channel is in Table 4. Any channels with a shear stress less than two pounds per square foot can be grass lined. The current design calls for a temporary erosion control blanket to stabilize these channels until the vegetation is established. The following equation was used to calculate shear stress:

$$\tau = \gamma_w \times S \times d$$

Where:

γ_w = Unit weight of H_2O (62.4 lb/ft^3)
S = Channel slope (ft/ft)
d = Flow depth (ft)

7) Table 4 summarizes the required lining for each channel

Table 2: Peak Flows for Each Channel Post Construction

Channel Location	Channel ID	Contributing Drainage Subareas/Channels	Peak Channel Flow (cfs)
			25-Year, 24-Hour
Southwest	Plateau Channel A1	A2	4.41
	Plateau Channel A2	A3	1.00
	Vertical Channel 1	A2, A3	4.88
	Perimeter Channel Ac1	A1	0.87
	Perimeter Channel Ac2	A1, A2, A3, A4, A5	6.51
Southeast	Plateau Channel B1	B2	6.76
	Plateau Channel B2	B3	1.26
	Vertical Channel 5	B2, B3	7.20
	Perimeter Channel Bc1	B2	7.62
	Perimeter Channel Bc2	B1, B2, B3, B4, B5	13.92
Northwest	Plateau Channel C1	C2	1.82
	Vertical Channel 2	C2	1.80
	Vertical Channel 3	C5	2.11
	Perimeter Channel Cc1	C1	6.69
	Perimeter Channel Cc2	C3, C4	16.31
	Perimeter Channel Cc3	C1, C2, C3, C4, C5, C6, C7	17.59
Northeast	Vertical Channel 4	D2	3.69
	Perimeter Channel Dc1	D3, D4	3.09
	Perimeter Channel Dc2	D1, D2, D3, D4	9.39

8) As seen in Table 4, Vertical Channels 1 and 5 have less than 0.25 feet of freeboard during a 25-year, 24-hour storm event. These channels, while considered lined channels, do not require any freeboard since good vegetation will be established in adjacent areas as part of the closure and post-closure maintenance (Assumption 12).

Table 3: Design Information for Channels

Channel ID	Channel Lining	Left Side Slope (ft/ft)	Bottom Width (ft)	Channel Depth (ft)	Right Side Slope (ft/ft)	Manning's "n" (left/right)	Channel Slope (ft/ft)
Plateau Channel A1	Vegetation	3H:1V	3	1	3H:1V	0.030	0.0145
Plateau Channel A2	Vegetation	3H:1V	3	1	3H:1V	0.030	0.009
Vertical Channel 1	Vegetation	10H:1V	-	0.5	10H:1V	0.030	0.2500
Perimeter Channel A	Aggregate / Vegetation	4H:1V	-	2	3H:1V	0.035/0.030	0.0025
Plateau Channel B1	Vegetation	3H:1V	3	1	3H:1V	0.030	0.0150
Plateau Channel B2	Vegetation	3H:1V	3	1	3H:1V	0.030	0.0240
Vertical Channel 5	Vegetation	10H:1V	-	0.5	10H:1V	0.030	0.0500
Perimeter Channel B	Aggregate / Vegetation	3H:1V	-	2	4H:1V	0.030/0.035	0.0025
Plateau Channel C1	Vegetation	3H:1V	3	1	3H:1V	0.030	0.0200
Vertical Channel 2	Vegetation	10H:1V	-	0.5	10H:1V	0.030	0.2000
Vertical Channel 3	Vegetation	10H:1V	-	0.5	10H:1V	0.030	0.2000
Perimeter Channel C	Aggregate / Vegetation	3H:1V	-	2	4H:1V	0.030/0.035	0.0025
Vertical Channel 4	Vegetation	10H:1V	-	0.5	10H:1V	0.030	0.2400
Perimeter Channel D	Aggregate / Vegetation	4H:1V	-	2	3H:1V	0.035/0.030	0.0025

Table 4: Channel Summary

Channel ID	25-Year, 24-Hour Storm				
	Normal Depth (ft)	Freeboard (ft)	Velocity (ft/s)	Shear Stress (psf)	Lining
Plateau Channel A1	0.39	0.61	2.67	0.35	Grass/ECB
Plateau Channel A2	0.20	0.80	1.39	0.13	Grass/ECB
Vertical Channel 1	0.27	0.23	6.54	4.21	Grass/TRM
Perimeter Channel A	1.12	0.88	1.49	0.18	Aggregate (Left) Grass/ECB (Right)
Plateau Channel B1	0.42	0.58	3.73	0.39	Grass/ECB
Plateau Channel B2	0.18	0.82	2.00	0.27	Grass/ECB
Vertical Channel 5	0.43	0.07	3.95	1.34	Grass/TRM
Perimeter Channel B	1.49	0.51	1.80	0.23	Aggregate (Left) Grass/ECB (Right)
Plateau Channel C1	0.22	0.78	2.26	0.27	Grass/ECB
Vertical Channel 2	0.20	0.30	4.69	2.50	Grass/TRM
Vertical Channel 3	0.21	0.29	4.88	2.62	Grass/TRM
Perimeter Channel C	1.62	0.38	1.91	0.25	Aggregate (Left) Grass/ECB (Right)
Vertical Channel 4	0.25	0.25	6.01	3.74	Grass/TRM
Perimeter Channel D	1.28	0.72	1.63	0.20	Aggregate (Left) Grass/ECB (Right)

6.0 CONCLUSION

HydroCAD was used to calculate the time of concentration and the peak flow rate for each subarea and channel. The flow was then input into FlowMaster and the proposed channel sizes were analyzed based on these peak flows and the assumptions made. The proposed perimeter, vertical and plateau diversion berm channels, as stated in Section 4.0 Assumptions, can adequately handle the peak flow rates from a 25-year, 24-hour storm event.

LEGEND

23	EXISTING GRADE MAJOR CONTOUR
	EXISTING GRADE MINOR CONTOUR
23	PROPOSED TOP OF FINAL GRADE MAJOR CONTOUR
	PROPOSED TOP OF FINAL GRADE MINOR CONTOUR
	EXISTING PROPERTY LINE
	EXISTING UTILITY EASEMENT
LOD	PROPOSED LIMIT OF DISTURBANCE
	LIMIT OF GEOSYNTHETIC CAP
CST	PROPOSED COMPOST LOG SEDIMENT TRAP
	PROPOSED EROSION CONTROL MATTING
	STORMWATER SUBAREA
CFL	COMPOST FILTER LOGS
SCD	PROPOSED STONE CHECK DAM

REFERENCE(S)

1. EXISTING CONTOURS SHOWN BASED ON BASE MAP TAKEN FROM RAMESH C. BATTA ASSOCIATES, P.A., DATED MARCH 15, 2006, MERGED WITH USGS FEBRUARY 2013; NATIONAL ELEVATION DATASET (NED) 1/9 ARC SECOND; http://ned.usgs.gov
2. EXISTING BASE FEATURES SHOWN TAKEN FROM RAMESH C. BATTA ASSOCIATES, P.A., DATED MARCH 15, 2006
3. HORIZONTAL CONTROL: DE NAD83
4. DATUM: NAVD 88

NOTE(S)

1. THIS DRAWING DEPICTS THE TOP OF THE FINAL SURFACE OF THE CAPPING SYSTEM.
2. ALL HYDROLOGY DRAINAGE AREAS AND STORMWATER STRUCTURES ARE DEPICTED TO AID IN THE REVIEW OF THE DESIGN CALCULATIONS.
3. TYPES AND LOCATIONS OF EROSION AND SEDIMENT CONTROLS ARE PROPOSED. ADDITIONAL OR DIFFERENT CONTROLS MAY BE UTILIZED AT THE TIME OF CONSTRUCTION BASED ON OBSERVED CONDITIONS. ALL CONTROLS WILL BE IN ACCORDANCE WITH THE MOST RECENT VERSION OF DELAWARE EROSION AND SEDIMENT CONTROL HANDBOOK.
4. PERIMETER EROSION AND SEDIMENT CONTROLS SHALL BE INSTALLED PRIOR TO CLEARING AND GRUBBING ACTIVITIES.

CHANNEL IDENTIFICATION	CHANNEL TYPE	APPROXIMATE LENGTH (FT)	CHANNEL TOP WIDTH (FT)	SLOPE (%)	SIDE SLOPES LEFT (H:V)	SIDE SLOPES RIGHT (H:V)	CHANNEL DEPTH (FT)	VELOCITY (FT/SEC)	SHEAR STRESS (PSF)	REQUIRED LINING
Apc1	PLATEAU	525	6.0	1.45	3:1	3:1	1.0	2.67	0.35	GRASS/ECB
Apc2	PLATEAU	170	6.0	1.00	3:1	3:1	1.0	1.39	0.125	GRASS/ECB
VC-1	VERTICAL	45	10.0	25.0	10:1	10:1	0.5	6.54	4.21	GRASS/TRM
Ac1	PERIMETER	115	14.0	0.25	4:1	3:1	2.0	1.60	0.175	GRASS/ECB
Ac2	PERIMETER	255	14.0	0.25	4:1	3:1	2.0	1.60	0.175	GRASS/ECB
Bpc1	PLATEAU	675	6.0	1.50	3:1	3:1	1.0	0.39	0.39	GRASS/ECB
Bpc2	PLATEAU	155	6.0	2.40	3:1	3:1	1.0	0.27	0.70	GRASS/ECB
VC-5	VERTICAL	50	10.0	5.00	10:1	10:1	0.5	1.34	1.34	GRASS/TRM
Bc1	PERIMETER	535	14.0	0.25	3:1	4:1	2.0	0.23	0.23	GRASS/ECB
Bc2	PERIMETER	240	14.0	0.25	3:1	4:1	2.0	0.23	0.23	GRASS/ECB
Cpc1	PLATEAU	60	6.0	2.00	3:1	3:1	1.0	0.27	0.27	GRASS/ECB
VC-2	VERTICAL	65	10.0	20.0	10:1	10:1	0.5	2.50	2.50	GRASS/TRM
VC-3	VERTICAL	75	10.0	20.0	10:1	10:1	0.5	2.62	2.62	GRASS/TRM
Cc1	PERIMETER	645	14.0	0.25	3:1	4:1	2.0	0.25	0.25	GRASS/ECB
Cc2	PERIMETER	730	14.0	0.25	3:1	4:1	2.0	0.25	0.25	GRASS/ECB
Cc3	PERIMETER	350	14.0	0.25	3:1	4:1	2.0	0.25	0.25	GRASS/ECB
VC-4	VERTICAL	50	10.0	24.00	10:1	10:1	0.5	3.74	3.74	GRASS/TRM
Dc1	PERIMETER	255	14.0	0.25	4:1	3:1	2.0	0.20	0.20	GRASS/ECB
Dc2	PERIMETER	320	14.0	0.25	4:1	3:1	2.0	0.20	0.20	GRASS/ECB

0 60 120 180
SCALE FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
A	2019-12-18	FOR REVIEW	ZEG	ZEG	XXX	XXX

CLIENT
CONECTIV PROPERTIES AND INVESTMENTS INC.

PROJECT
EDGE MOOR SITE II ASH LANDFILL CLOSURE

CONSULTANT
GOLDER

BRISTOL
10 CANAL STREET, SUITE 217
BRISTOL, PENNSYLVANIA
USA
(215) 826-1560
www.golder.com

TITLE
CONSTRUCTION SITE STORMWATER MANAGEMENT PLAN

PROJECT NO. 19129265
CONTROL SMP001
REV. 0
of
DRAWING SMP01

1 in
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

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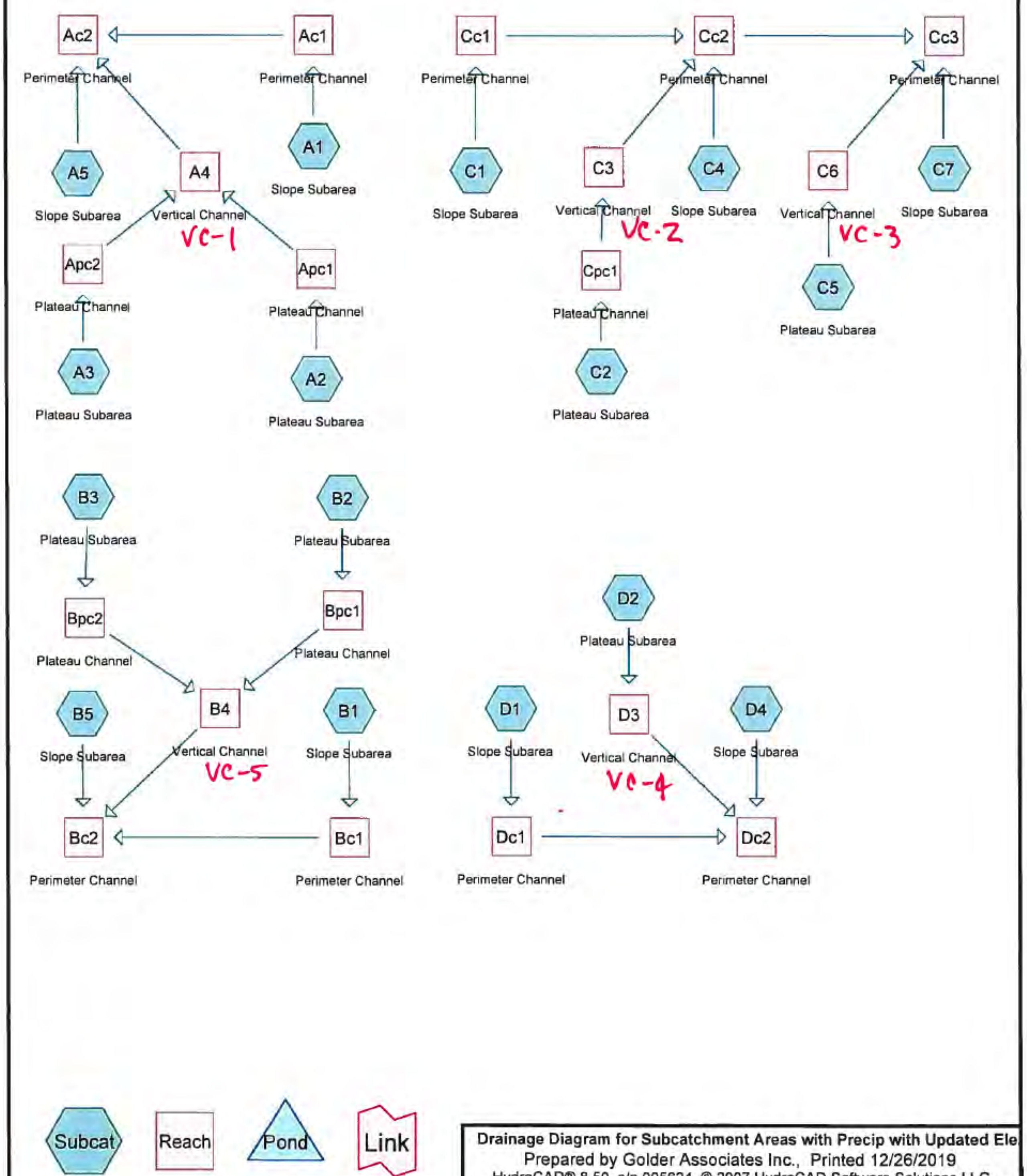


Drainage Diagram for Subcatchment Areas with Precip with Updated Ele
Prepared by Golder Associates Inc., Printed 12/26/2019
HydroCAD® 8.50 s/n 005624 © 2007 HydroCAD Software Solutions LLC

Summary for Subcatchment A1: Slope Subarea

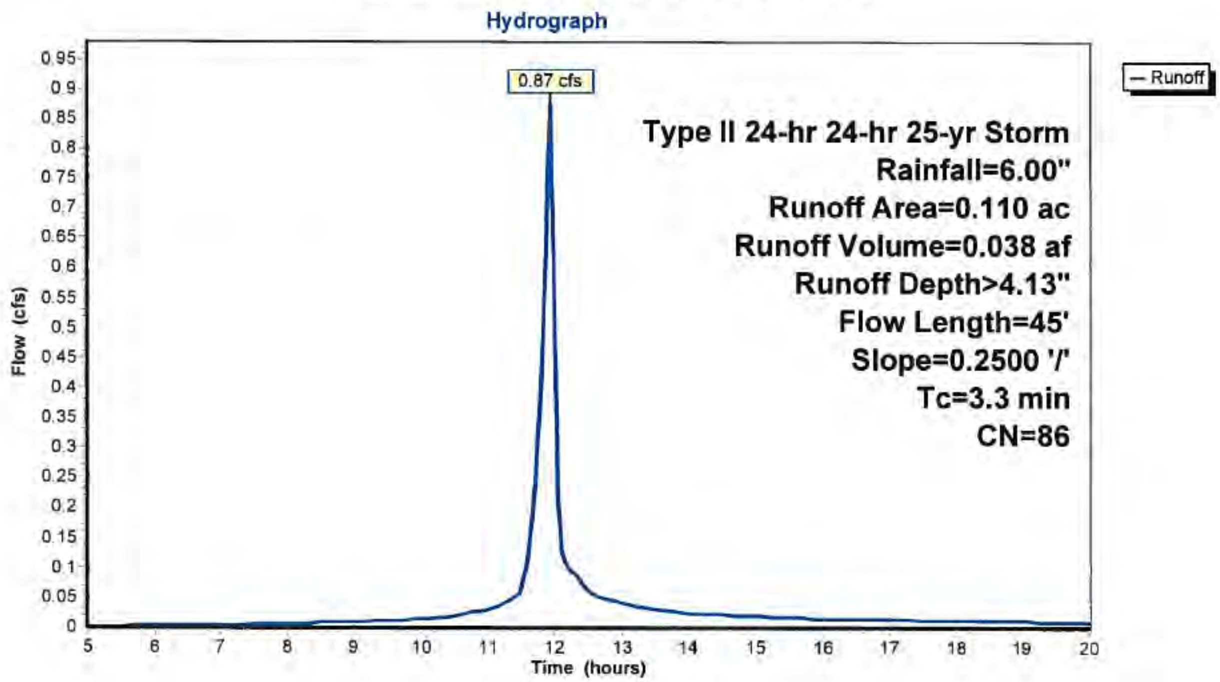
Runoff = 0.87 cfs @ 11.94 hrs, Volume= 0.038 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.110	86	Area and CN are approximate.
	0.110		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.3	45	0.2500	0.23		**Sheet Flow, Steep Slope** n= 0.300 P2= 3.20"

Subcatchment A1: Slope Subarea



Summary for Subcatchment A2: Plateau Subarea

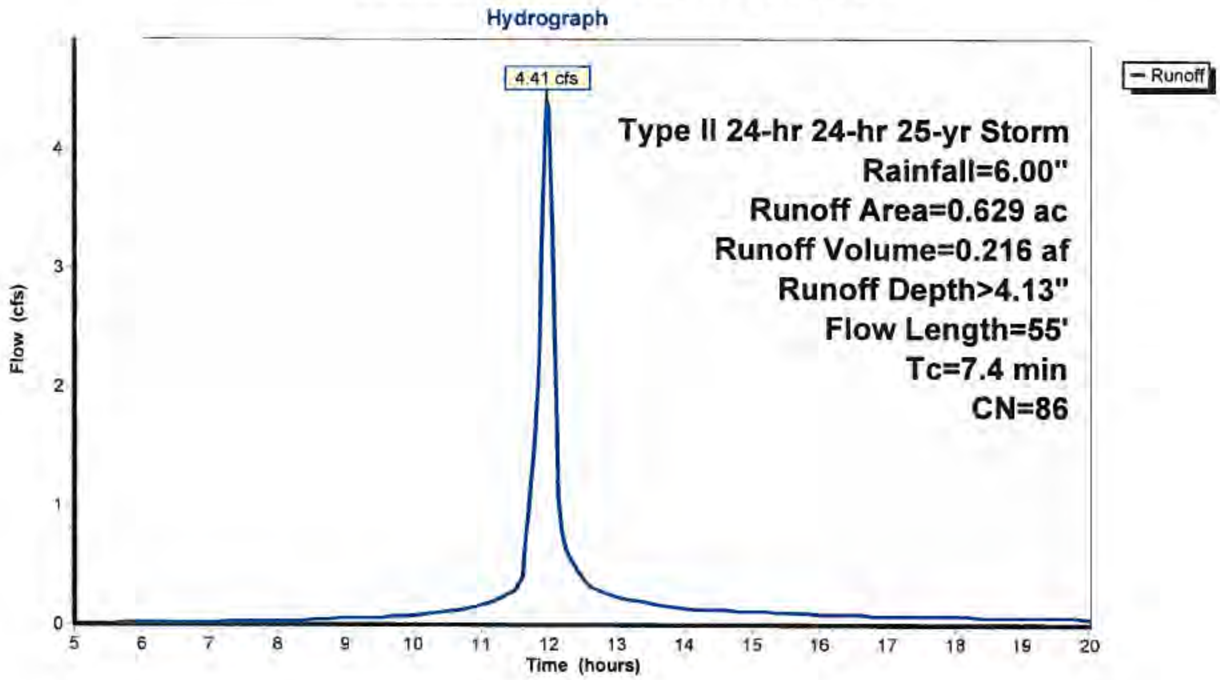
Runoff = 4.41 cfs @ 11.98 hrs, Volume= 0.216 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.629	86	Area and CN are approximate.
	0.629		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	45	0.0450	0.12		**Sheet Flow, Sheet Flow on Shallow Slopes** n= 0.300 P2= 3.20"
0.9	10	0.3300	0.19		**Sheet Flow, Sheet Flow on Steep Slopes** n= 0.300 P2= 3.20"
7.4	55	Total			

Subcatchment A2: Plateau Subarea



Summary for Subcatchment A3: Plateau Subarea

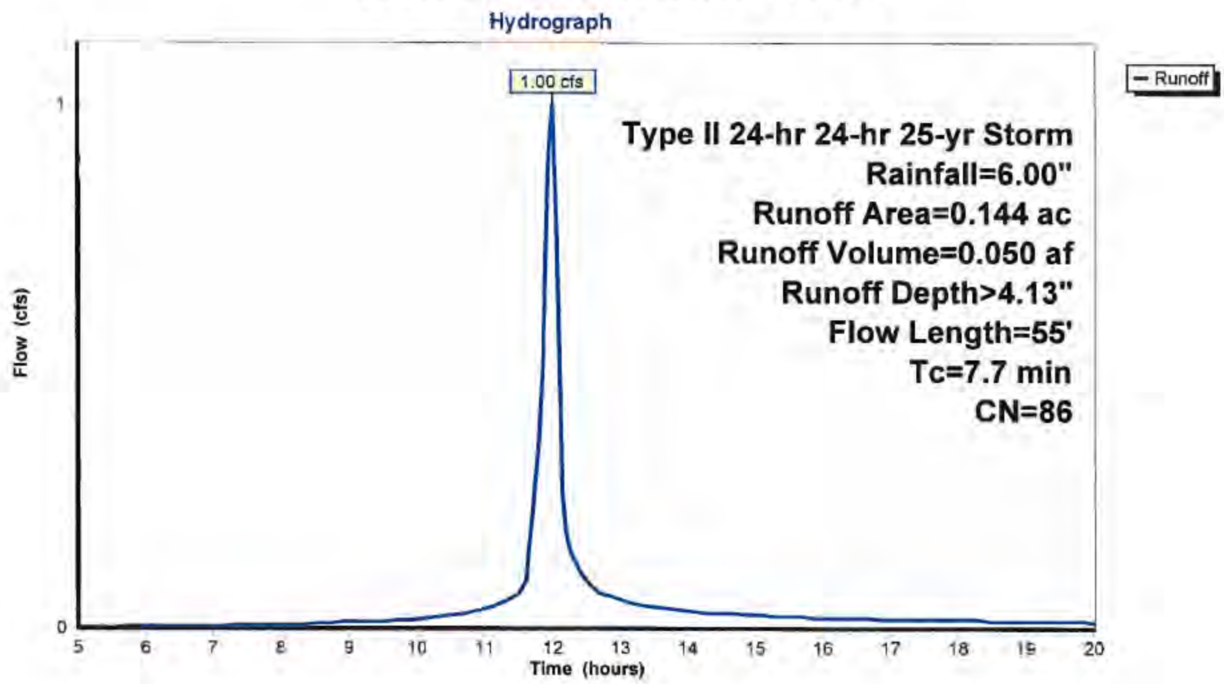
Runoff = 1.00 cfs @ 11.99 hrs, Volume= 0.050 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.144	86	Area and CN are approximate.
	0.144		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.8	45	0.0400	0.11		**Sheet Flow, Sheet Flow on Shallow Slopes** n= 0.300 P2= 3.20"
0.9	10	0.3300	0.19		**Sheet Flow, Sheet Flow on Steep Slopes** n= 0.300 P2= 3.20"
7.7	55	Total			

Subcatchment A3: Plateau Subarea



Summary for Subcatchment A5: Slope Subarea

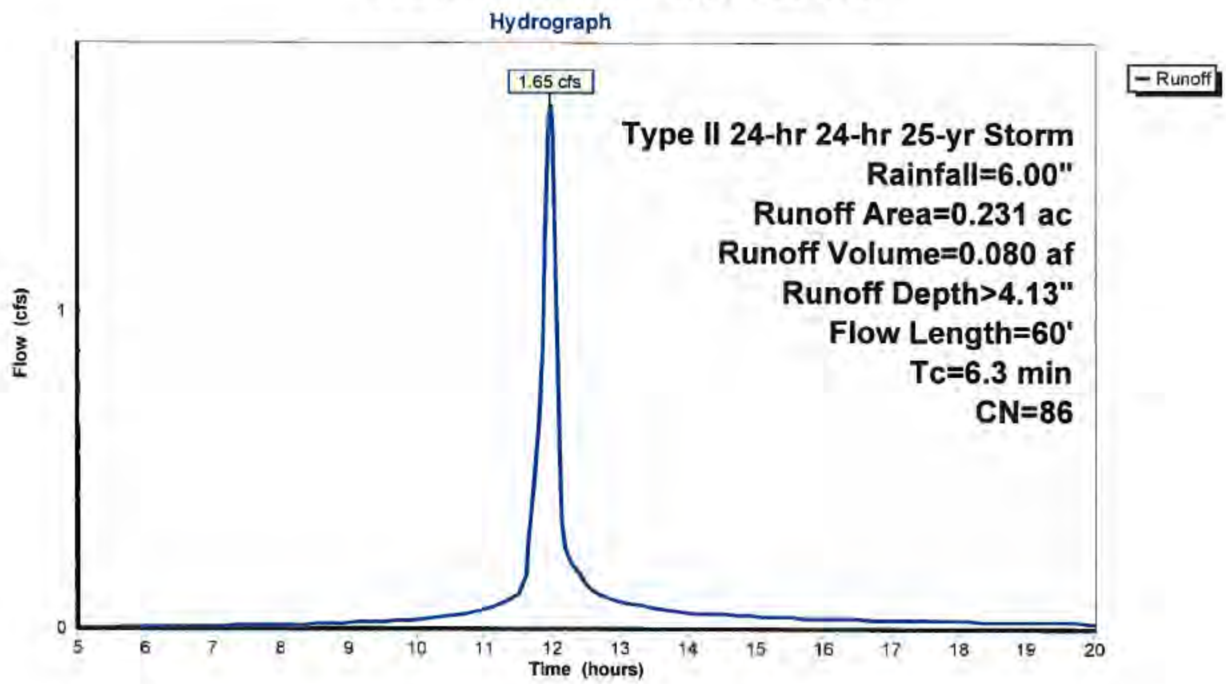
Runoff = 1.65 cfs @ 11.97 hrs, Volume= 0.080 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.231	86	Area and CN are approximate.
	0.231		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.0	40	0.2500	0.22		**Sheet Flow, Steep Slope** n= 0.300 P2= 3.20"
3.3	20	0.0500	0.10		**Sheet Flow, Shallow Slope** n= 0.300 P2= 3.20"
6.3	60	Total			

Subcatchment A5: Slope Subarea



Summary for Subcatchment B1: Slope Subarea

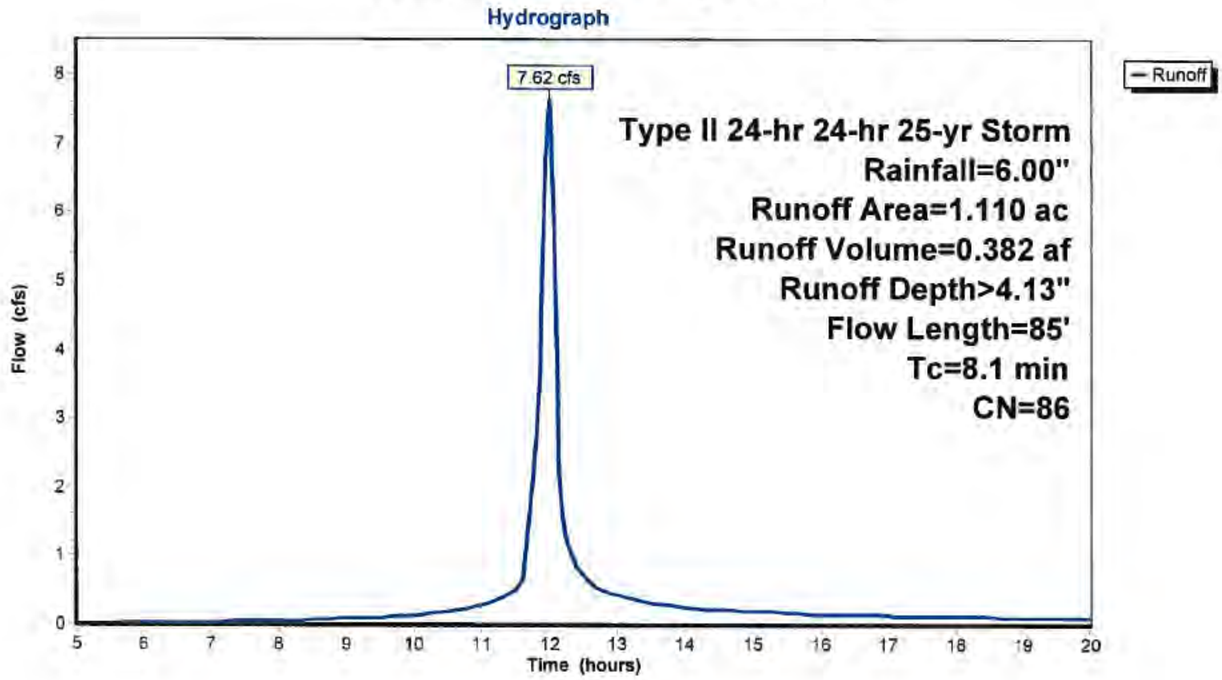
Runoff = 7.62 cfs @ 11.99 hrs, Volume= 0.382 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	1.110	86	Area and CN are approximate.
	1.110		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	70	0.1670	0.21		**Sheet Flow, Steep Slope** n= 0.300 P2= 3.20"
2.6	15	0.0500	0.10		**Sheet Flow, Shallow Slope** n= 0.300 P2= 3.20"
8.1	85	Total			

Subcatchment B1: Slope Subarea



Summary for Subcatchment B2: Plateau Subarea

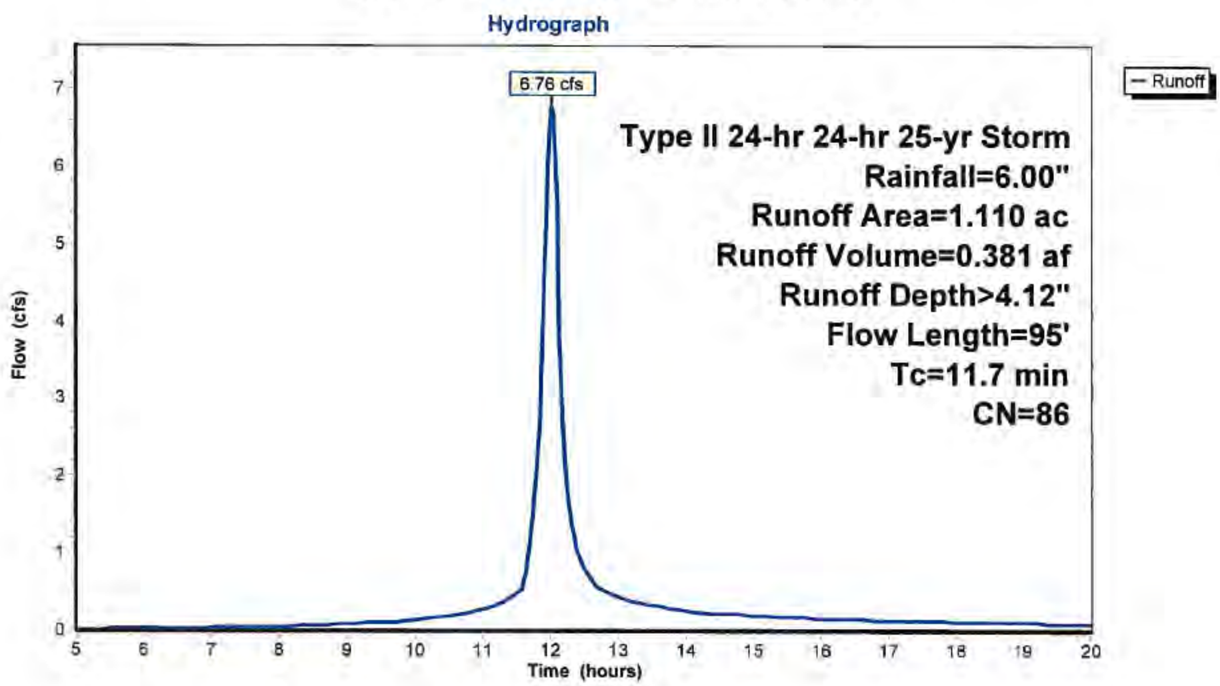
Runoff = 6.76 cfs @ 12.03 hrs, Volume= 0.381 af, Depth> 4.12"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	1.110	86	Area and CN are approximate.
	1.110		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.8	85	0.0450	0.13		**Sheet Flow, Sheet Flow on Shallow Slopes** n= 0.300 P2= 3.20"
0.9	10	0.3300	0.19		**Sheet Flow, Sheet Flow on Steep Slopes** n= 0.300 P2= 3.20"
11.7	95	Total			

Subcatchment B2: Plateau Subarea



Summary for Subcatchment B3: Plateau Subarea

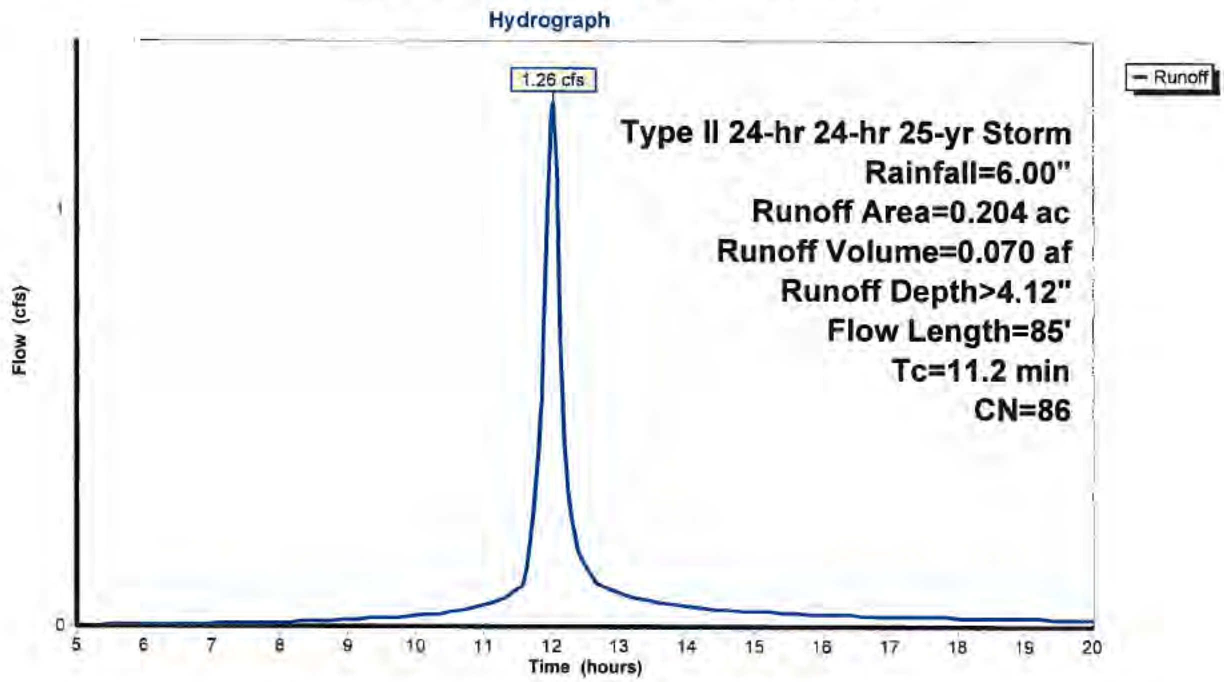
Runoff = 1.26 cfs @ 12.02 hrs, Volume= 0.070 af, Depth> 4.12"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.204	86	Area and CN are approximate.
	0.204		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.3	75	0.0400	0.12		**Sheet Flow, Sheet Flow on Shallow Slopes** n= 0.300 P2= 3.20"
0.9	10	0.3300	0.19		**Sheet Flow, Sheet Flow on Steep Slopes** n= 0.300 P2= 3.20"
11.2	85	Total			

Subcatchment B3: Plateau Subarea



Summary for Subcatchment B5: Slope Subarea

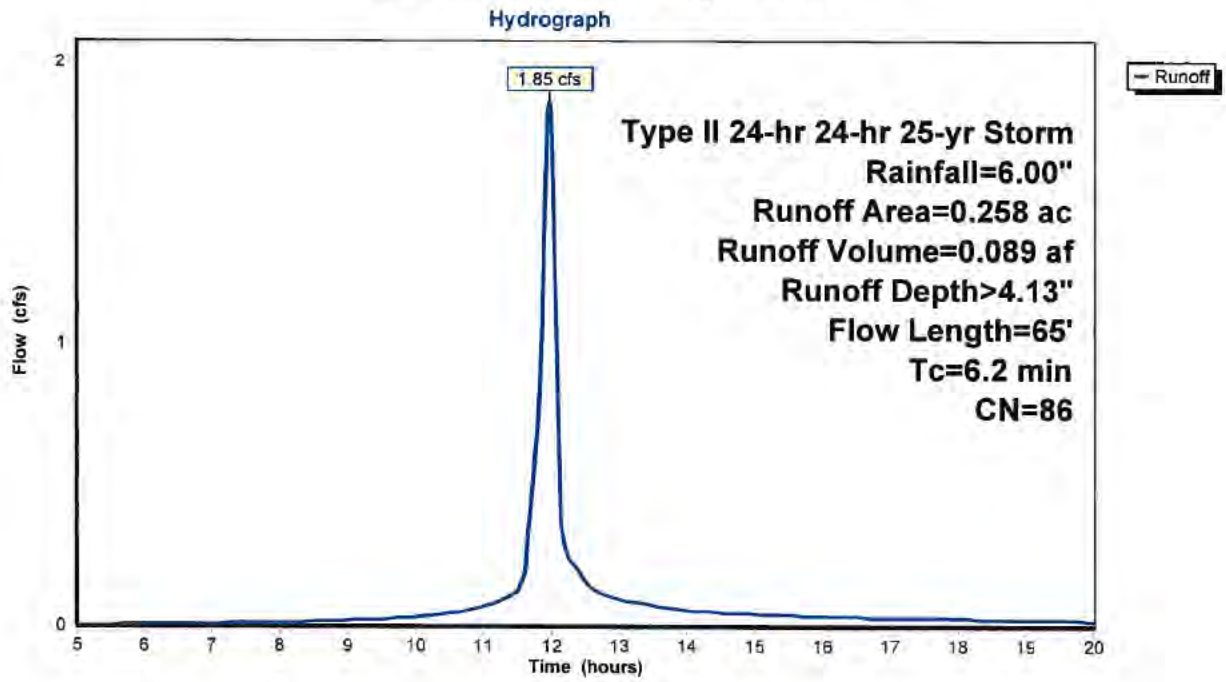
Runoff = 1.85 cfs @ 11.97 hrs, Volume= 0.089 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.258	86	Area and CN are approximate.
	0.258		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.6	50	0.2500	0.23		**Sheet Flow, Steep Slope** n= 0.300 P2= 3.20"
2.6	15	0.0500	0.10		**Sheet Flow, Shallow Slope** n= 0.300 P2= 3.20"
6.2	65	Total			

Subcatchment B5: Slope Subarea



Summary for Subcatchment C1: Slope Subarea

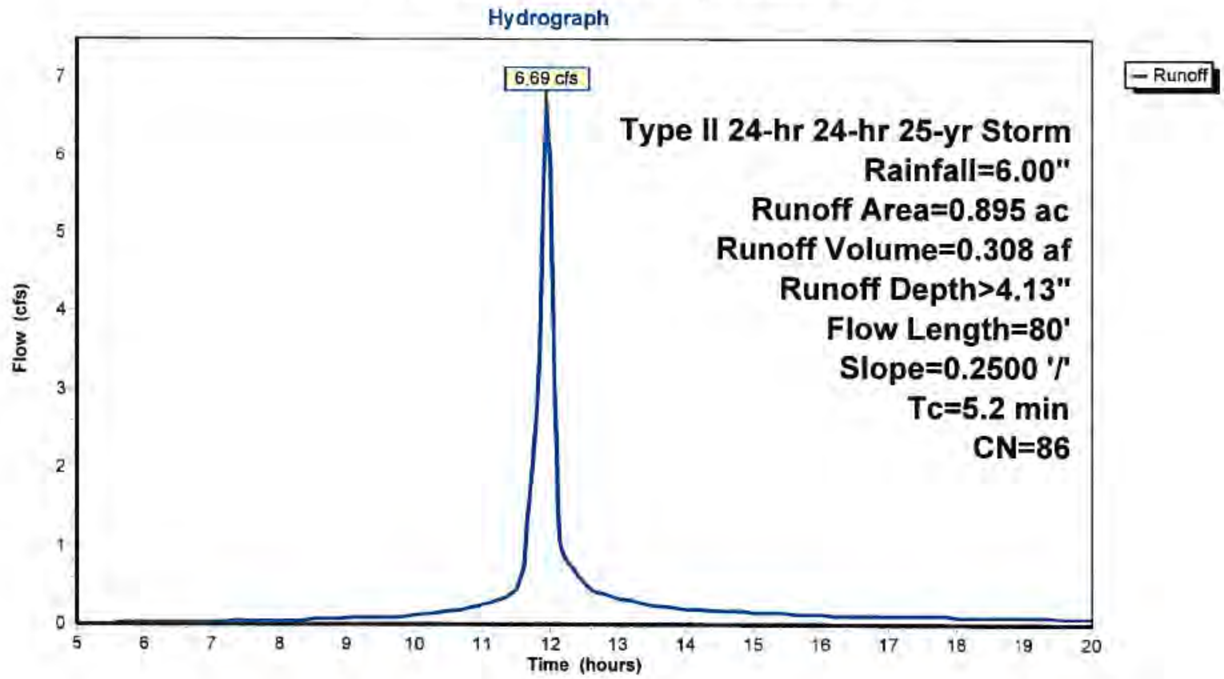
Runoff = 6.69 cfs @ 11.96 hrs, Volume= 0.308 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.895	86	Area and CN are approximate.
	0.895		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	80	0.2500	0.26		**Sheet Flow, Steep Slope** n= 0.300 P2= 3.20"

Subcatchment C1: Slope Subarea



Summary for Subcatchment C2: Plateau Subarea

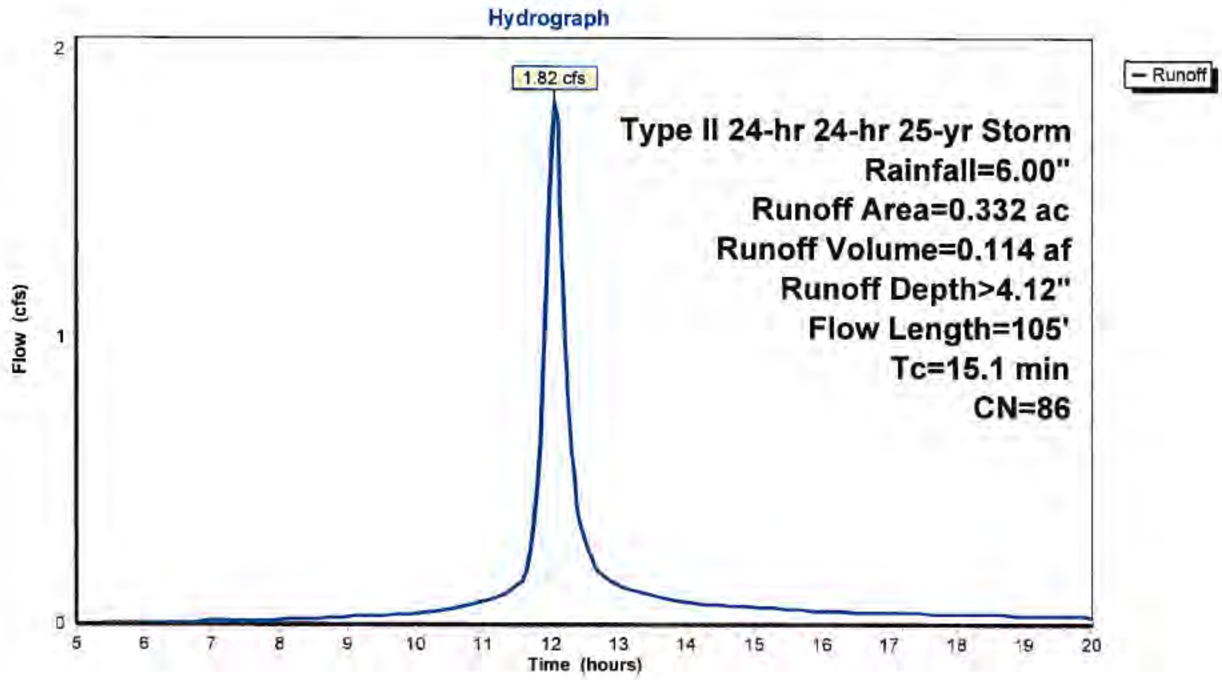
Runoff = 1.82 cfs @ 12.07 hrs, Volume= 0.114 af, Depth> 4.12"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.332	86	Area and CN are approximate.
	0.332		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.0	55	0.0400	0.11		**Sheet Flow, Sheet Flow on Shallow Slopes** n= 0.300 P2= 3.20"
0.9	10	0.3300	0.19		**Sheet Flow, Sheet Flow on Steep Slopes** n= 0.300 P2= 3.20"
6.2	40	0.0400	0.11		**Sheet Flow, Sheet Flow on Shallow Slopes** n= 0.300 P2= 3.20"
15.1	105	Total			

Subcatchment C2: Plateau Subarea



Summary for Subcatchment C4: Slope Subarea

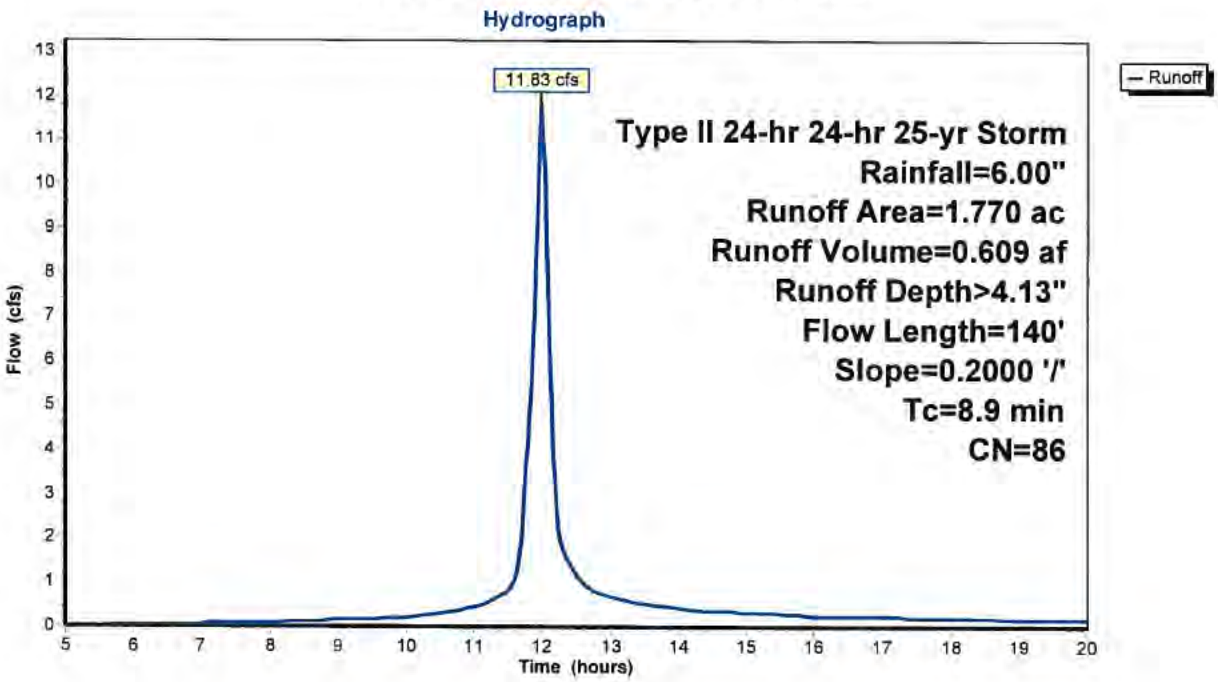
Runoff = 11.83 cfs @ 12.00 hrs, Volume= 0.609 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	1.770	86	Area and CN are approximate.
	1.770		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.9	140	0.2000	0.26		**Sheet Flow, Steep Slope** n= 0.300 P2= 3.20"

Subcatchment C4: Slope Subarea



Summary for Subcatchment C5: Plateau Subarea

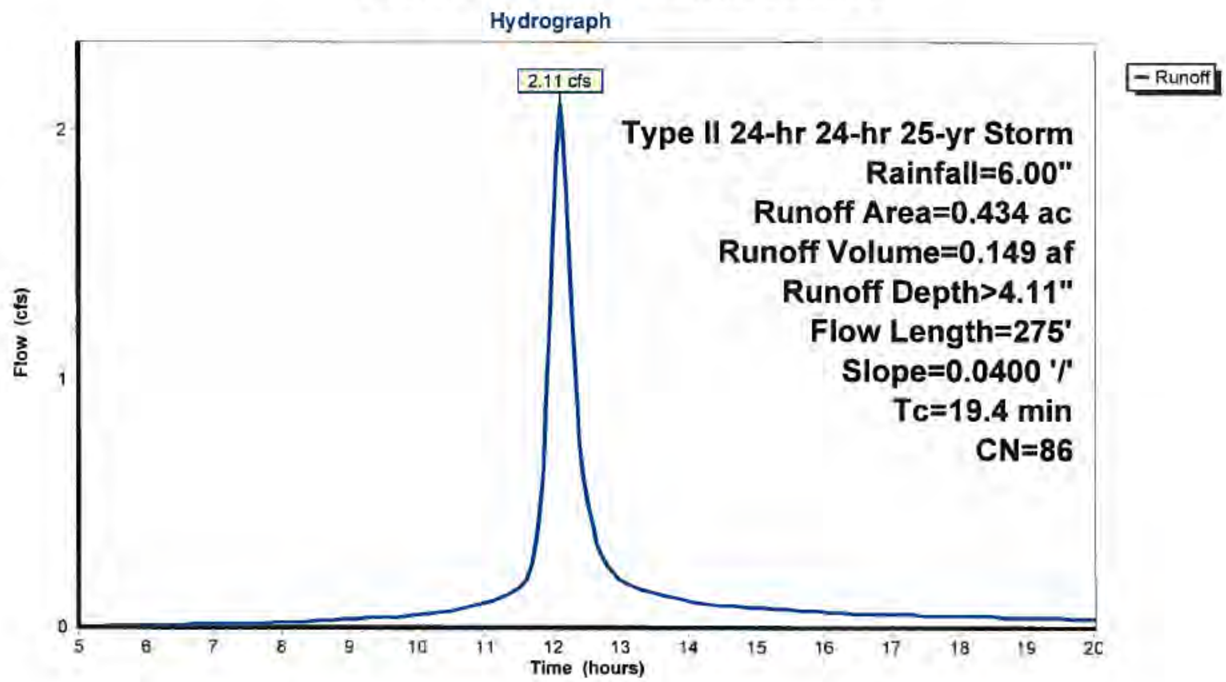
Runoff = 2.11 cfs @ 12.11 hrs, Volume= 0.149 af, Depth> 4.11"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.434	86	Area and CN are approximate.
	0.434		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
17.9	150	0.0400	0.14		**Sheet Flow, Sheet Flow for 150'** n= 0.300 P2= 3.20"
1.5	125	0.0400	1.40		**Shallow Concentrated Flow, Sheet Flow after 150'** Short Grass Pasture Kv= 7.0 fps
19.4	275	Total			

Subcatchment C5: Plateau Subarea



Summary for Subcatchment C7: Slope Subarea

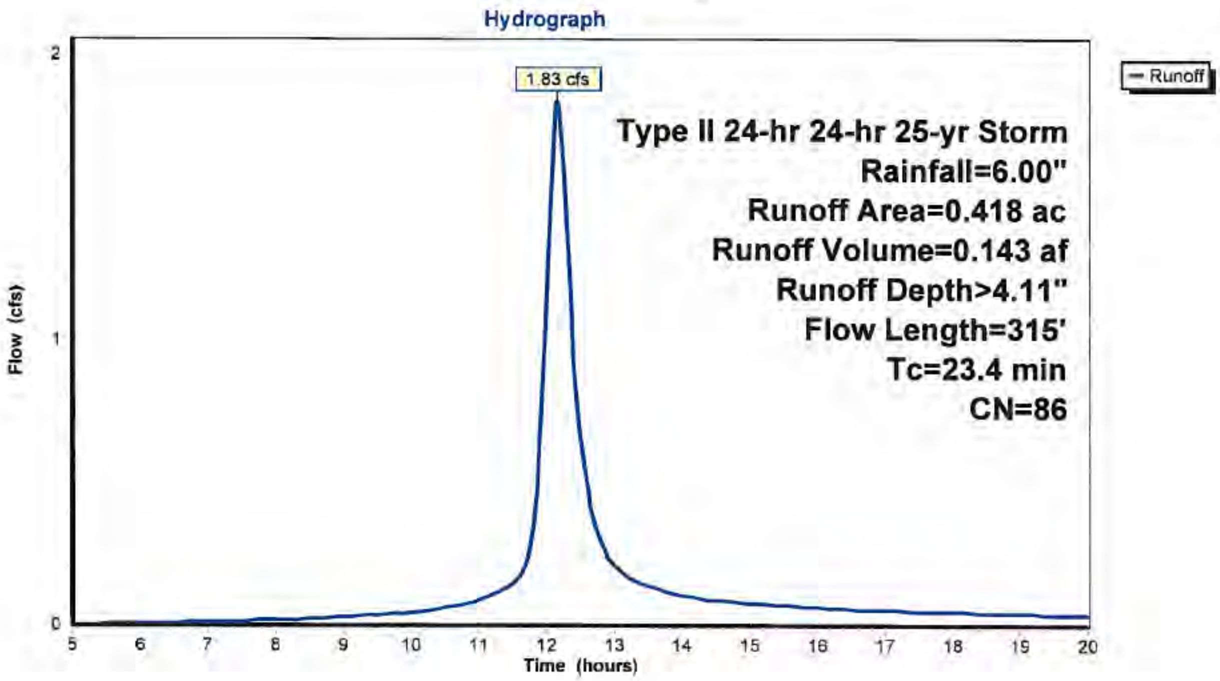
Runoff = 1.83 cfs @ 12.16 hrs, Volume= 0.143 af, Depth> 4.11"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.418	86	Area and CN are approximate.
	0.418		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.2	55	0.2000	0.22		**Sheet Flow, Steep Slopes** n= 0.300 P2= 3.20"
16.4	95	0.0200	0.10		**Sheet Flow, Shallow Slopes before 150'** n= 0.300 P2= 3.20"
2.8	165	0.0200	0.99		**Shallow Concentrated Flow, Shallow Slopes after 150'** Short Grass Pasture Kv= 7.0 fps
23.4	315	Total			

Subcatchment C7: Slope Subarea



Summary for Subcatchment D1: Slope Subarea

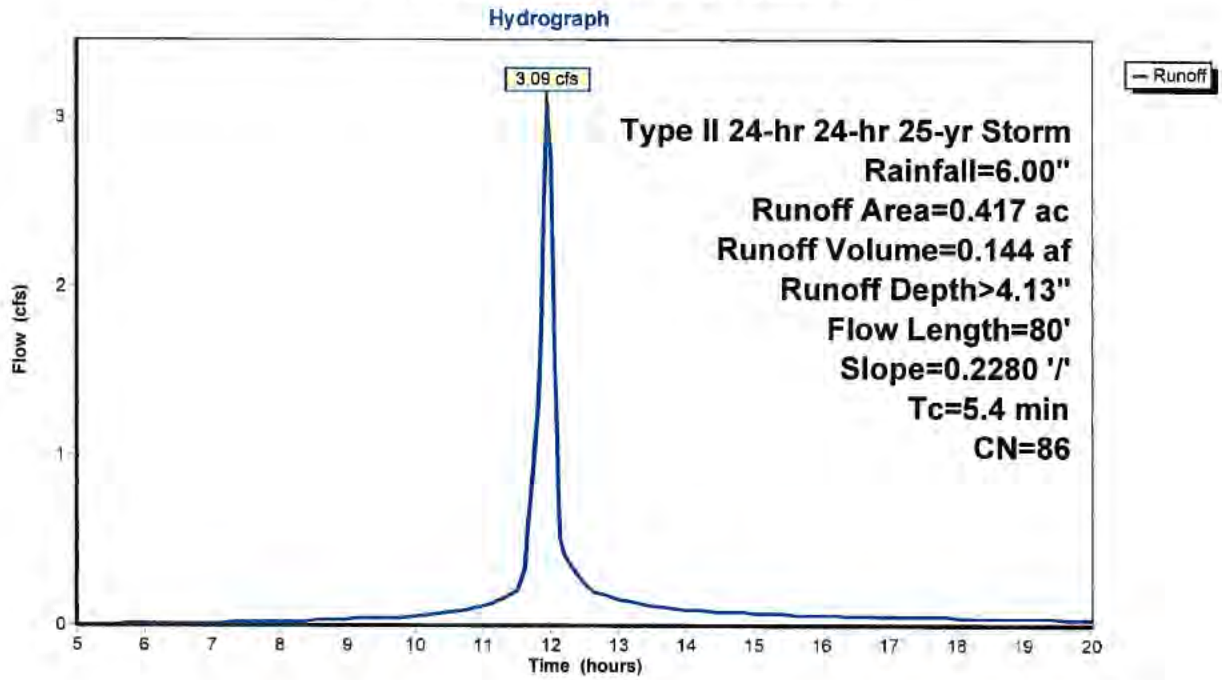
Runoff = 3.09 cfs @ 11.96 hrs, Volume= 0.144 af, Depth> 4.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.417	86	Area and CN are approximate.
	0.417		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	80	0.2280	0.25		**Sheet Flow, Steep Slope** n= 0.300 P2= 3.20"

Subcatchment D1: Slope Subarea



Summary for Subcatchment D2: Plateau Subarea

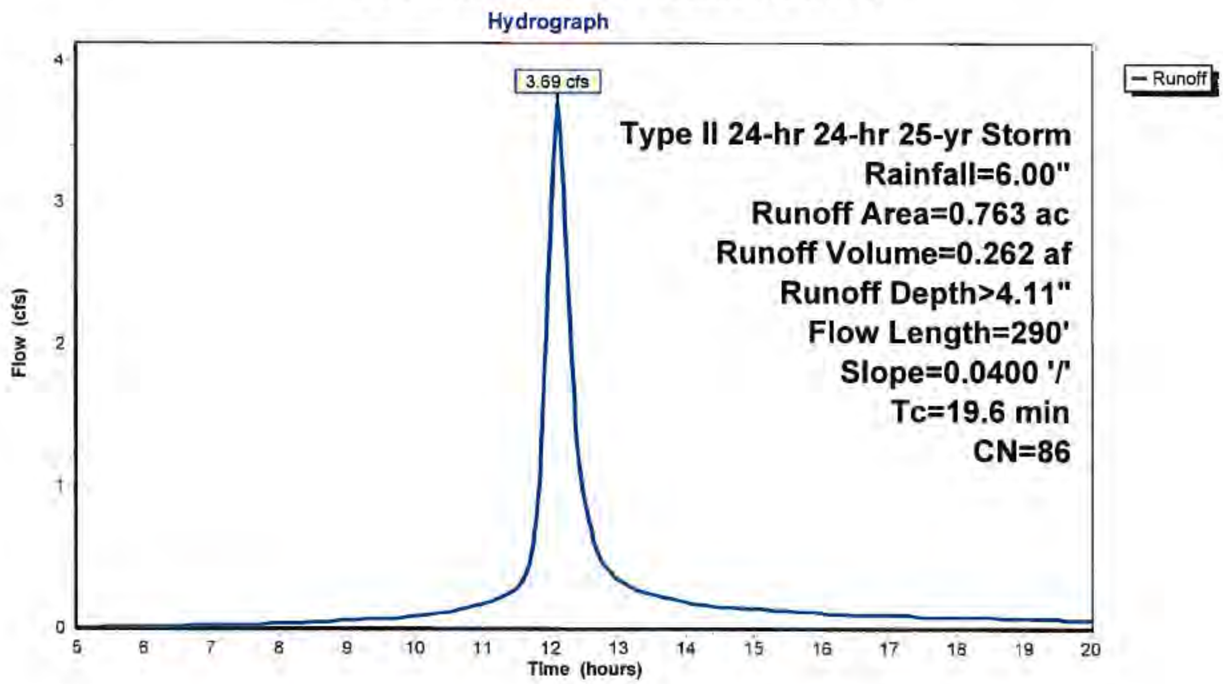
Runoff = 3.69 cfs @ 12.12 hrs, Volume= 0.262 af, Depth> 4.11"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.763	86	Area and CN are approximate.
	0.763		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
17.9	150	0.0400	0.14		**Sheet Flow, Shallow Slopes** n= 0.300 P2= 3.20"
1.7	140	0.0400	1.40		**Shallow Concentrated Flow, Access Road on Landfill Plateau** Short Grass Pasture Kv= 7.0 fps
19.6	290	Total			

Subcatchment D2: Plateau Subarea



Summary for Subcatchment D4: Slope Subarea

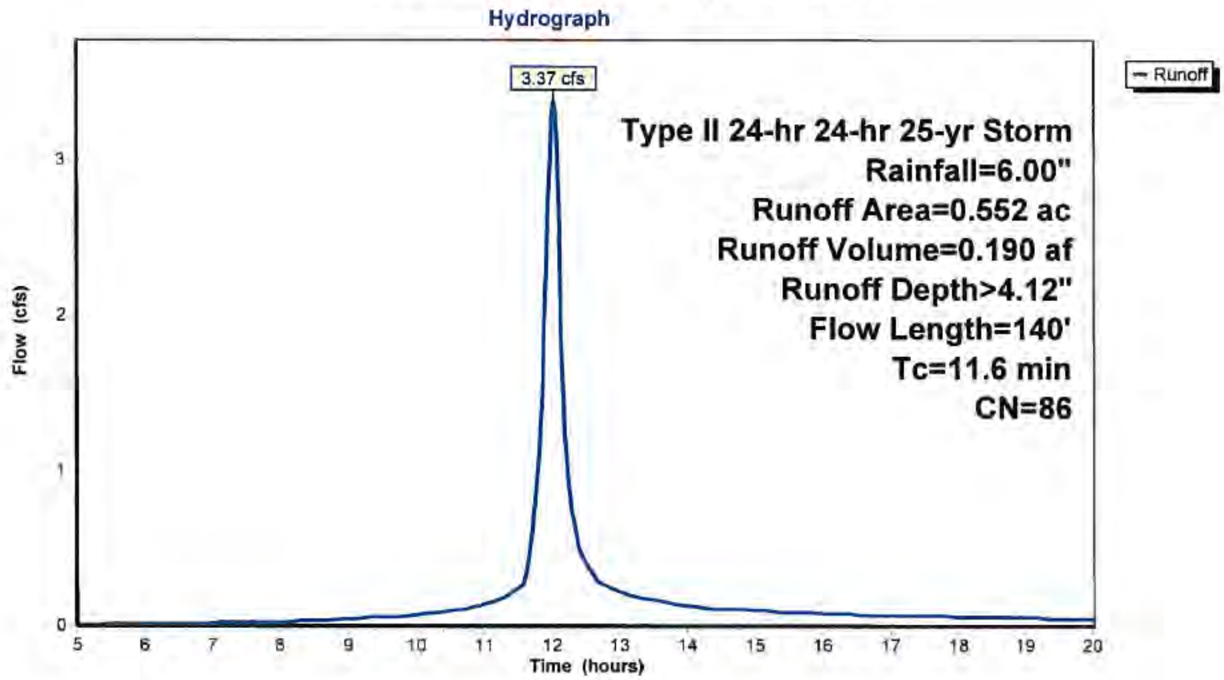
Runoff = 3.37 cfs @ 12.03 hrs, Volume= 0.190 af, Depth> 4.12"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 24-hr 25-yr Storm Rainfall=6.00"

	Area (ac)	CN	Description
*	0.552	86	Area and CN are approximate.
	0.552		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	110	0.1822	0.24		**Sheet Flow, Steep Slope** n= 0.300 P2= 3.20"
4.0	30	0.0693	0.13		**Sheet Flow, Shallow Slope** n= 0.300 P2= 3.20"
11.6	140	Total			

Subcatchment D4: Slope Subarea



Summary for Reach A4: Vertical Channel 1

Inflow Area =	0.773 ac,	0.00% Impervious, Inflow Depth > 4.11"	for 24-hr 25-yr Storm event
Inflow =	4.88 cfs @	12.06 hrs, Volume=	0.264 af
Outflow =	4.86 cfs @	12.07 hrs, Volume=	0.264 af, Atten= 1%, Lag= 0.2 min

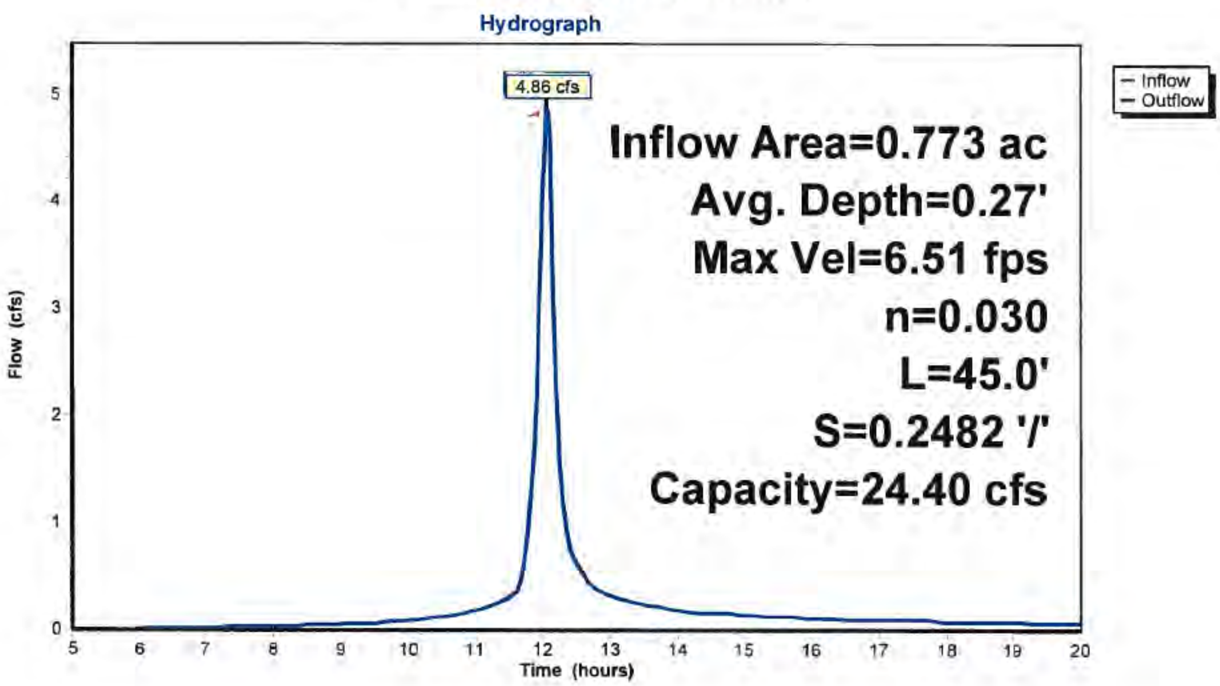
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 6.51 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 2.47 fps, Avg. Travel Time= 0.3 min

Peak Storage= 34 cf @ 12.07 hrs, Average Depth at Peak Storage= 0.27'
Bank-Full Depth= 0.50', Capacity at Bank-Full= 24.40 cfs

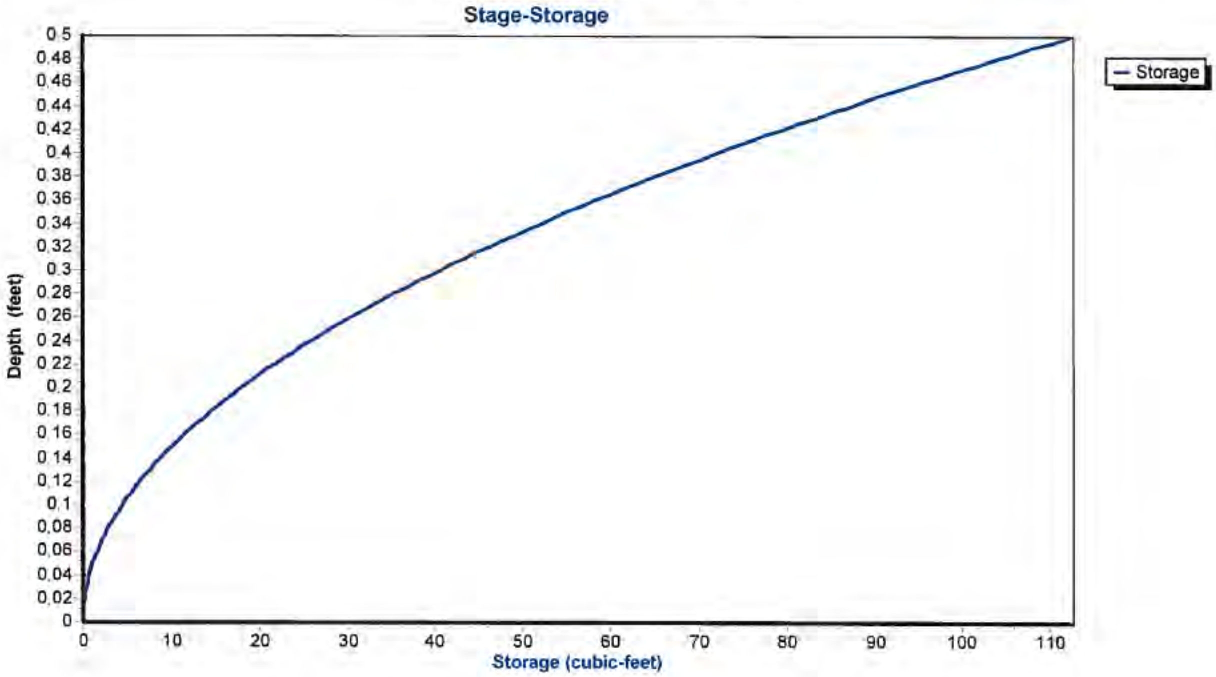
0.00' x 0.50' deep channel, n= 0.030
Side Slope Z-value= 10.0 '/' Top Width= 10.00'
Length= 45.0' Slope= 0.2482 '/'
Inlet Invert= 22.22', Outlet Invert= 11.05'

‡

Reach A4: Vertical Channel



Reach A4: Vertical Channel



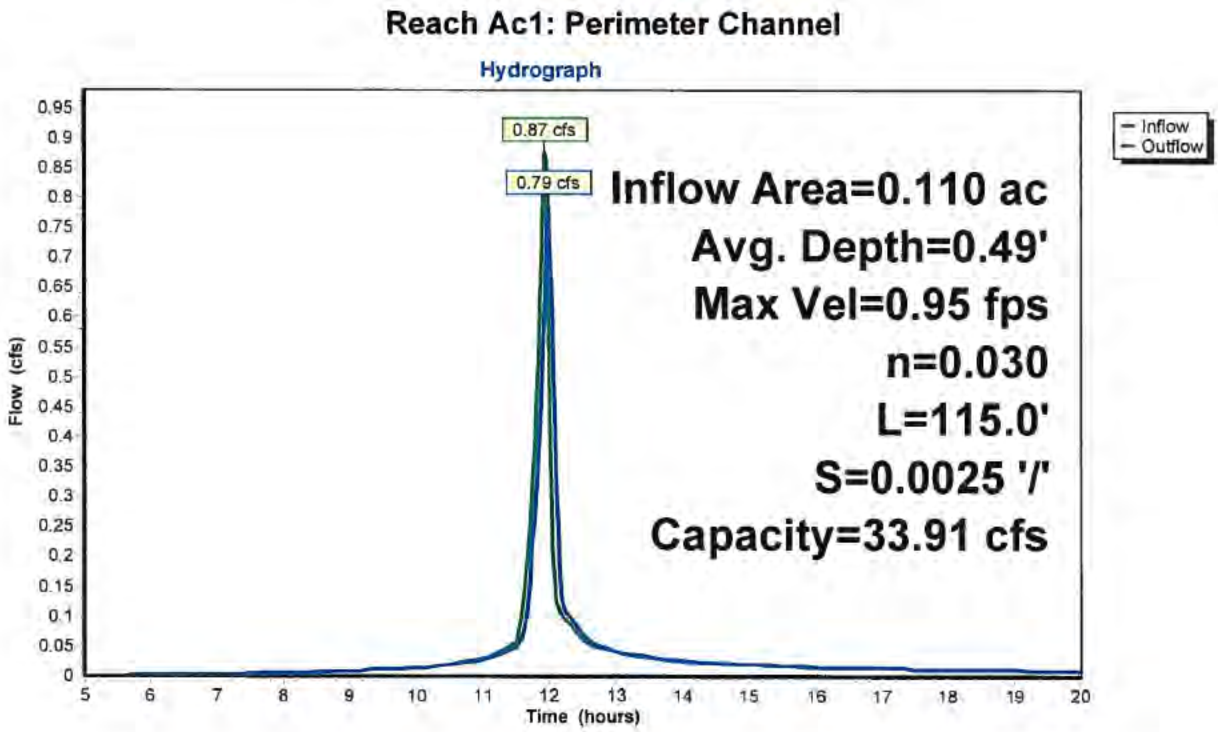
Summary for Reach Ac1: Perimeter Channel

Inflow Area =	0.110 ac,	0.00% Impervious, Inflow Depth > 4.13"	for 24-hr 25-yr Storm event	
Inflow =	0.87 cfs @	11.94 hrs, Volume=	0.038 af	
Outflow =	0.79 cfs @	11.99 hrs, Volume=	0.038 af, Atten= 10%, Lag= 3.2 min	

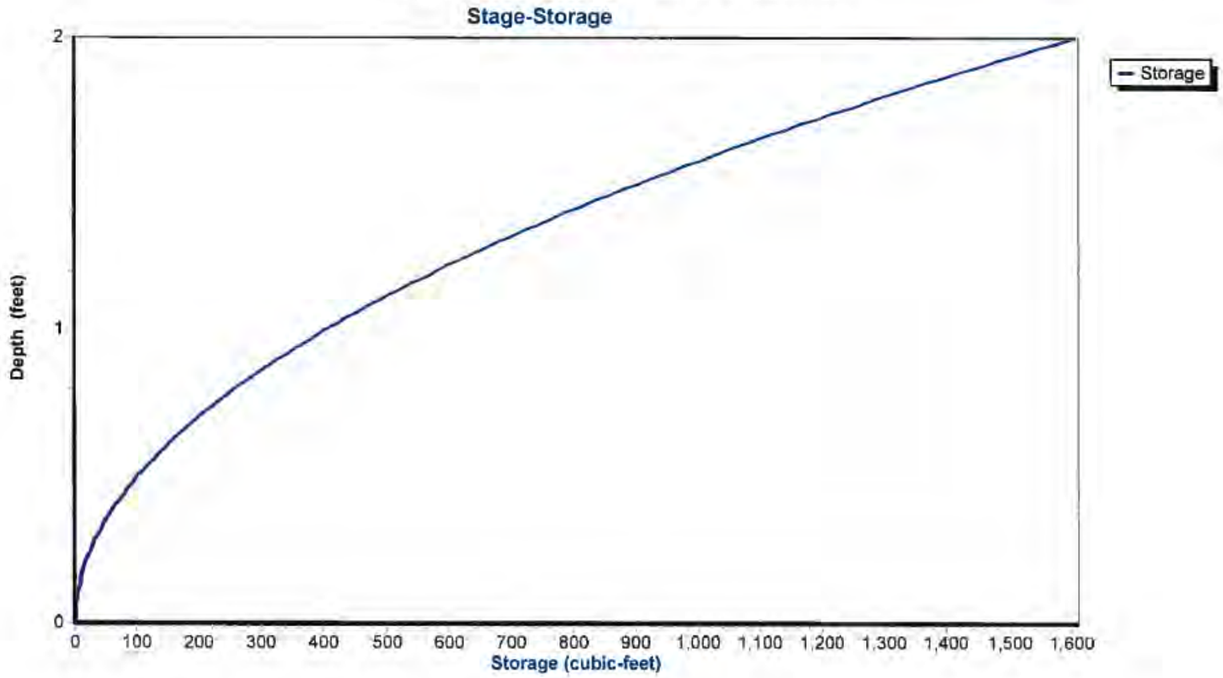
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.95 fps, Min. Travel Time= 2.0 min
Avg. Velocity = 0.35 fps, Avg. Travel Time= 5.5 min

Peak Storage= 98 cf @ 11.95 hrs, Average Depth at Peak Storage= 0.49'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.91 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 4.0 3.0 '/' Top Width= 14.00'
Length= 115.0' Slope= 0.0025 '/'
Inlet Invert= 11.34', Outlet Invert= 11.05'



Reach Ac1: Perimeter Channel



Summary for Reach Ac2: Perimeter Channel

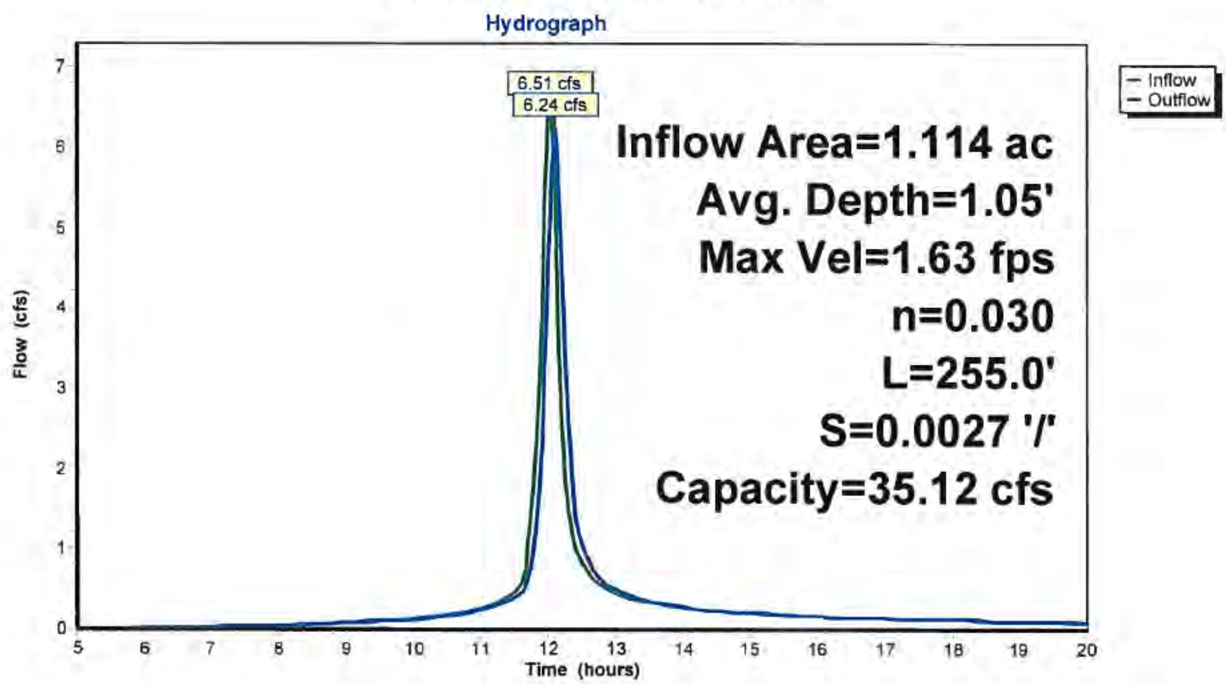
Inflow Area =	1.114 ac,	0.00% Impervious, Inflow Depth > 4.11"	for 24-hr 25-yr Storm event	
Inflow =	6.51 cfs @	12.03 hrs, Volume=	0.382 af	
Outflow =	6.24 cfs @	12.11 hrs, Volume=	0.380 af,	Atten= 4%, Lag= 4.6 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.63 fps, Min. Travel Time= 2.6 min
Avg. Velocity = 0.63 fps, Avg. Travel Time= 6.7 min

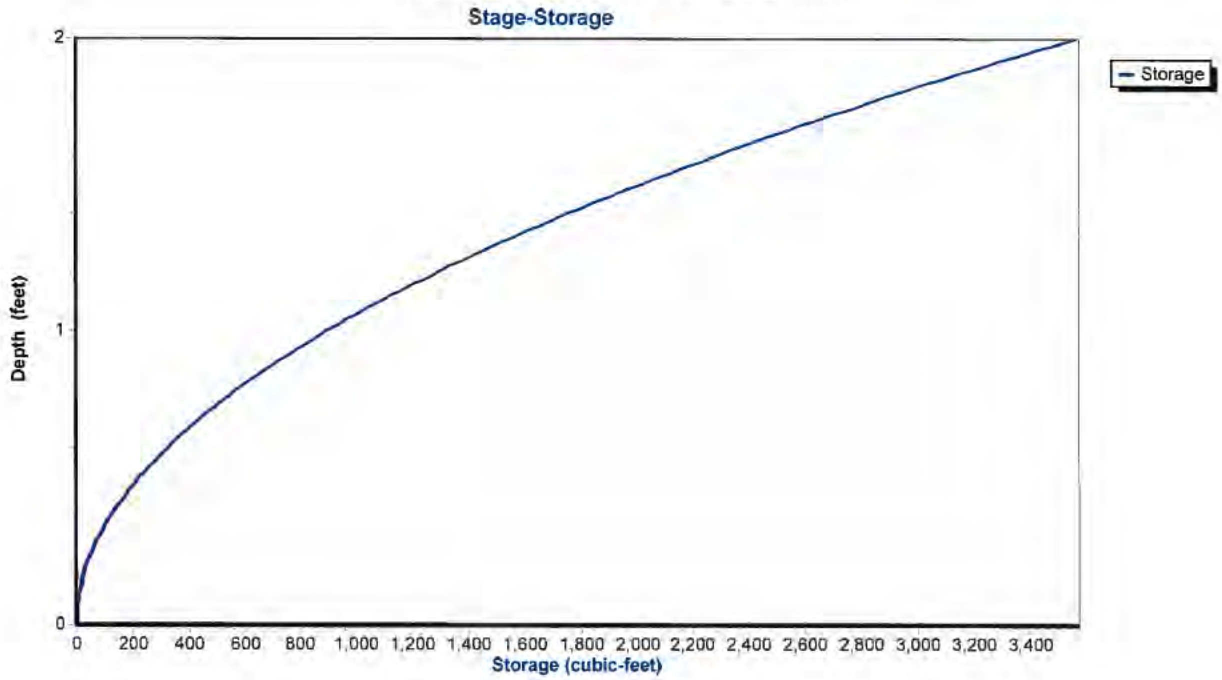
Peak Storage= 983 cf @ 12.06 hrs, Average Depth at Peak Storage= 1.05'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 35.12 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 4.0 3.0 '/' Top Width= 14.00'
Length= 255.0' Slope= 0.0027 '/'
Inlet Invert= 11.05', Outlet Invert= 10.36'

Reach Ac2: Perimeter Channel



Reach Ac2: Perimeter Channel



Summary for Reach Apc1: Plateau Channel

Inflow Area =	0.629 ac,	0.00% Impervious, Inflow Depth > 4.13"	for 24-hr 25-yr Storm event
Inflow =	4.41 cfs @	11.98 hrs, Volume=	0.216 af
Outflow =	3.99 cfs @	12.07 hrs, Volume=	0.215 af, Atten= 10%, Lag= 5.3 min

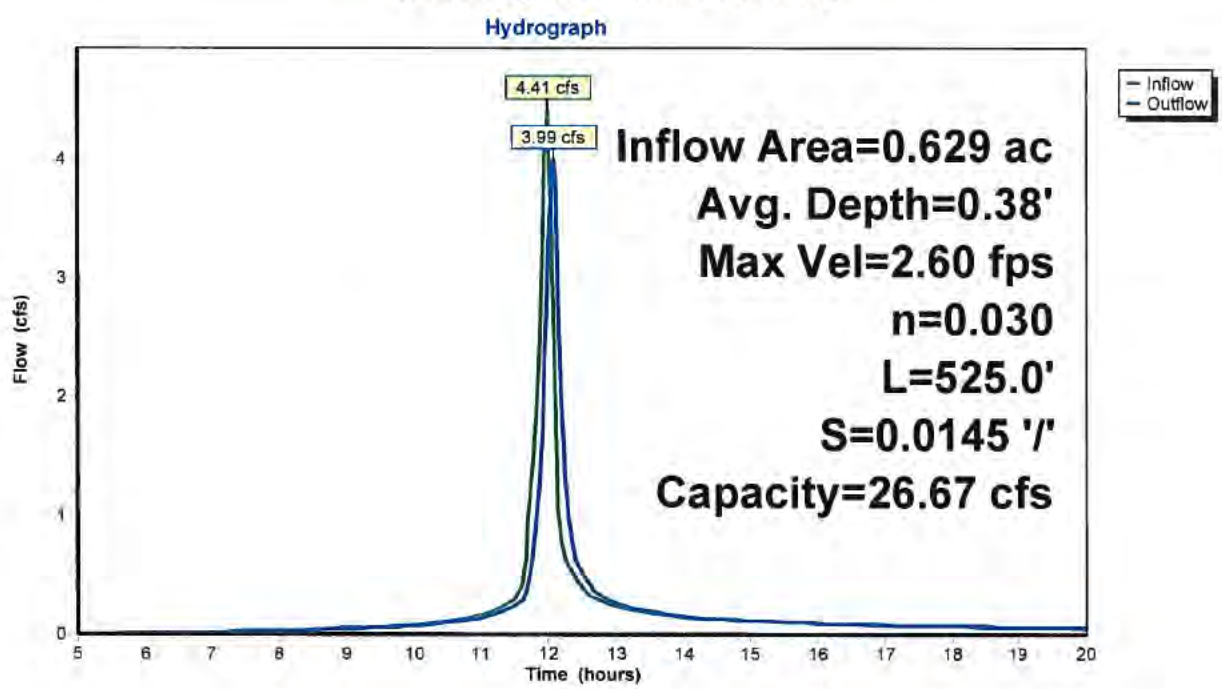
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.60 fps, Min. Travel Time= 3.4 min
Avg. Velocity = 0.70 fps, Avg. Travel Time= 12.5 min

Peak Storage= 815 cf @ 12.02 hrs, Average Depth at Peak Storage= 0.38'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 26.67 cfs

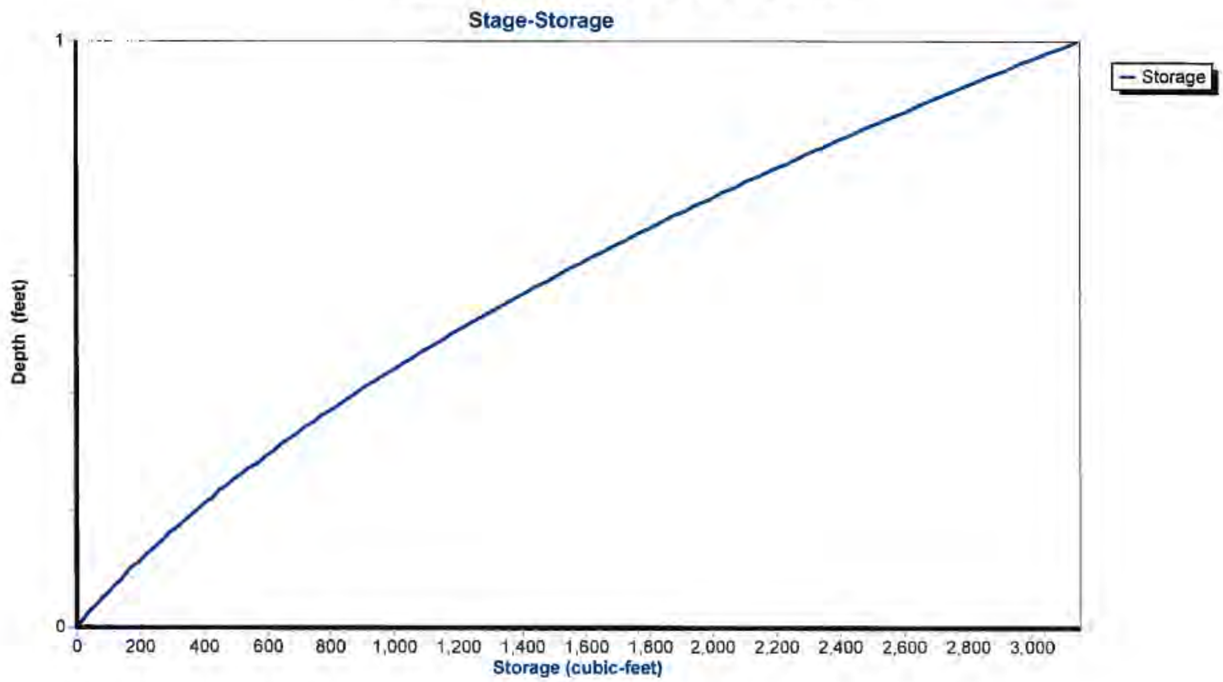
3.00' x 1.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 '/' Top Width= 9.00'
Length= 525.0' Slope= 0.0145 '/'
Inlet Invert= 29.83', Outlet Invert= 22.22'

‡

Reach Apc1: Plateau Channel



Reach Apc1: Plateau Channel



Summary for Reach Apc2: Plateau Channel

Inflow Area = 0.144 ac, 0.00% Impervious, Inflow Depth > 4.13" for 24-hr 25-yr Storm event
Inflow = 1.00 cfs @ 11.99 hrs, Volume= 0.050 af
Outflow = 0.94 cfs @ 12.04 hrs, Volume= 0.049 af, Atten= 6%, Lag= 3.1 min

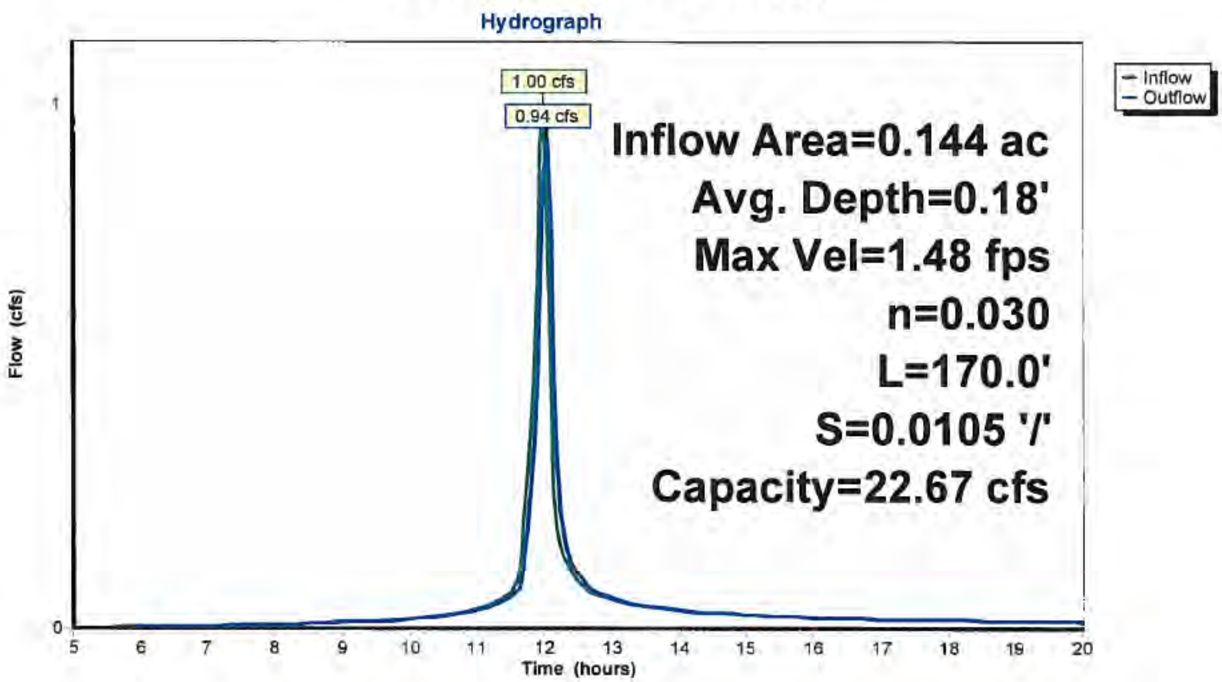
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.48 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 0.38 fps, Avg. Travel Time= 7.5 min

Peak Storage= 111 cf @ 12.01 hrs, Average Depth at Peak Storage= 0.18'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 22.67 cfs

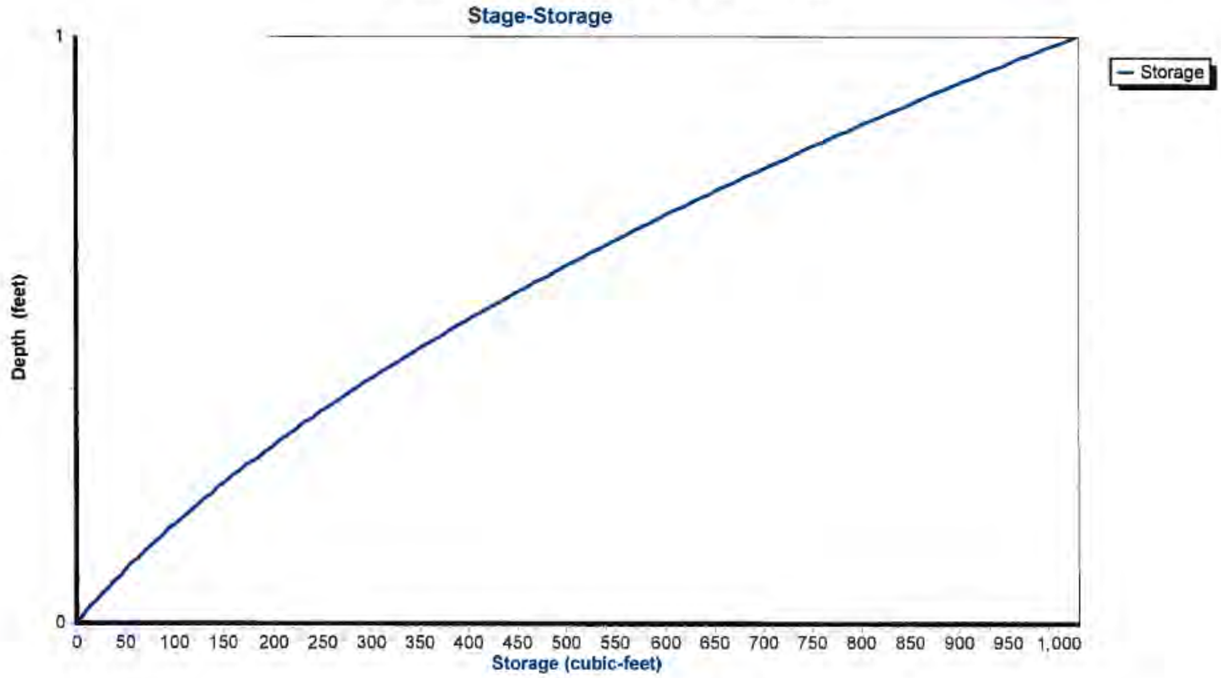
3.00' x 1.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 '/' Top Width= 9.00'
Length= 170.0' Slope= 0.0105 '/'
Inlet Invert= 24.00', Outlet Invert= 22.22'

‡

Reach Apc2: Plateau Channel



Reach Apc2: Plateau Channel



Summary for Reach B4: Vertical Channel 5

Inflow Area = 1.314 ac, 0.00% Impervious, Inflow Depth > 4.10" for 24-hr 25-yr Storm event
Inflow = 7.20 cfs @ 12.12 hrs, Volume= 0.449 af
Outflow = 7.17 cfs @ 12.12 hrs, Volume= 0.449 af, Atten= 0%, Lag= 0.2 min

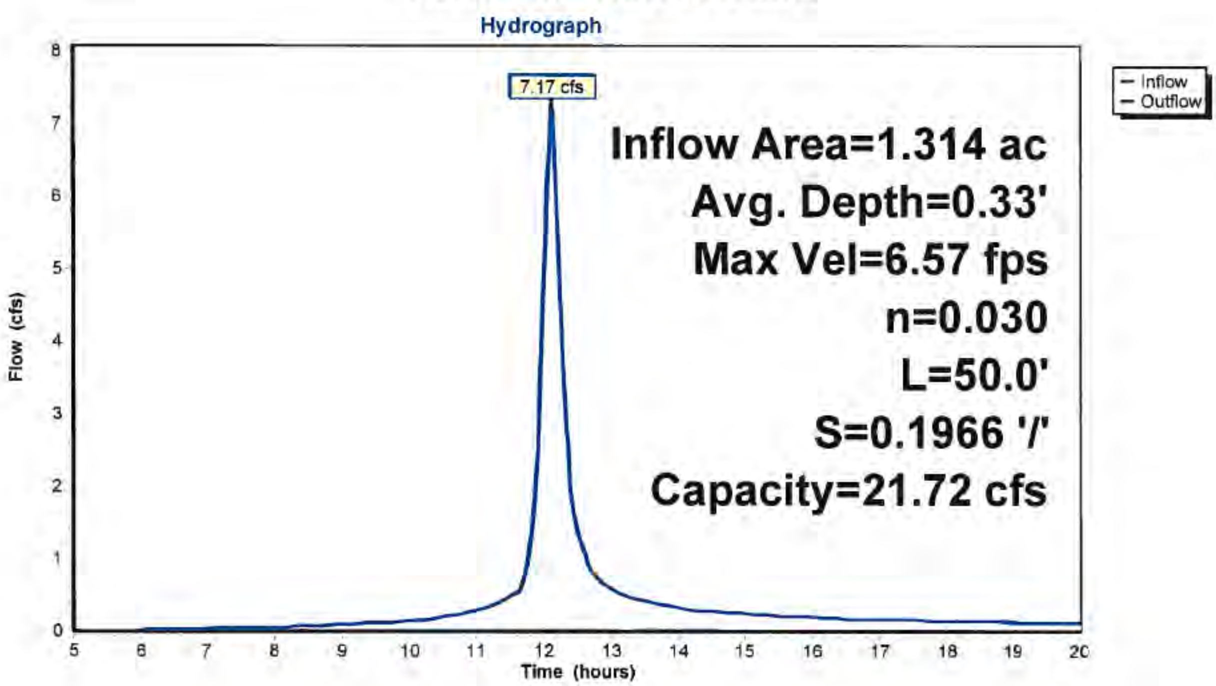
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 6.57 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 2.58 fps, Avg. Travel Time= 0.3 min

Peak Storage= 55 cf @ 12.12 hrs, Average Depth at Peak Storage= 0.33'
Bank-Full Depth= 0.50', Capacity at Bank-Full= 21.72 cfs

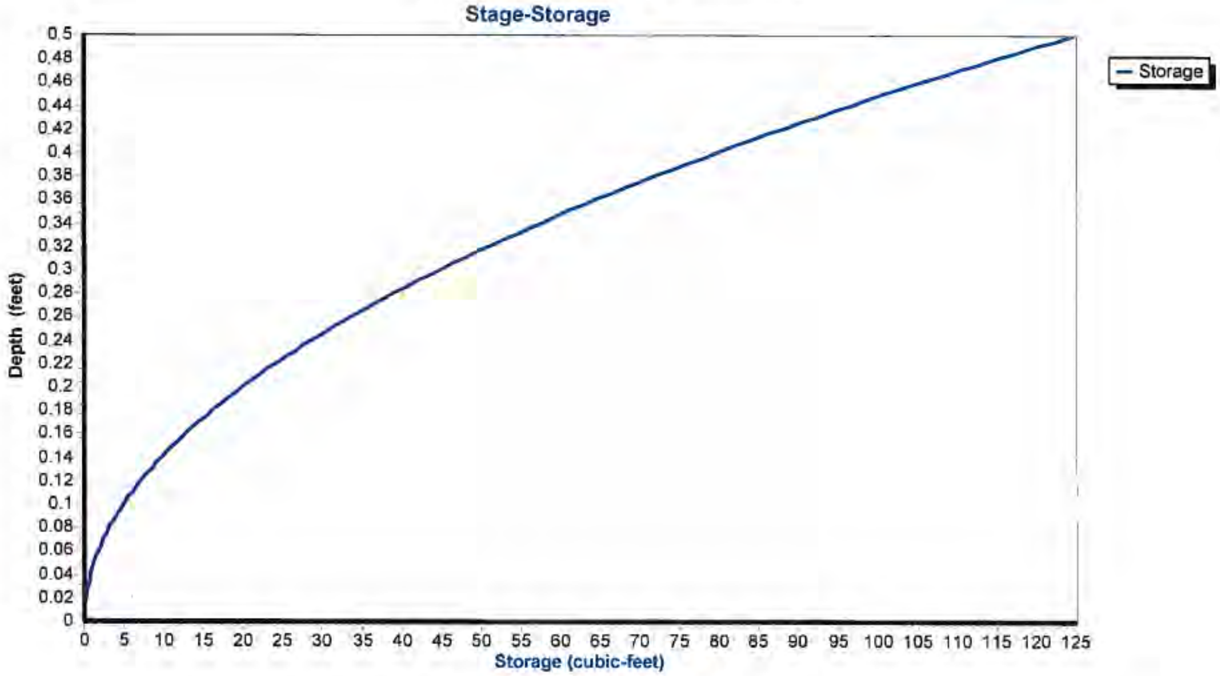
0.00' x 0.50' deep channel, n= 0.030
Side Slope Z-value= 10.0 '/' Top Width= 10.00'
Length= 50.0' Slope= 0.1966 '/'
Inlet Invert= 20.23', Outlet Invert= 10.40'

‡

Reach B4: Vertical Channel



Reach B4: Vertical Channel



Summary for Reach Bc1: Perimeter Channel

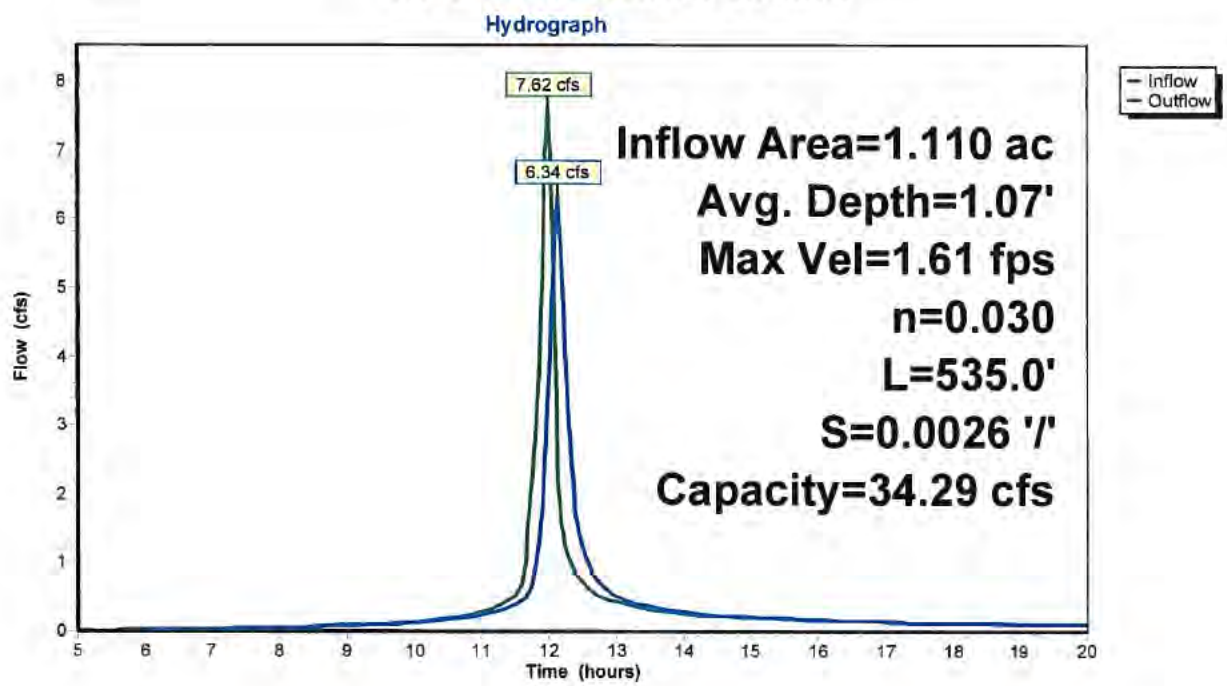
Inflow Area =	1.110 ac,	0.00% Impervious, Inflow Depth > 4.13"	for 24-hr 25-yr Storm event
Inflow =	7.62 cfs @	11.99 hrs, Volume=	0.382 af
Outflow =	6.34 cfs @	12.14 hrs, Volume=	0.379 af, Atten= 17%, Lag= 8.7 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.61 fps, Min. Travel Time= 5.5 min
Avg. Velocity = 0.62 fps, Avg. Travel Time= 14.3 min

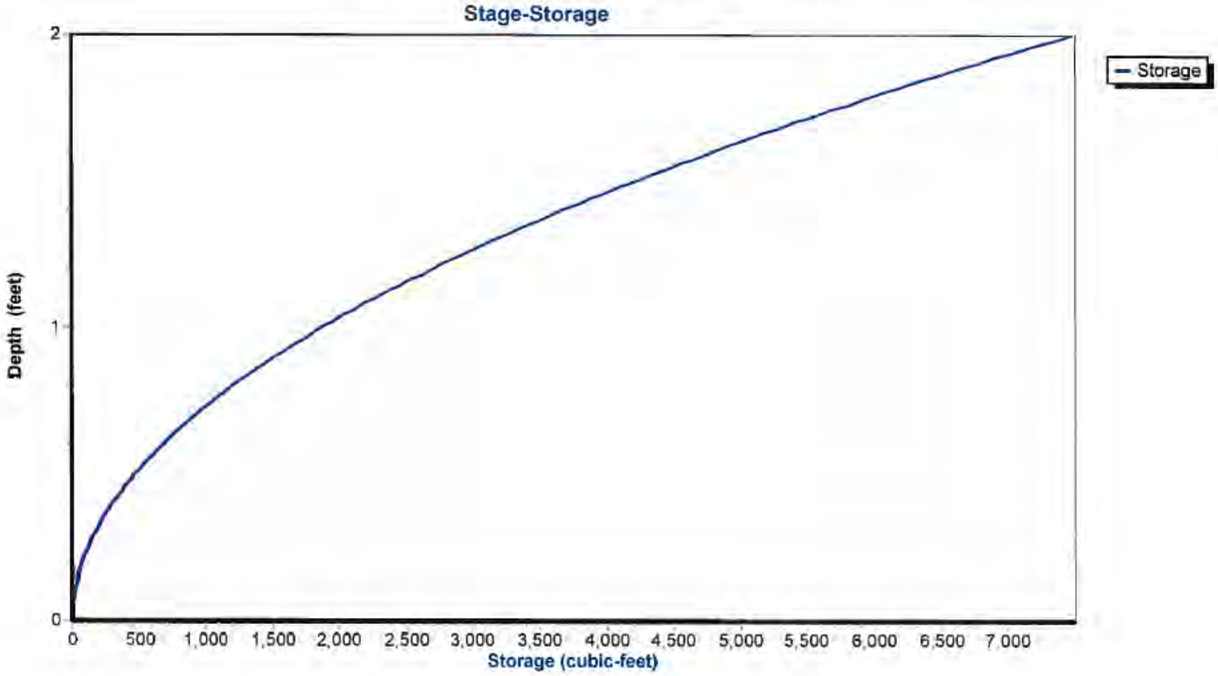
Peak Storage= 2,135 cf @ 12.04 hrs, Average Depth at Peak Storage= 1.07'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 34.29 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 4.0 '/' Top Width= 14.00'
Length= 535.0' Slope= 0.0026 '/'
Inlet Invert= 11.78', Outlet Invert= 10.40'

Reach Bc1: Perimeter Channel



Reach Bc1: Perimeter Channel



Summary for Reach Bc2: Perimeter Channel

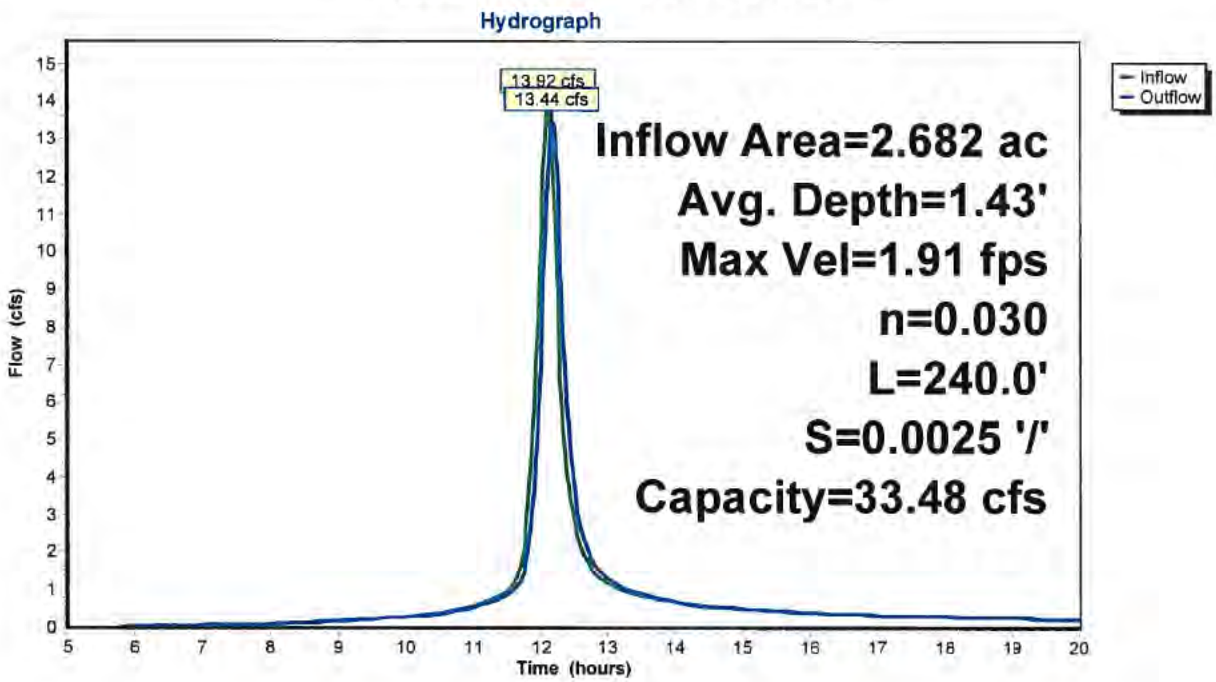
Inflow Area = 2.682 ac, 0.00% Impervious, Inflow Depth > 4.10" for 24-hr 25-yr Storm event
Inflow = 13.92 cfs @ 12.13 hrs, Volume= 0.917 af
Outflow = 13.44 cfs @ 12.18 hrs, Volume= 0.915 af, Atten= 3%, Lag= 3.6 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.91 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 0.76 fps, Avg. Travel Time= 5.3 min

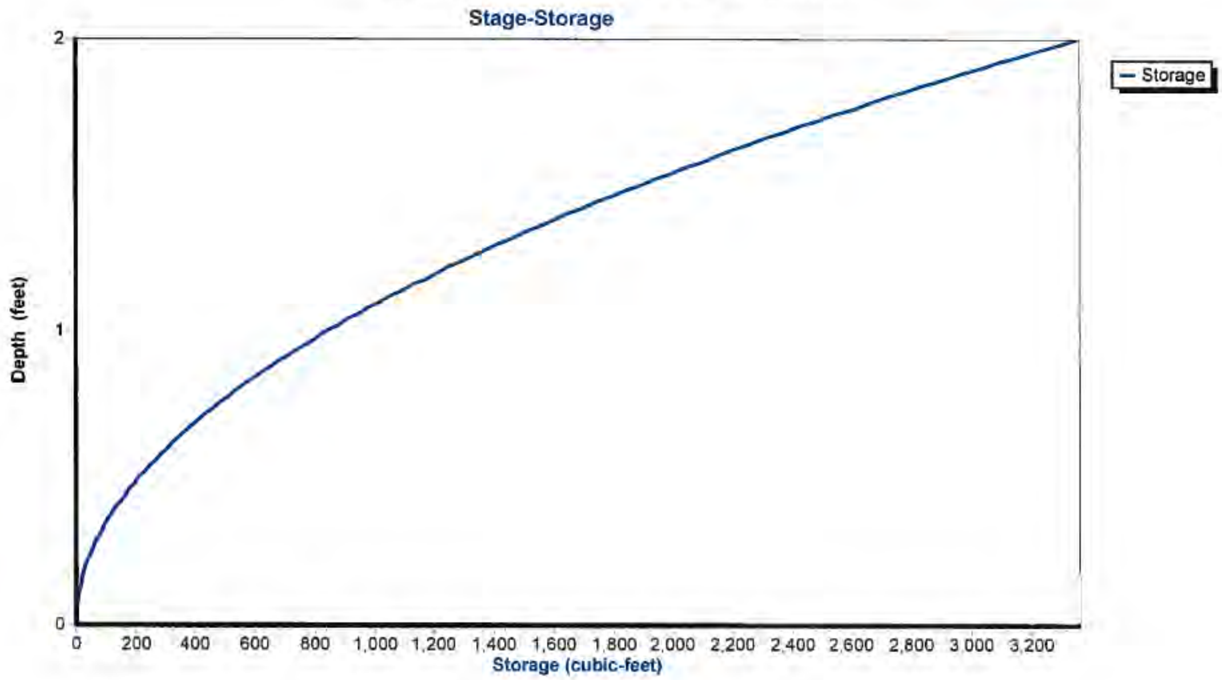
Peak Storage= 1,714 cf @ 12.15 hrs, Average Depth at Peak Storage= 1.43'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.48 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 4.0 '/' Top Width= 14.00'
Length= 240.0' Slope= 0.0025 '/'
Inlet Invert= 10.40', Outlet Invert= 9.81'

Reach Bc2: Perimeter Channel



Reach Bc2: Perimeter Channel



Summary for Reach Bpc1: Plateau Channel B1

Inflow Area = 1.110 ac, 0.00% Impervious, Inflow Depth > 4.12" for 24-hr 25-yr Storm event
Inflow = 6.76 cfs @ 12.03 hrs, Volume= 0.381 af
Outflow = 6.18 cfs @ 12.13 hrs, Volume= 0.379 af, Atten= 9%, Lag= 6.1 min

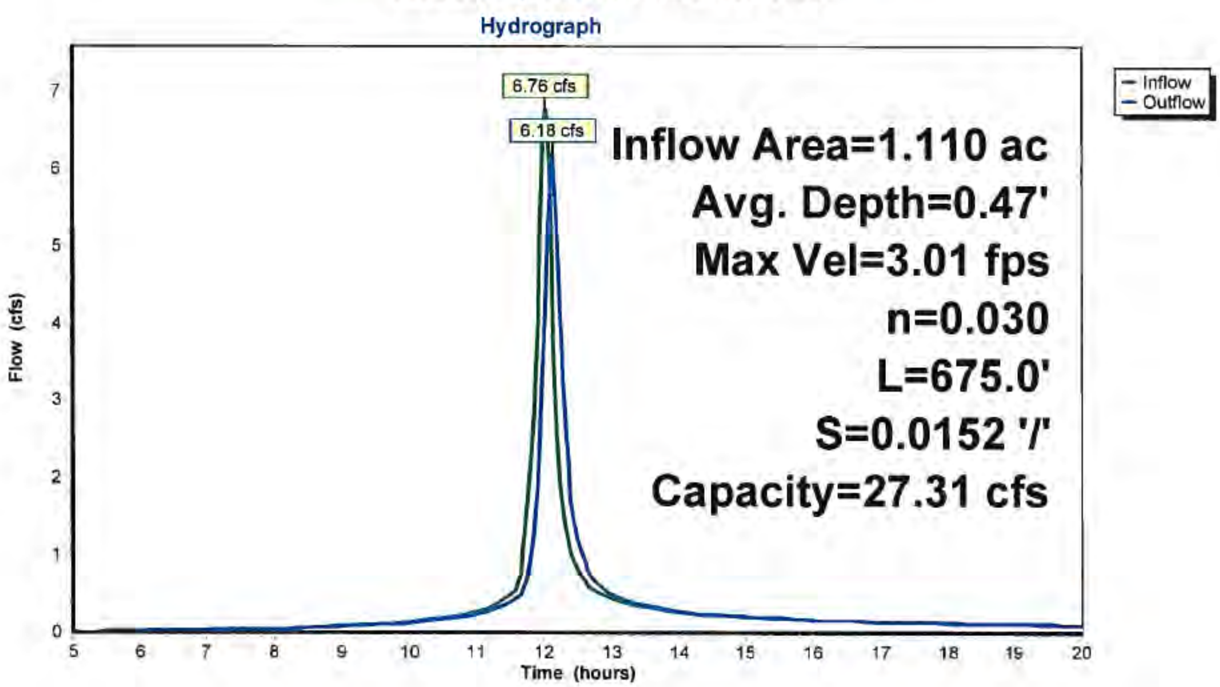
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.01 fps, Min. Travel Time= 3.7 min
Avg. Velocity = 0.87 fps, Avg. Travel Time= 13.0 min

Peak Storage= 1,406 cf @ 12.07 hrs, Average Depth at Peak Storage= 0.47'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 27.31 cfs

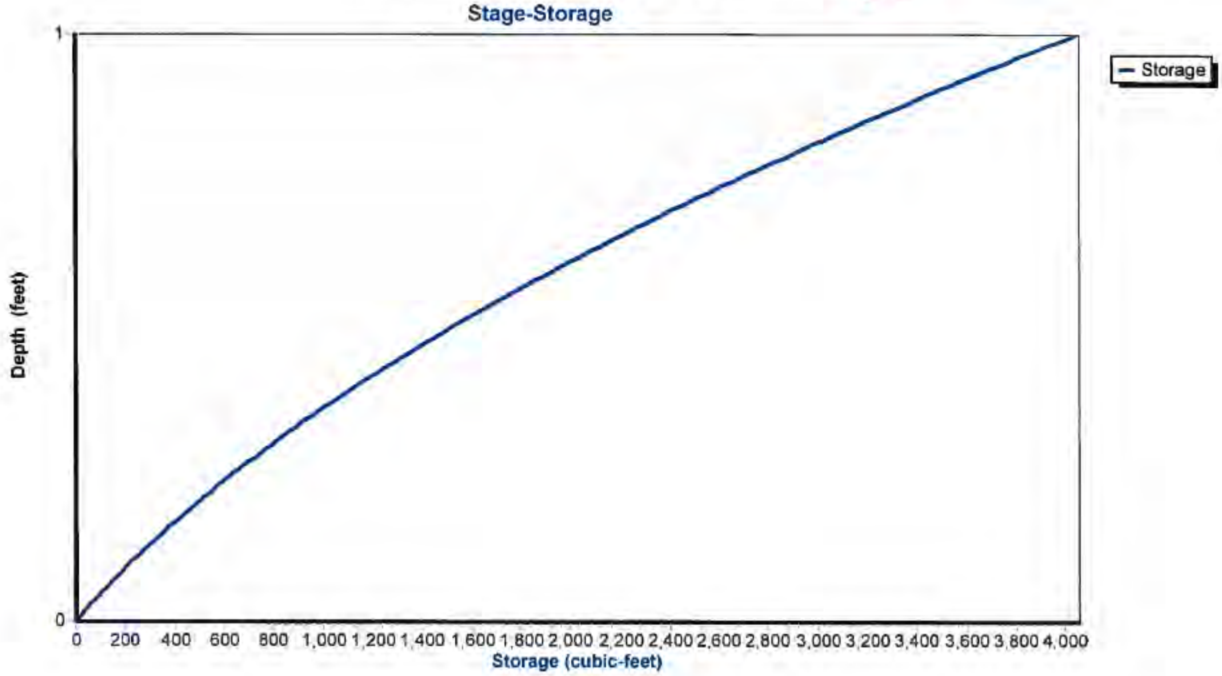
3.00' x 1.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 '/' Top Width= 9.00'
Length= 675.0' Slope= 0.0152 '/'
Inlet Invert= 30.49', Outlet Invert= 20.23'

‡

Reach Bpc1: Plateau Channel



Reach Bpc1: Plateau Channel B1



Summary for Reach Bpc2: Plateau Channel B2

Inflow Area =	0.204 ac,	0.00% Impervious, Inflow Depth > 4.12"	for 24-hr 25-yr Storm event	
Inflow =	1.26 cfs @	12.02 hrs, Volume=	0.070 af	
Outflow =	1.22 cfs @	12.06 hrs, Volume=	0.070 af, Atten= 3%, Lag= 1.9 min	

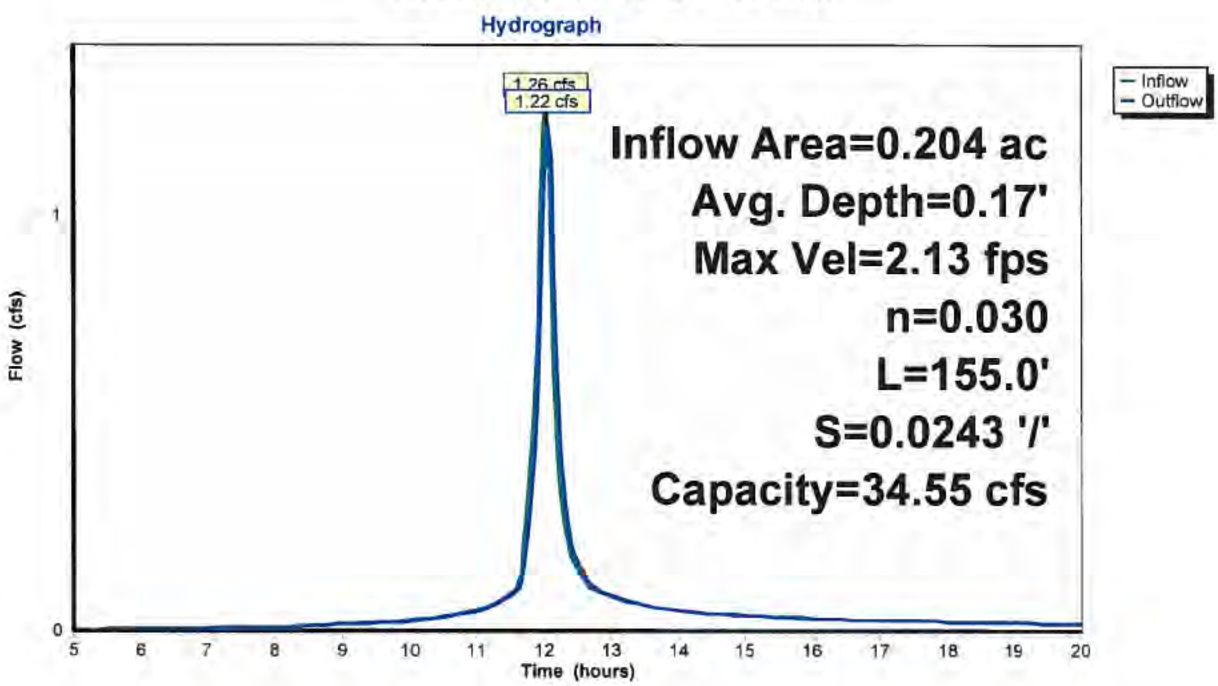
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.13 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 0.56 fps, Avg. Travel Time= 4.6 min

Peak Storage= 91 cf @ 12.04 hrs, Average Depth at Peak Storage= 0.17'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 34.55 cfs

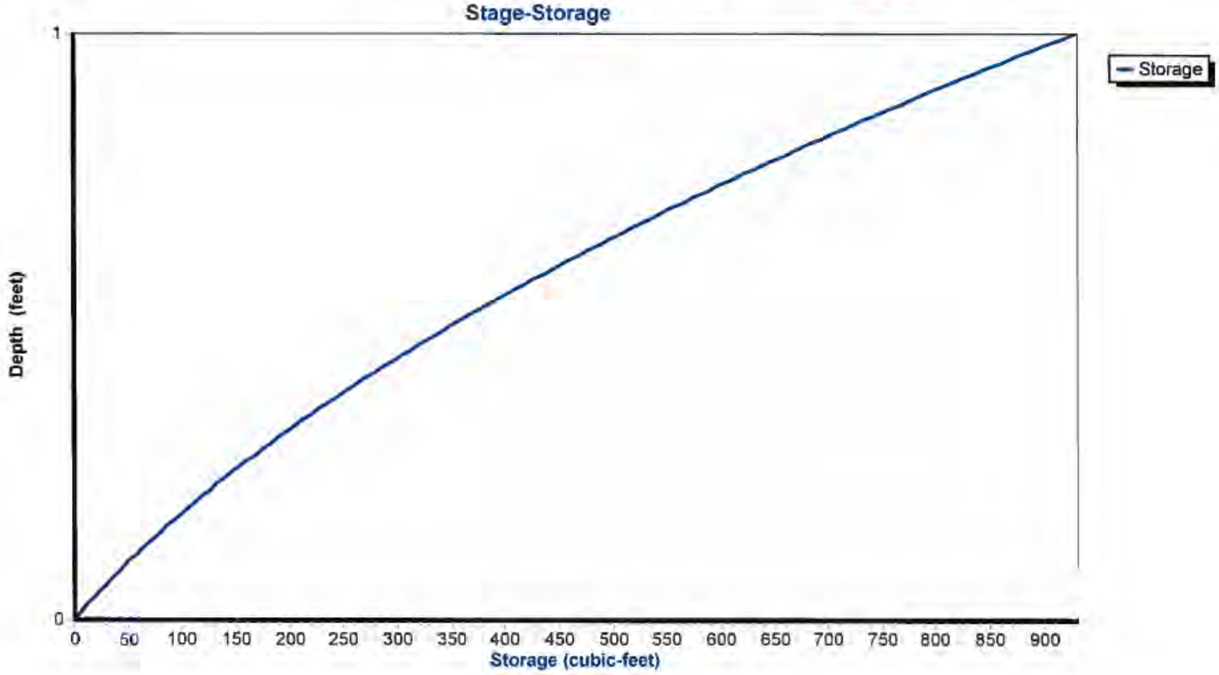
3.00' x 1.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 '/' Top Width= 9.00'
Length= 155.0' Slope= 0.0243 '/'
Inlet Invert= 24.00', Outlet Invert= 20.23'

‡

Reach Bpc2: Plateau Channel



Reach Bpc2: Plateau Channel B2



Summary for Reach C3: Vertical Channel 2

Inflow Area = 0.332 ac, 0.00% Impervious, Inflow Depth > 4.12" for 24-hr 25-yr Storm event
Inflow = 1.80 cfs @ 12.08 hrs, Volume= 0.114 af
Outflow = 1.79 cfs @ 12.09 hrs, Volume= 0.114 af, Atten= 0%, Lag= 0.4 min

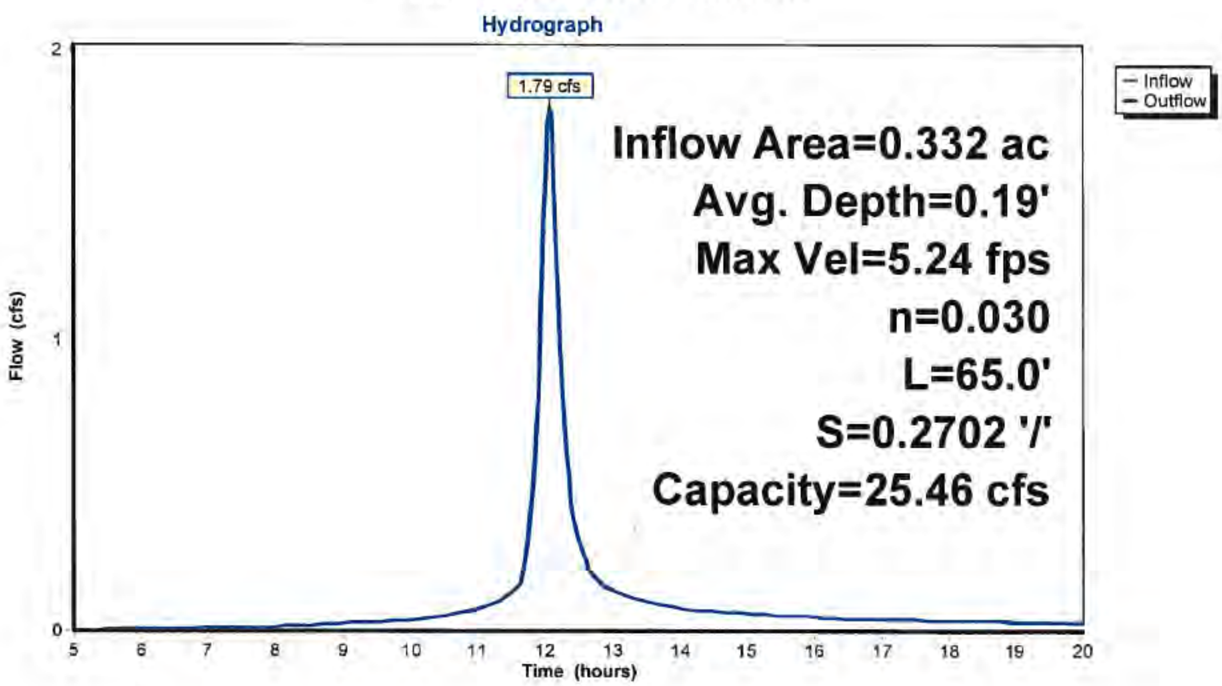
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.24 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.08 fps, Avg. Travel Time= 0.5 min

Peak Storage= 22 cf @ 12.08 hrs, Average Depth at Peak Storage= 0.19'
Bank-Full Depth= 0.50', Capacity at Bank-Full= 25.46 cfs

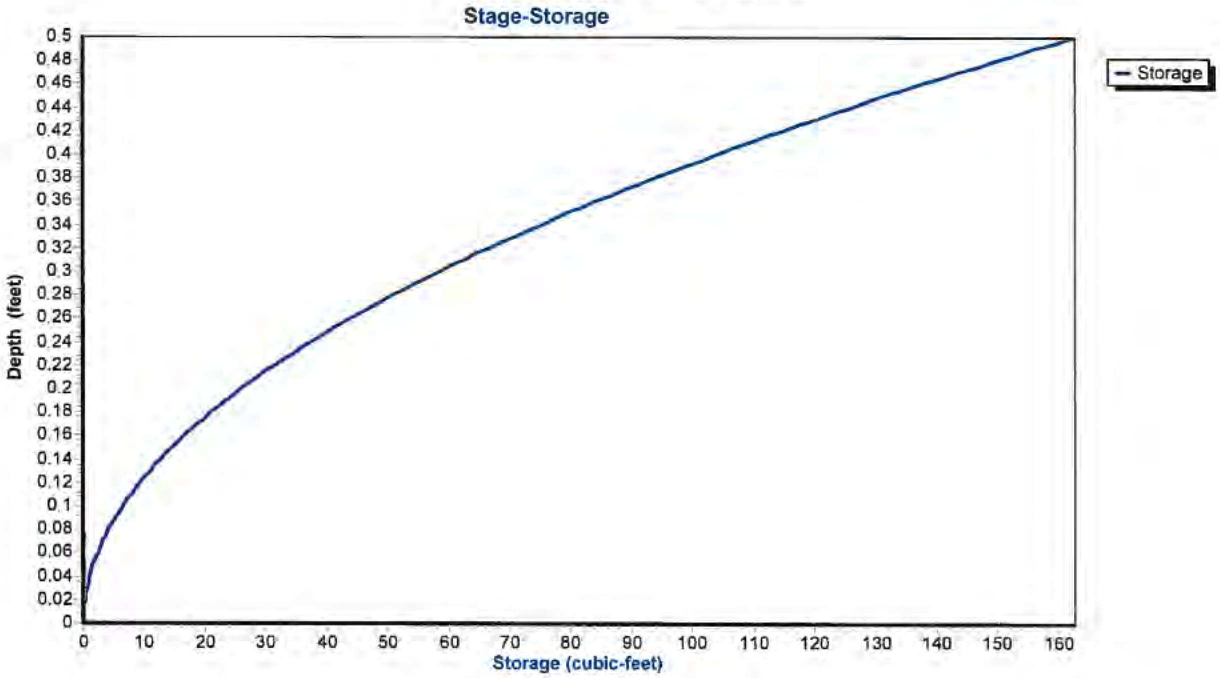
0.00' x 0.50' deep channel, n= 0.030
Side Slope Z-value= 10.0 '/' Top Width= 10.00'
Length= 65.0' Slope= 0.2702 '/'
Inlet Invert= 27.28', Outlet Invert= 9.72'

‡

Reach C3: Vertical Channel



Reach C3: Vertical Channel



Summary for Reach C6: Vertical Channel 3

Inflow Area = 0.434 ac, 0.00% Impervious, Inflow Depth > 4.11" for 24-hr 25-yr Storm event
Inflow = 2.11 cfs @ 12.11 hrs, Volume= 0.149 af
Outflow = 2.10 cfs @ 12.12 hrs, Volume= 0.149 af, Atten= 1%, Lag= 0.4 min

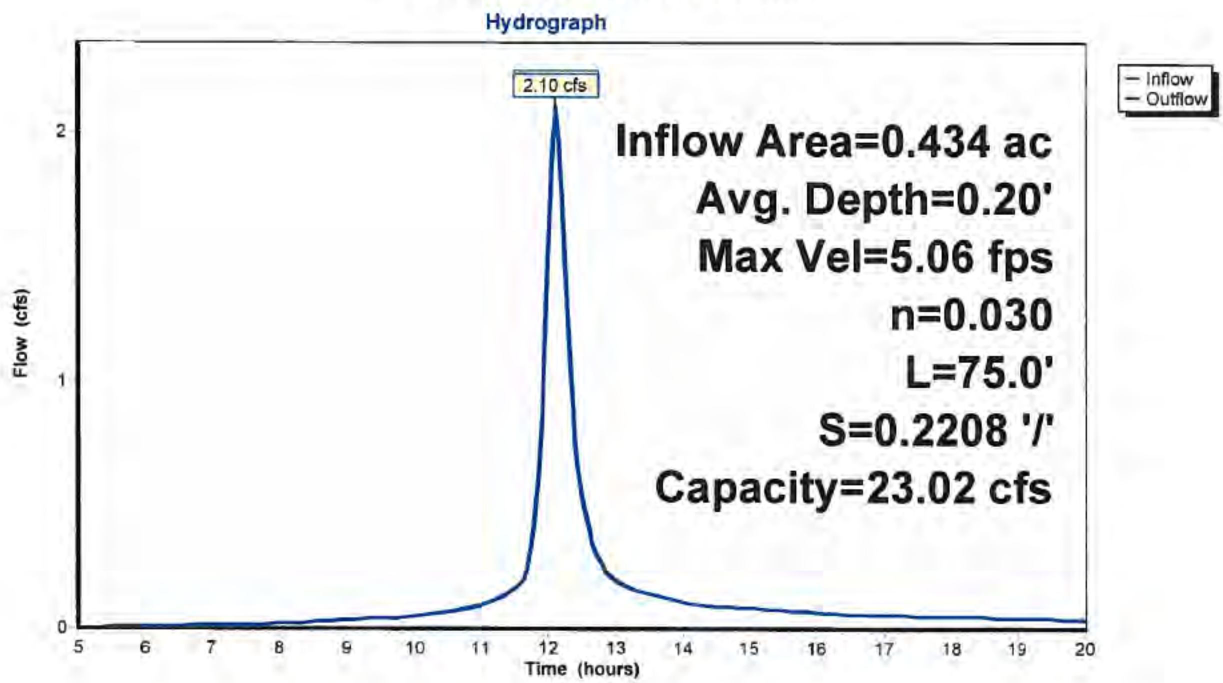
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.06 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.07 fps, Avg. Travel Time= 0.6 min

Peak Storage= 31 cf @ 12.12 hrs, Average Depth at Peak Storage= 0.20'
Bank-Full Depth= 0.50', Capacity at Bank-Full= 23.02 cfs

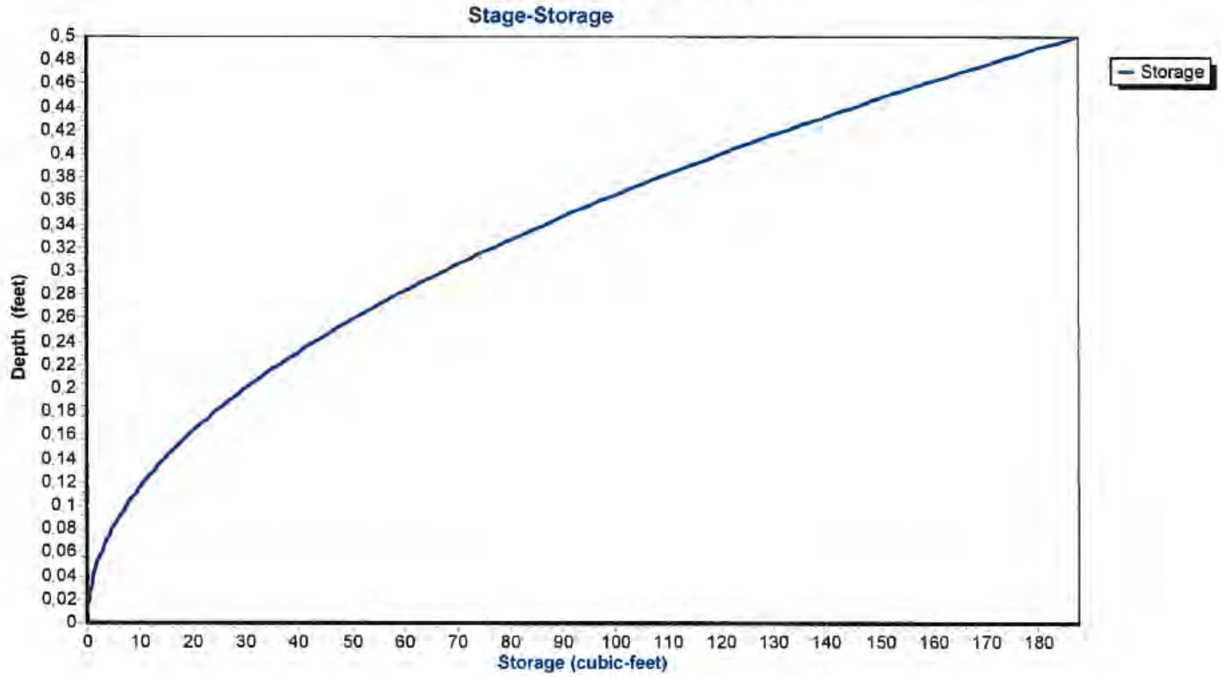
0.00' x 0.50' deep channel, n= 0.030
Side Slope Z-value= 10.0 '/' Top Width= 10.00'
Length= 75.0' Slope= 0.2208 '/'
Inlet Invert= 24.46', Outlet Invert= 7.90'

‡

Reach C6: Vertical Channel



Reach C6: Vertical Channel



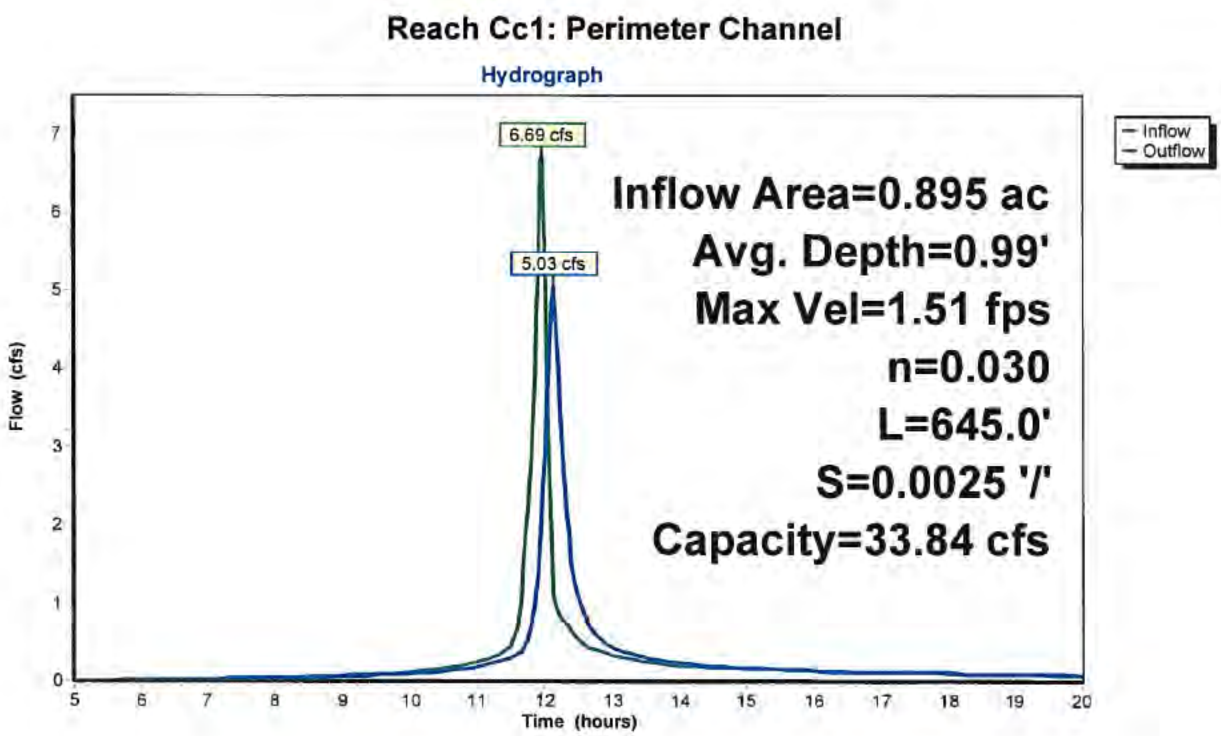
Summary for Reach Cc1: Perimeter Channel

Inflow Area =	0.895 ac,	0.00% Impervious, Inflow Depth > 4.13"	for 24-hr 25-yr Storm event	
Inflow =	6.69 cfs @	11.96 hrs, Volume=	0.308 af	
Outflow =	5.03 cfs @	12.13 hrs, Volume=	0.305 af, Atten= 25%, Lag= 10.6 min	

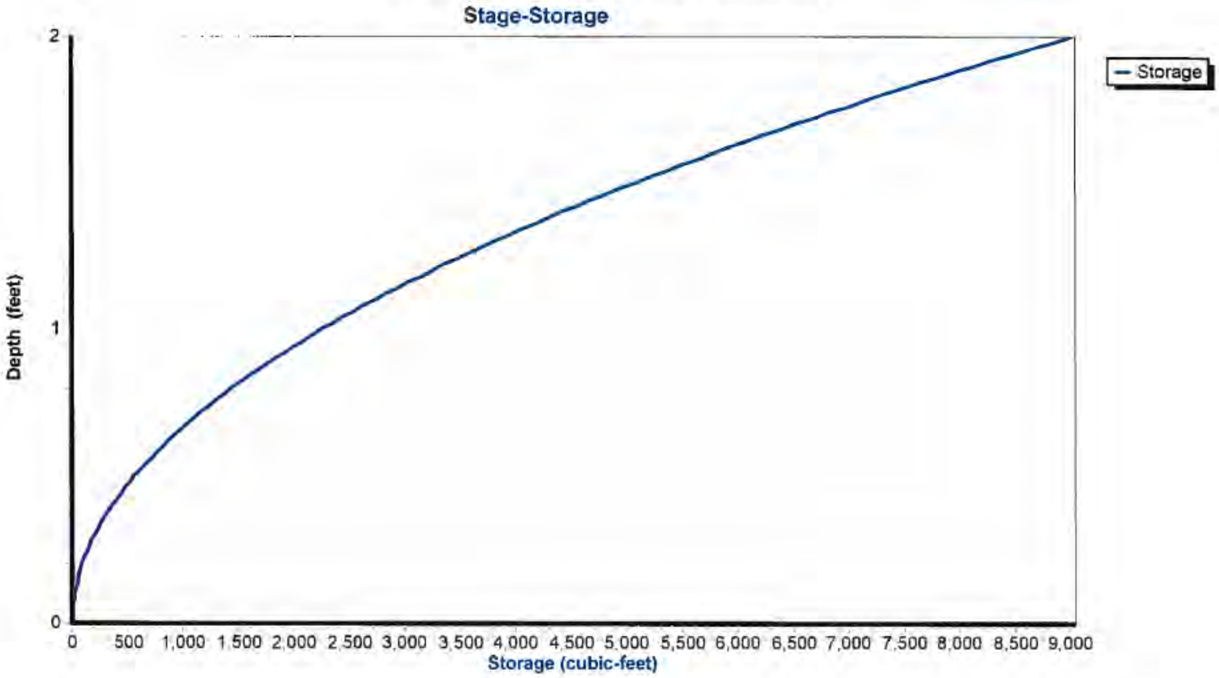
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.51 fps, Min. Travel Time= 7.1 min
Avg. Velocity = 0.59 fps, Avg. Travel Time= 18.4 min

Peak Storage= 2,212 cf @ 12.01 hrs, Average Depth at Peak Storage= 0.99'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.84 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 4.0 '/' Top Width= 14.00'
Length= 645.0' Slope= 0.0025 '/'
Inlet Invert= 11.34', Outlet Invert= 9.72'



Reach Cc1: Perimeter Channel



Summary for Reach Cc2: Perimeter Channel

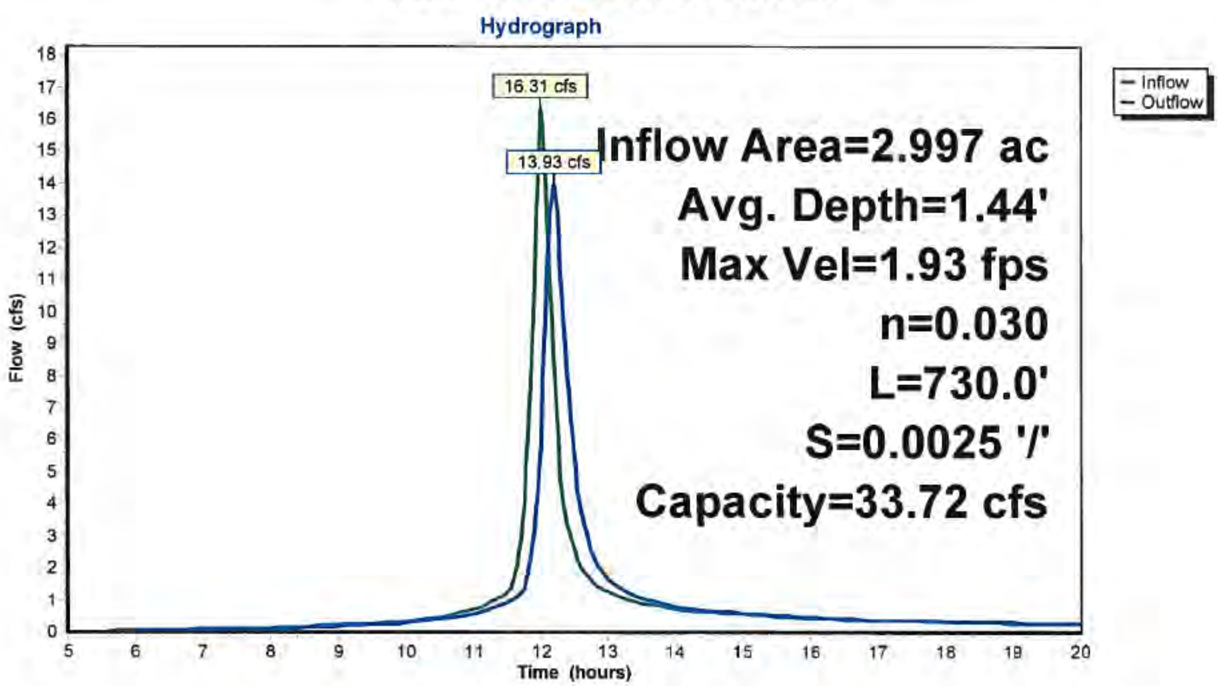
Inflow Area =	2.997 ac,	0.00% Impervious, Inflow Depth > 4.12"	for 24-hr 25-yr Storm event
Inflow =	16.31 cfs @	12.02 hrs, Volume=	1.028 af
Outflow =	13.93 cfs @	12.20 hrs, Volume=	1.020 af, Atten= 15%, Lag= 10.7 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.93 fps, Min. Travel Time= 6.3 min
Avg. Velocity = 0.79 fps, Avg. Travel Time= 15.5 min

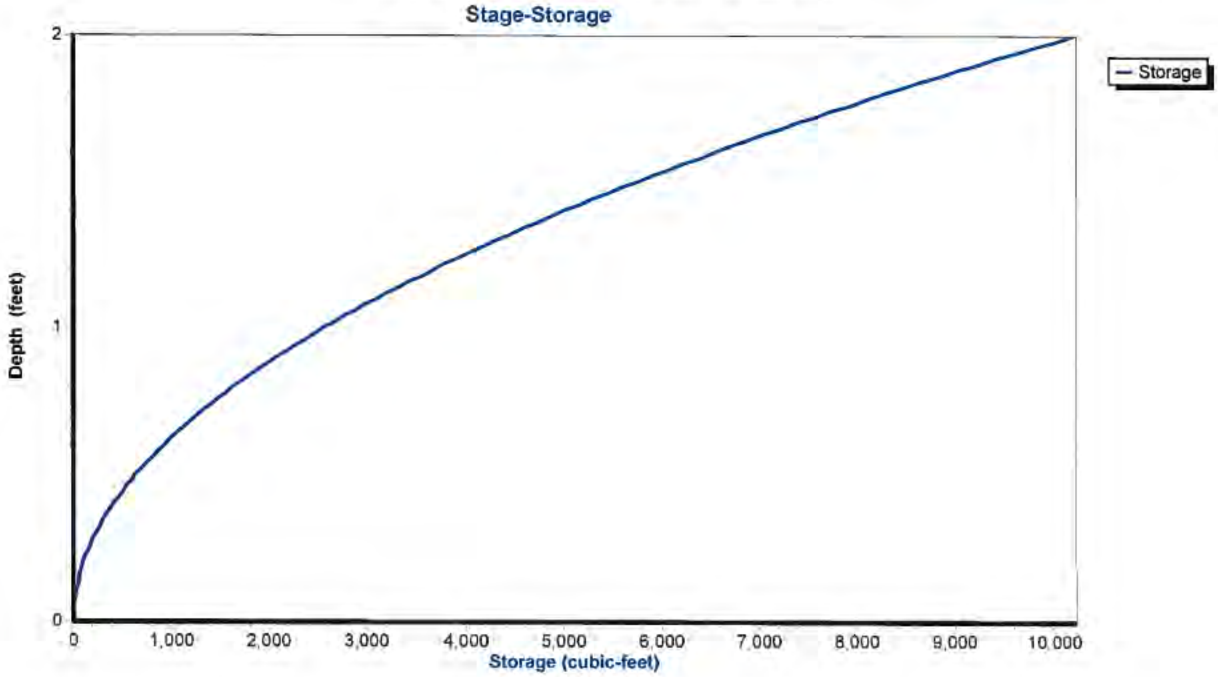
Peak Storage= 5,285 cf @ 12.09 hrs, Average Depth at Peak Storage= 1.44'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.72 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 4.0 '/' Top Width= 14.00'
Length= 730.0' Slope= 0.0025 '/'
Inlet Invert= 9.72', Outlet Invert= 7.90'

Reach Cc2: Perimeter Channel



Reach Cc2: Perimeter Channel



Summary for Reach Cc3: Perimeter Channel

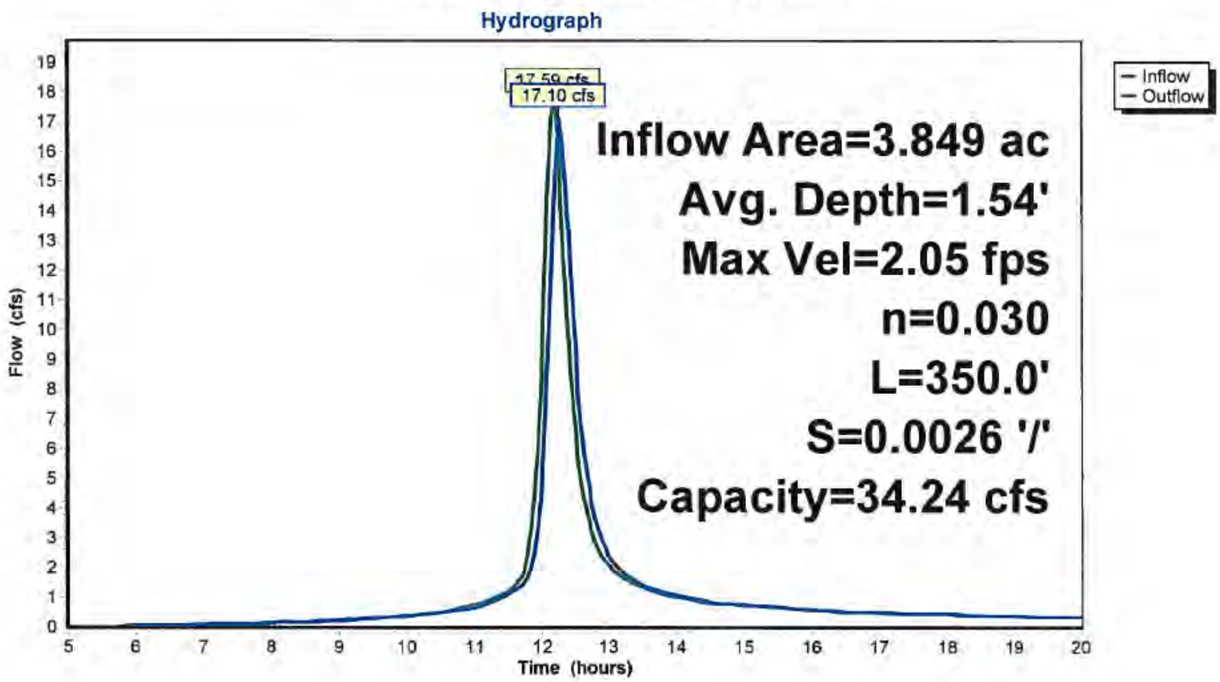
Inflow Area = 3.849 ac, 0.00% Impervious, Inflow Depth > 4.09" for 24-hr 25-yr Storm event
Inflow = 17.59 cfs @ 12.19 hrs, Volume= 1.312 af
Outflow = 17.10 cfs @ 12.27 hrs, Volume= 1.307 af, Atten= 3%, Lag= 5.1 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.05 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 0.84 fps, Avg. Travel Time= 6.9 min

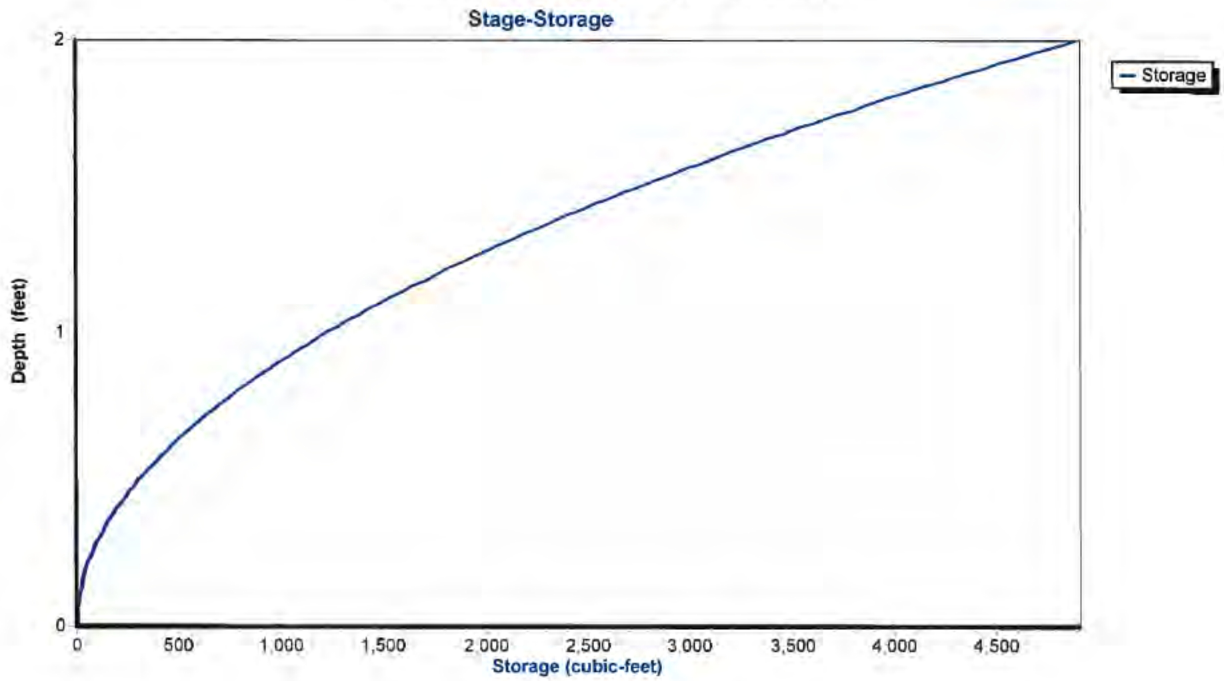
Peak Storage= 2,917 cf @ 12.22 hrs, Average Depth at Peak Storage= 1.54'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 34.24 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 4.0 '/' Top Width= 14.00'
Length= 350.0' Slope= 0.0026 '/'
Inlet Invert= 7.90', Outlet Invert= 7.00'

Reach Cc3: Perimeter Channel



Reach Cc3: Perimeter Channel



Summary for Reach Cpc1: Plateau Channel

Inflow Area =	0.332 ac, 0.00% Impervious, Inflow Depth > 4.12"	for 24-hr 25-yr Storm event
Inflow =	1.82 cfs @ 12.07 hrs, Volume=	0.114 af
Outflow =	1.80 cfs @ 12.08 hrs, Volume=	0.114 af, Atten= 1%, Lag= 0.8 min

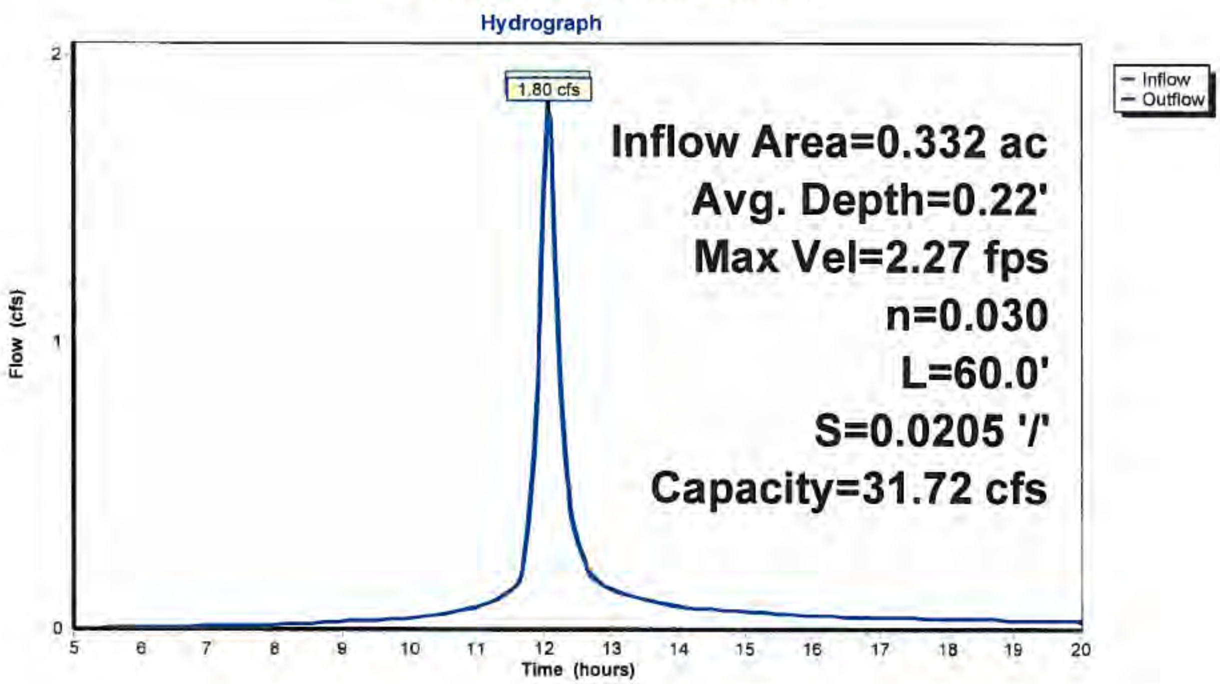
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.27 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 0.63 fps, Avg. Travel Time= 1.6 min

Peak Storage= 48 cf @ 12.07 hrs, Average Depth at Peak Storage= 0.22'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 31.72 cfs

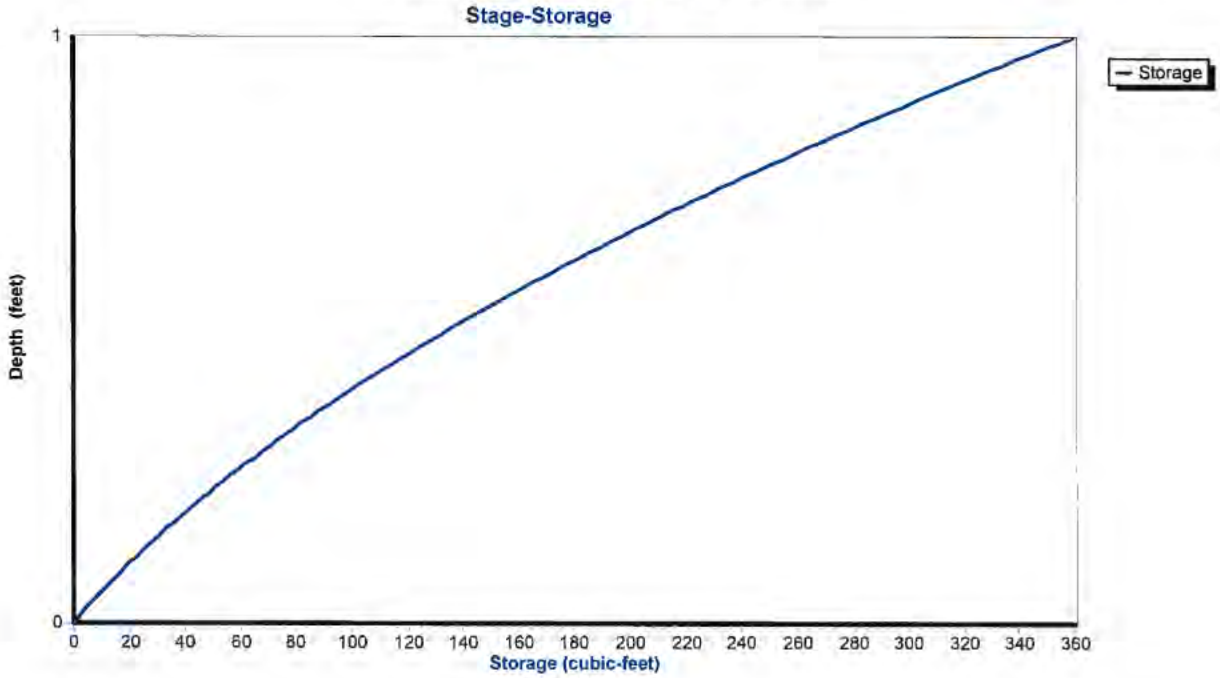
3.00' x 1.00' deep channel, n= 0.030
Side Slope Z-value= 3.0 '/' Top Width= 9.00'
Length= 60.0' Slope= 0.0205 '/'
Inlet Invert= 29.83', Outlet Invert= 28.60'

‡

Reach Cpc1: Plateau Channel



Reach Cpc1: Plateau Channel



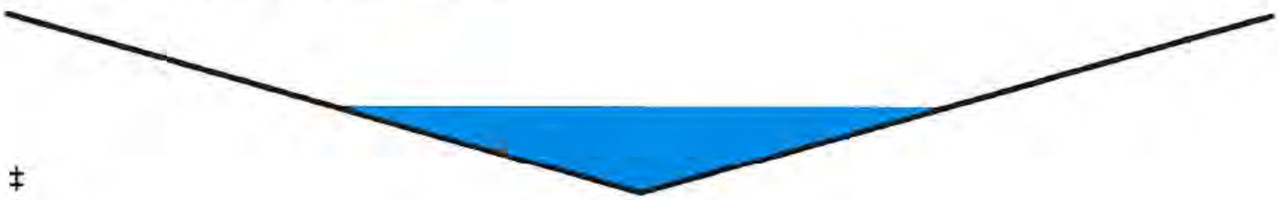
Summary for Reach D3: Vertical Channel 4

Inflow Area = 0.763 ac, 0.00% Impervious, Inflow Depth > 4.11" for 24-hr 25-yr Storm event
Inflow = 3.69 cfs @ 12.12 hrs, Volume= 0.262 af
Outflow = 3.68 cfs @ 12.12 hrs, Volume= 0.262 af, Atten= 0%, Lag= 0.2 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 6.21 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 2.54 fps, Avg. Travel Time= 0.3 min

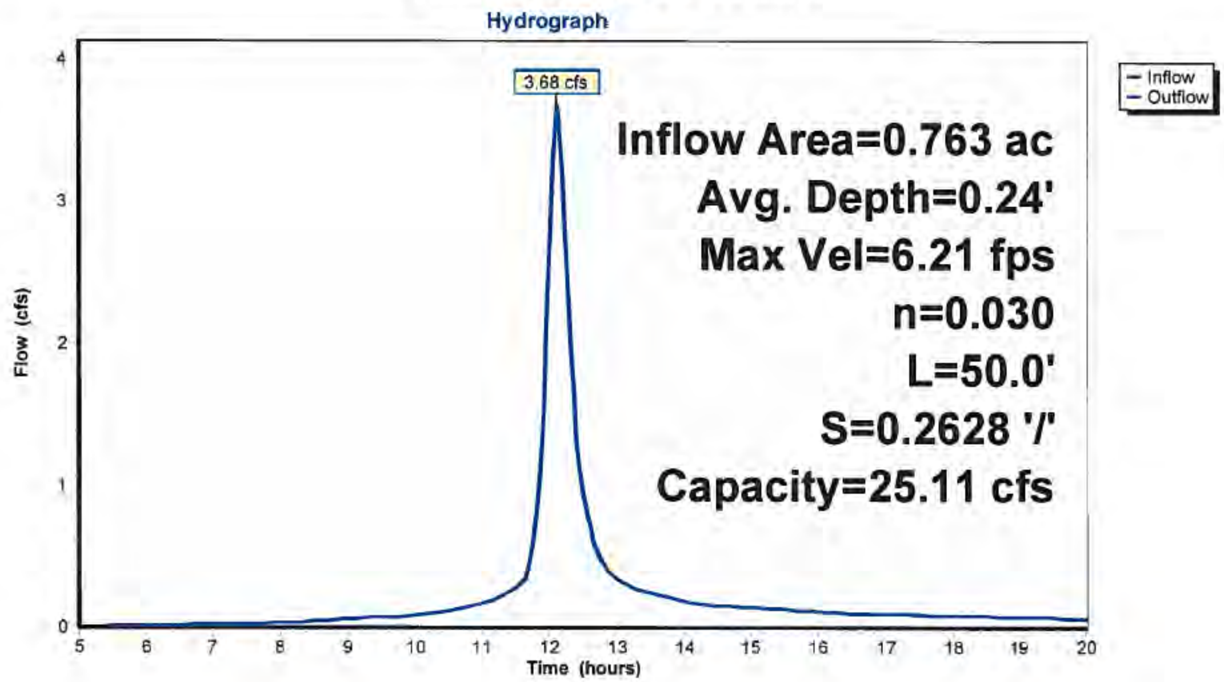
Peak Storage= 30 cf @ 12.12 hrs, Average Depth at Peak Storage= 0.24'
Bank-Full Depth= 0.50', Capacity at Bank-Full= 25.11 cfs

0.00' x 0.50' deep channel, n= 0.030
Side Slope Z-value= 10.0 '/' Top Width= 10.00'
Length= 50.0' Slope= 0.2628 '/'
Inlet Invert= 24.28', Outlet Invert= 11.14'

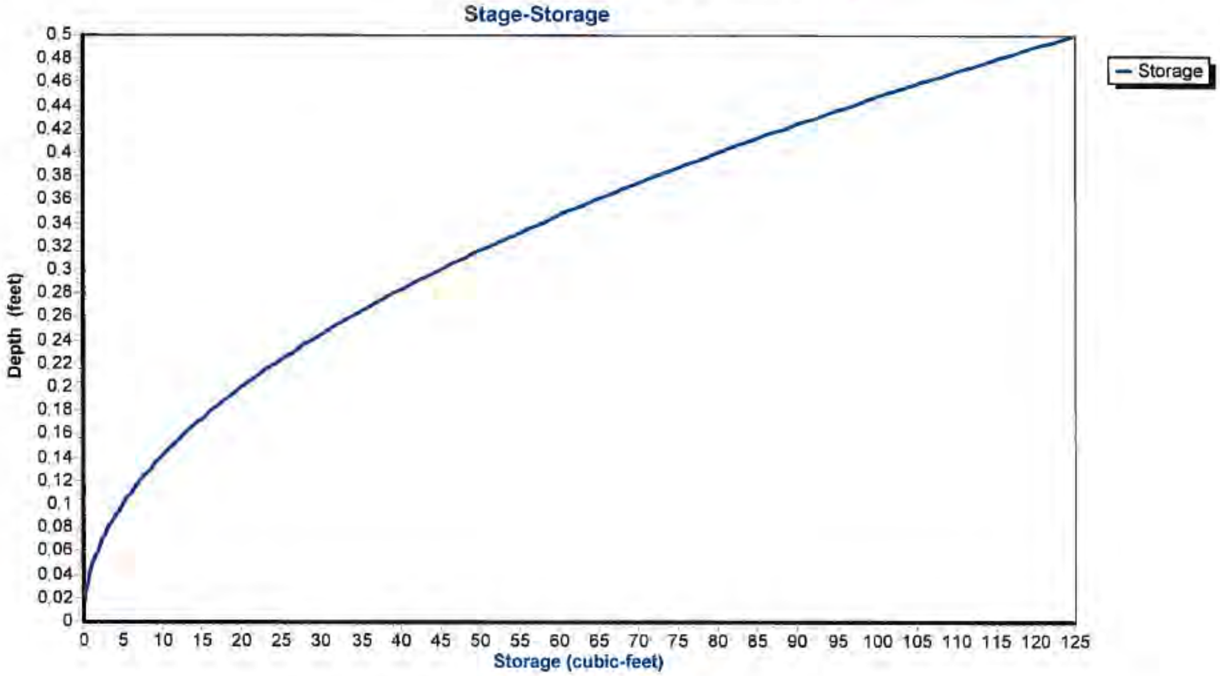


‡

Reach D3: Vertical Channel



Reach D3: Vertical Channel 4—



Summary for Reach Dc1: Perimeter Channel

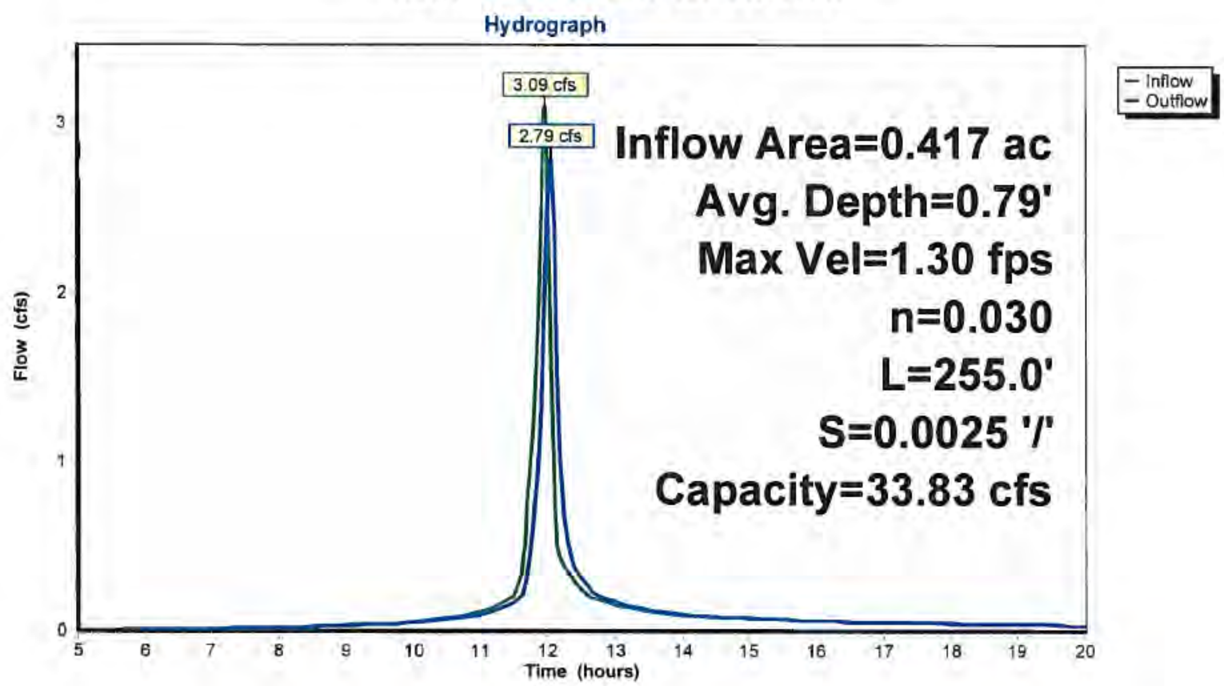
Inflow Area =	0.417 ac,	0.00% Impervious, Inflow Depth > 4.13"	for 24-hr 25-yr Storm event
Inflow =	3.09 cfs @	11.96 hrs, Volume=	0.144 af
Outflow =	2.79 cfs @	12.05 hrs, Volume=	0.143 af, Atten= 10%, Lag= 5.4 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.30 fps, Min. Travel Time= 3.3 min
Avg. Velocity = 0.49 fps, Avg. Travel Time= 8.8 min

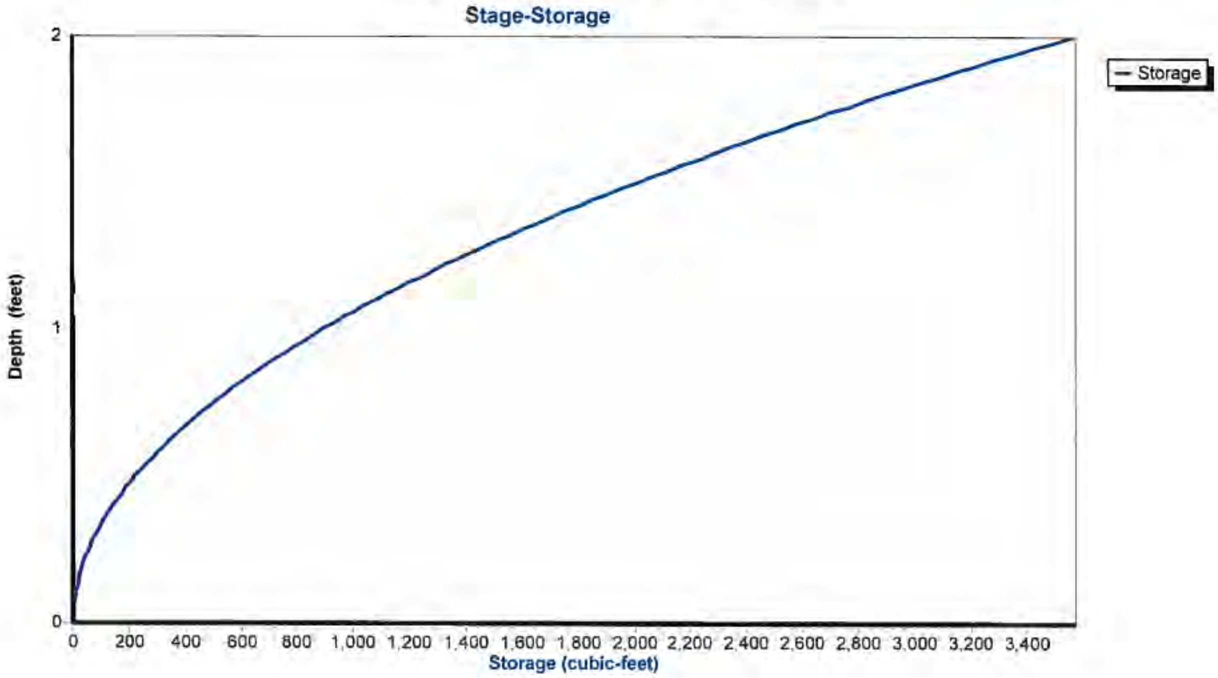
Peak Storage= 554 cf @ 11.99 hrs, Average Depth at Peak Storage= 0.79'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.83 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 4.0 3.0 '/' Top Width= 14.00'
Length= 255.0' Slope= 0.0025 '/'
Inlet Invert= 11.78', Outlet Invert= 11.14'

Reach Dc1: Perimeter Channel



Reach Dc1: Perimeter Channel



Summary for Reach Dc2: Perimeter Channel

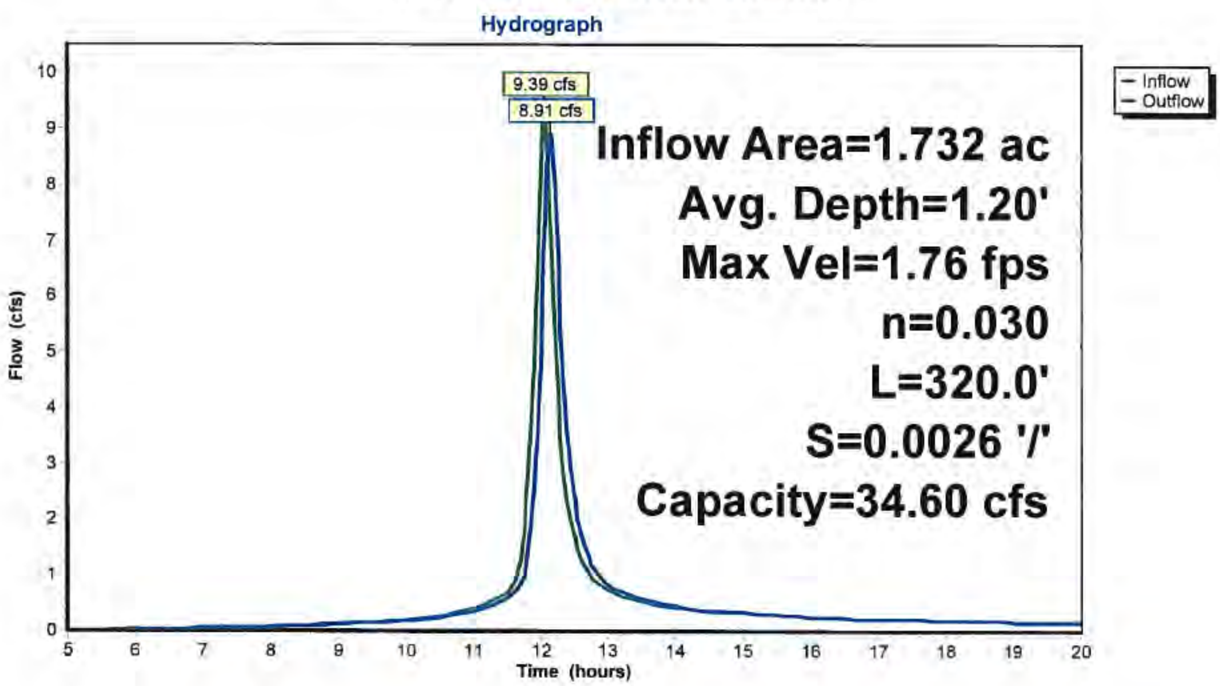
Inflow Area = 1.732 ac, 0.00% Impervious, Inflow Depth > 4.12" for 24-hr 25-yr Storm event
Inflow = 9.39 cfs @ 12.06 hrs, Volume= 0.594 af
Outflow = 8.91 cfs @ 12.14 hrs, Volume= 0.592 af, Atten= 5%, Lag= 5.4 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.76 fps, Min. Travel Time= 3.0 min
Avg. Velocity = 0.70 fps, Avg. Travel Time= 7.6 min

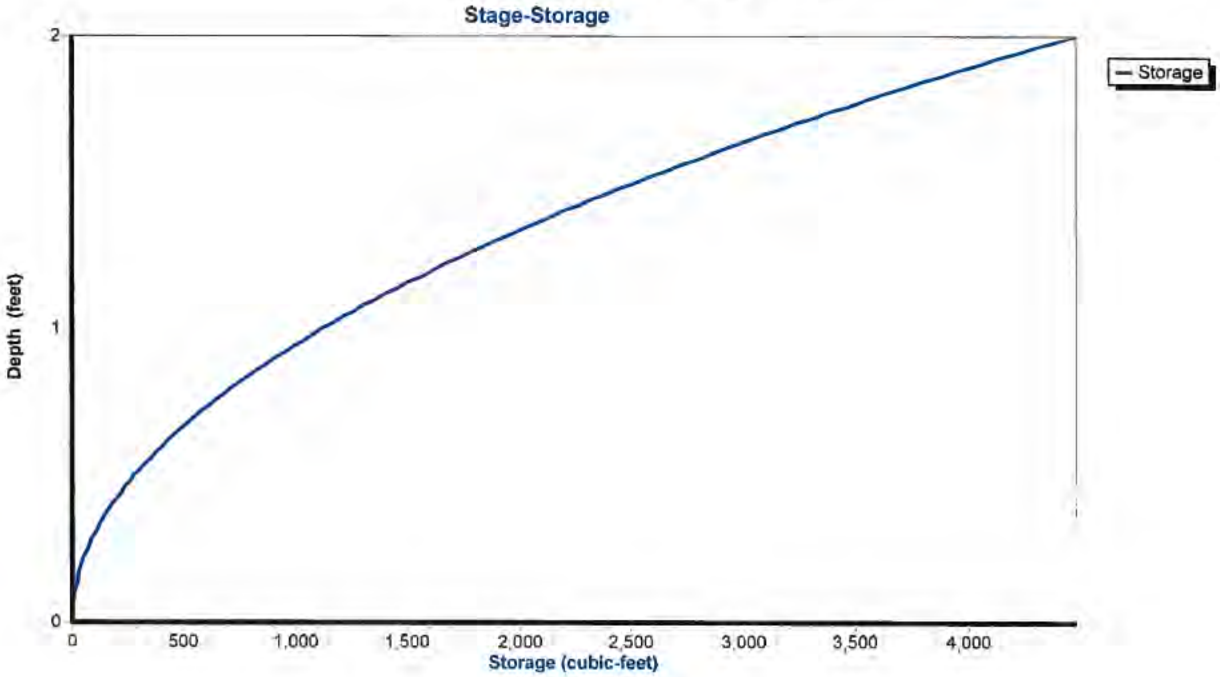
Peak Storage= 1,621 cf @ 12.09 hrs, Average Depth at Peak Storage= 1.20'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 34.60 cfs

0.00' x 2.00' deep channel, n= 0.030
Side Slope Z-value= 4.0 3.0 '/' Top Width= 14.00'
Length= 320.0' Slope= 0.0026 '/'
Inlet Invert= 11.14', Outlet Invert= 10.30'

Reach Dc2: Perimeter Channel



Reach Dc2: Perimeter Channel



Plateau Channel A1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.01450	ft/ft
Discharge	4.41	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	3.00
0+09	0.00
0+12	0.00
0+15	1.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 3.00)	(0+15, 1.00)	0.030

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	0.39	ft
Elevation Range	0.00 to 3.00 ft	
Flow Area	1.65	ft²
Wetted Perimeter	5.49	ft
Hydraulic Radius	0.30	ft
Top Width	5.37	ft
Normal Depth	0.39	ft
Critical Depth	0.36	ft
Critical Slope	0.02056	ft/ft

Plateau Channel A1

Results

Velocity		2.67	ft/s
Velocity Head		0.11	ft
Specific Energy		0.51	ft
Froude Number		0.85	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.39	ft
Critical Depth	0.36	ft
Channel Slope	0.01450	ft/ft
Critical Slope	0.02056	ft/ft

Plateau Channel A2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00850	ft/ft
Discharge	1.00	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	1.00
0+03	0.00
0+06	0.00
0+15	3.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 1.00)	(0+15, 3.00)	0.030

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	0.20	ft
Elevation Range	0.00 to 3.00 ft	
Flow Area	0.72	ft²
Wetted Perimeter	4.26	ft
Hydraulic Radius	0.17	ft
Top Width	4.20	ft
Normal Depth	0.20	ft
Critical Depth	0.14	ft
Critical Slope	0.02645	ft/ft

Plateau Channel A2

Results

Velocity		1.39	ft/s
Velocity Head		0.03	ft
Specific Energy		0.23	ft
Froude Number		0.59	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.20	ft
Critical Depth	0.14	ft
Channel Slope	0.00850	ft/ft
Critical Slope	0.02645	ft/ft

A4 - Vertical Channel 1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.25000	ft/ft
Left Side Slope	10.00	ft/ft (H:V)
Right Side Slope	10.00	ft/ft (H:V)
Discharge	4.88	ft³/s

Results

Normal Depth	0.27	ft
Flow Area	0.75	ft²
Wetted Perimeter	5.49	ft
Hydraulic Radius	0.14	ft
Top Width	5.46	ft
Critical Depth	0.43	ft
Critical Slope	0.02203	ft/ft
Velocity	6.54	ft/s
Velocity Head	0.67	ft
Specific Energy	0.94	ft
Froude Number	3.12	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.27	ft
Critical Depth	0.43	ft
Channel Slope	0.25000	ft/ft
Critical Slope	0.02203	ft/ft

Perimeter Channel Ac1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	0.87	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+08	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+08, 0.00)	0.035
(0+08, 0.00)	(0+14, 2.00)	0.030

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	0.53	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	0.97	ft^2
Wetted Perimeter	3.83	ft
Hydraulic Radius	0.25	ft
Top Width	3.68	ft
Normal Depth	0.53	ft
Critical Depth	0.33	ft
Critical Slope	0.03041	ft/ft

Perimeter Channel Ac1

Results

Velocity		0.90	ft/s
Velocity Head		0.01	ft
Specific Energy		0.54	ft
Froude Number		0.31	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.53	ft
Critical Depth	0.33	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.03041	ft/ft

Perimeter Channel Ac2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	6.51	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+08	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+08, 0.00)	0.035
(0+08, 0.00)	(0+14, 2.00)	0.030

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	1.12	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	4.37	ft^2
Wetted Perimeter	8.14	ft
Hydraulic Radius	0.54	ft
Top Width	7.82	ft
Normal Depth	1.12	ft
Critical Depth	0.74	ft
Critical Slope	0.02325	ft/ft

Perimeter Channel Ac2

Results

Velocity		1.49	ft/s
Velocity Head		0.03	ft
Specific Energy		1.15	ft
Froude Number		0.35	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.12	ft
Critical Depth	0.74	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02325	ft/ft

Plateau Channel B1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.02600	ft/ft
Discharge	6.76	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	1.00
0+03	0.00
0+06	0.00
0+15	3.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 1.00)	(0+15, 3.00)	0.030

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	0.42	ft
Elevation Range	0.00 to 3.00 ft	
Flow Area	1.81	ft^2
Wetted Perimeter	5.68	ft
Hydraulic Radius	0.32	ft
Top Width	5.55	ft
Normal Depth	0.42	ft
Critical Depth	0.46	ft
Critical Slope	0.01926	ft/ft

Plateau Channel B1

Results

Velocity		3.73	ft/s
Velocity Head		0.22	ft
Specific Energy		0.64	ft
Froude Number		1.15	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.42	ft
Critical Depth	0.46	ft
Channel Slope	0.02600	ft/ft
Critical Slope	0.01926	ft/ft

Plateau Channel B2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.02000	ft/ft
Discharge	1.26	ft³/s
Section Definitions		

Station (ft)	Elevation (ft)
0+00	3.00
0+09	0.00
0+12	0.00
0+15	1.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 3.00)	(0+15, 1.00)	0.030

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	0.18	ft
Elevation Range	0.00 to 3.00 ft	
Flow Area	0.63	ft²
Wetted Perimeter	4.13	ft
Hydraulic Radius	0.15	ft
Top Width	4.07	ft
Normal Depth	0.18	ft
Critical Depth	0.17	ft
Critical Slope	0.02537	ft/ft

Plateau Channel B2

Results

Velocity		2.00	ft/s
Velocity Head		0.06	ft
Specific Energy		0.24	ft
Froude Number		0.90	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth		0.00	ft
Length		0.00	ft
Number Of Steps		0	

GVF Output Data

Upstream Depth		0.00	ft
Profile Description			
Profile Headloss		0.00	ft
Downstream Velocity		Infinity	ft/s
Upstream Velocity		Infinity	ft/s
Normal Depth		0.18	ft
Critical Depth		0.17	ft
Channel Slope		0.02000	ft/ft
Critical Slope		0.02537	ft/ft

B4 - Vertical Channel 5

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.05000	ft/ft
Left Side Slope	10.00	ft/ft (H:V)
Right Side Slope	10.00	ft/ft (H:V)
Discharge	7.20	ft³/s

Results

Normal Depth	0.43	ft
Flow Area	1.82	ft²
Wetted Perimeter	8.59	ft
Hydraulic Radius	0.21	ft
Top Width	8.54	ft
Critical Depth	0.50	ft
Critical Slope	0.02091	ft/ft
Velocity	3.95	ft/s
Velocity Head	0.24	ft
Specific Energy	0.67	ft
Froude Number	1.51	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.43	ft
Critical Depth	0.50	ft
Channel Slope	0.05000	ft/ft
Critical Slope	0.02091	ft/ft

Perimeter Channel Bc1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	7.62	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+06	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+06, 0.00)	0.030
(0+06, 0.00)	(0+14, 2.00)	0.035

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	1.19	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	4.92	ft^2
Wetted Perimeter	8.63	ft
Hydraulic Radius	0.57	ft
Top Width	8.30	ft
Normal Depth	1.19	ft
Critical Depth	0.78	ft
Critical Slope	0.02277	ft/ft

Perimeter Channel Bc1

Results

Velocity		1.55	ft/s
Velocity Head		0.04	ft
Specific Energy		1.22	ft
Froude Number		0.36	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.19	ft
Critical Depth	0.78	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02277	ft/ft

Perimeter Channel Bc2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	13.92	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+06	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+06, 0.00)	0.030
(0+06, 0.00)	(0+14, 2.00)	0.035

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	1.49	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	7.72	ft^2
Wetted Perimeter	10.82	ft
Hydraulic Radius	0.71	ft
Top Width	10.40	ft
Normal Depth	1.49	ft
Critical Depth	1.00	ft
Critical Slope	0.02101	ft/ft

Perimeter Channel Bc2

Results

Velocity		1.80	ft/s
Velocity Head		0.05	ft
Specific Energy		1.54	ft
Froude Number		0.37	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.49	ft
Critical Depth	1.00	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02101	ft/ft

Plateau Channel C1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.02000	ft/ft
Discharge	1.82	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	1.00
0+03	0.00
0+06	0.00
0+15	3.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 1.00)	(0+15, 3.00)	0.030

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	0.22	ft
Elevation Range	0.00 to 3.00 ft	
Flow Area	0.81	ft²
Wetted Perimeter	4.39	ft
Hydraulic Radius	0.18	ft
Top Width	4.32	ft
Normal Depth	0.22	ft
Critical Depth	0.21	ft
Critical Slope	0.02379	ft/ft

Plateau Channel C1

Results

Velocity	2.26	ft/s
Velocity Head	0.08	ft
Specific Energy	0.30	ft
Froude Number	0.92	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.22	ft
Critical Depth	0.21	ft
Channel Slope	0.02000	ft/ft
Critical Slope	0.02379	ft/ft

C3 - Vertical Channel 2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.20000	ft/ft
Left Side Slope	10.00	ft/ft (H:V)
Right Side Slope	10.00	ft/ft (H:V)
Discharge	1.80	ft³/s

Results

Normal Depth	0.20	ft
Flow Area	0.38	ft²
Wetted Perimeter	3.94	ft
Hydraulic Radius	0.10	ft
Top Width	3.92	ft
Critical Depth	0.29	ft
Critical Slope	0.02516	ft/ft
Velocity	4.69	ft/s
Velocity Head	0.34	ft
Specific Energy	0.54	ft
Froude Number	2.64	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.20	ft
Critical Depth	0.29	ft
Channel Slope	0.20000	ft/ft
Critical Slope	0.02516	ft/ft

C6 - Vertical Channel 3

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.20000	ft/ft
Left Side Slope	10.00	ft/ft (H:V)
Right Side Slope	10.00	ft/ft (H:V)
Discharge	2.11	ft³/s

Results

Normal Depth	0.21	ft
Flow Area	0.43	ft²
Wetted Perimeter	4.18	ft
Hydraulic Radius	0.10	ft
Top Width	4.16	ft
Critical Depth	0.31	ft
Critical Slope	0.02464	ft/ft
Velocity	4.88	ft/s
Velocity Head	0.37	ft
Specific Energy	0.58	ft
Froude Number	2.67	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.21	ft
Critical Depth	0.31	ft
Channel Slope	0.20000	ft/ft
Critical Slope	0.02464	ft/ft

Perimeter Channel Cc1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	6.69	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+06	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+06, 0.00)	0.030
(0+06, 0.00)	(0+14, 2.00)	0.035

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	1.13	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	4.46	ft²
Wetted Perimeter	8.22	ft
Hydraulic Radius	0.54	ft
Top Width	7.90	ft
Normal Depth	1.13	ft
Critical Depth	0.74	ft
Critical Slope	0.02317	ft/ft

Perimeter Channel Cc1

Results

Velocity		1.50	ft/s
Velocity Head		0.03	ft
Specific Energy		1.16	ft
Froude Number		0.35	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.13	ft
Critical Depth	0.74	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02317	ft/ft

Perimeter Channel Cc2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	16.31	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+06	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+06, 0.00)	0.030
(0+06, 0.00)	(0+14, 2.00)	0.035

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	1.58	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	8.70	ft^2
Wetted Perimeter	11.49	ft
Hydraulic Radius	0.76	ft
Top Width	11.04	ft
Normal Depth	1.58	ft
Critical Depth	1.06	ft
Critical Slope	0.02057	ft/ft

Perimeter Channel Cc2

Results

Velocity		1.88	ft/s
Velocity Head		0.05	ft
Specific Energy		1.63	ft
Froude Number		0.37	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.58	ft
Critical Depth	1.06	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02057	ft/ft

Perimeter Channel Cc3

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	17.59	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+06	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+06, 0.00)	0.030
(0+06, 0.00)	(0+14, 2.00)	0.035

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	1.62	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	9.21	ft^2
Wetted Perimeter	11.82	ft
Hydraulic Radius	0.78	ft
Top Width	11.35	ft
Normal Depth	1.62	ft
Critical Depth	1.09	ft
Critical Slope	0.02037	ft/ft

Perimeter Channel Cc3

Results

Velocity		1.91	ft/s
Velocity Head		0.06	ft
Specific Energy		1.68	ft
Froude Number		0.37	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.62	ft
Critical Depth	1.09	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02037	ft/ft

D3 - Vertical Channel 4

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.24000	ft/ft
Left Side Slope	10.00	ft/ft (H:V)
Right Side Slope	10.00	ft/ft (H:V)
Discharge	3.69	ft^3/s

Results

Normal Depth	0.25	ft
Flow Area	0.61	ft^2
Wetted Perimeter	4.98	ft
Hydraulic Radius	0.12	ft
Top Width	4.96	ft
Critical Depth	0.39	ft
Critical Slope	0.02286	ft/ft
Velocity	6.01	ft/s
Velocity Head	0.56	ft
Specific Energy	0.81	ft
Froude Number	3.01	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.25	ft
Critical Depth	0.39	ft
Channel Slope	0.24000	ft/ft
Critical Slope	0.02286	ft/ft

Perimeter Channel Dc1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	3.09	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+08	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+08, 0.00)	0.035
(0+08, 0.00)	(0+14, 2.00)	0.030

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	0.84	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	2.50	ft^2
Wetted Perimeter	6.15	ft
Hydraulic Radius	0.41	ft
Top Width	5.91	ft
Normal Depth	0.84	ft
Critical Depth	0.55	ft
Critical Slope	0.02568	ft/ft

Perimeter Channel Dc1

Results

Velocity		1.24	ft/s
Velocity Head		0.02	ft
Specific Energy		0.87	ft
Froude Number		0.34	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.84	ft
Critical Depth	0.55	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02568	ft/ft

Perimeter Channel Dc2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00250	ft/ft
Discharge	9.39	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	2.00
0+08	0.00
0+14	2.00

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 2.00)	(0+08, 0.00)	0.035
(0+08, 0.00)	(0+14, 2.00)	0.030

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	1.28	ft
Elevation Range	0.00 to 2.00 ft	
Flow Area	5.75	ft^2
Wetted Perimeter	9.34	ft
Hydraulic Radius	0.62	ft
Top Width	8.97	ft
Normal Depth	1.28	ft
Critical Depth	0.85	ft
Critical Slope	0.02214	ft/ft

Perimeter Channel Dc2

Results

Velocity		1.63	ft/s
Velocity Head		0.04	ft
Specific Energy		1.32	ft
Froude Number		0.36	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.28	ft
Critical Depth	0.85	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02214	ft/ft

Reference 2

Rainfall Depths for Delaware* ***(NRCS Type II, 24-Hour Duration)***			
	County		
Storm Event	*New Castle*	*Kent*	*Sussex*
Latitude	39.547 N	39.070 N	38.673 N
Longitude	75.681 W	75.602 W	75.417 W
6-MO (WQ)	2.0	2.0	2.0
1-YR (RPv)	2.7	2.7	2.7
2-YR	3.2	3.3	3.4
5-YR	4.1	4.3	4.4
10-YR (Cv)	4.8	5.2	5.3
25-YR	6.0	6.5	6.7
50-YR	6.9	7.6	7.9
100-YR (Fv)	8.0	8.9	9.2
500-YR	10.9	12.6	13.0

* Ref: NOAA Atlas 14 Volume 2, Version 3

EFFECTIVE DATE: January 1, 2014

Reference 4

Design Criteria

1. Capacity

The minimum capacity shall be that required to confine the peak rate of runoff expected from a 10-year frequency, 24-hour NRCS Type II rainfall event or a higher frequency corresponding to the hazard involved.

Peak rates of runoff values used in determining the capacity requirements shall be based on USDA-NRCS methodology as outlined in TR 55 Urban Hydrology and/or TR 20 Project Formulation - Hydrology. Special situations which warrant a different methodology require approval from the Department.

2. Stability

The recommended methodology for stability design of conveyance channels is the tractive force method. **Design Guide 1** outlines the procedures for this type of analysis. This methodology is applicable to a wider range of lining types (including combination linings) and channel slopes than the allowable velocity method. This allows the use of a single design procedure for most of the water conveyance practices contained in this handbook. Vegetated channels may be specified for maximum design shear stresses less than 2 psf. If the maximum design shear stress is equal to or greater than 2 psf, a lined channel shall be specified.

3. Cross Section

The cross section shall be triangular, parabolic, or trapezoidal.

4. Freeboard

The minimum freeboard for lined channels shall be 0.25 feet above the design high water in areas where erosion-resistant vegetation cannot be grown adjacent to the lining on the side slopes. No freeboard is required where good vegetation can be grown and is maintained.

5. Side Slope

The steepest permissible side slopes, horizontal to vertical will be as follows:

Rock riprap...................2 to 1
Gabions.......................Vertical

6. Lining Thickness - The minimum lining thickness shall be as follows:

Rock riprap...................1.5 x maximum stone size
Gabion..........................9 in. mattress

7. Related Structures

Side inlets, drop structures, and energy dissipators shall meet the hydraulic and structural requirements of the site.

STANDARD AND SPECIFICATIONS FOR VEGETATED CHANNEL

Definition: A natural or man-made channel of parabolic or trapezoidal cross-section that is below adjacent ground level and is stabilized by suitable vegetation. The flow channel is normally wide and shallow and conveys the runoff down the slope to a stable outlet.

Purpose: The purpose of a vegetated channel is to convey runoff without causing damage by erosion.

Conditions Where Practice Applies

Vegetated channels are used where added vegetative protection is needed to control erosion resulting from concentrated runoff. They are generally considered to be permanent structures, but may also be used where the design criteria for temporary conveyance structures are exceeded and an engineered design is required. Vegetated channels intended to act as permantent stormwater management practices shall be designed and constructed in accordance with the **Delaware Post-Constructiion Stormwater BMP Standards & Specifications**.

Design Criteria

1. Capacity

The minimum capacity shall be that required to confine the peak rate of runoff expected from a 10-year frequency, 24-hour NRCS Type II rainfall event or a higher frequency corresponding to the hazard involved.

Peak rates of runoff values used in determining the capacity requirements shall be based on USDA-NRCS methodology as outlined in TR 55 Urban Hydrology and/or TR 20 Project Formulation - Hydrology. Special situations which warrant a different methodology, such as the use of NRCS drainage curves for very flat landscapes, require prior approval from the Department.

2. Stability

All vegetated channels shall be stabilized with a temporary-type matting to accommodate a minimum flow depth of 1 foot. Refer to the Standard and Specifications for Stabilization Matting for additional guidance.

The recommended methodology for stability design of vegetated channels is the tractive force method. **Design Guide 1** outlines the procedures for this type of analysis. This methodology is applicable to a wider range of lining types (including combination linings) and channel slopes than the allowable velocity method. This allows the use of a single design procedure for most of the water conveyance practices contained in this handbook. Vegetated channels may be specified for maximum design shear stresses less than 2 psf. If the maximum design shear stress is equal to or greater than 2 psf, a lined channel shall be specified.

Turf Reinforcement Mats

Types I through IV (TRM-I through TRM-IV) are permanent, non-degradable three-dimensional mattings that provide a matrix for the roots of vegetation to penetrate and entangle. TRMs can be used both in slope applications and as permanent channel liners. Some TRMs offer the option of being soil-filled or non-soil-filled, depending upon the site conditions and desired results.

TRM-I provides permanent soil and turf reinforcement on slopes steeper than 1:1 and in channels where maximum design shear stress over a 50-hour flow duration is 2 psf or less and where natural vegetation alone will not provide long term stabilization. *Example Products: Landlok TRM 450, North American Green P300 and East Coast Erosion Blanket ECP-2 10 oz. (all non-vegetated).*

TRM-II provides permanent soil and turf reinforcement on slopes steeper than 1:1 and in channels where maximum design shear stress over a 50-hour flow duration ranges from 2.1 psf to 5.9 psf and where natural vegetation alone will not provide long term stabilization. *Example Products: North American Green P550 (non-vegetated), Landlok TRM 435 (vegetated), 1060 and 1061B (all vegetated), Mirafi Miramat TM8 (vegetated), Contech C-60 (vegetated) and East Coast Erosion Blanket ECP-2/ECSC-3/ECC-3/ECP-3 (all non-vegetated).*

TRM-III provides permanent soil and turf reinforcement on slopes steeper than 1:1 and in channels where maximum design shear stress over a 50-hour flow duration ranges from 6 psf to 8 psf and where natural vegetation alone will not provide long term stabilization. Products in the **TRM-III** category have a maximum tensile strength in the machine direction of less than 1,500 lbs. *Example Products: North American Green P300 and P550 (vegetated), East Coast Erosion Blanket ECP-2/ECSC-3/ECC-3/ECP-3 (all vegetated) and LandLok 450/1051 (all vegetated).*

TRM-IV provides permanent soil and turf reinforcement on slopes steeper than 1:1 and in channels where the maximum design shear stress over a 50-hour duration of flow ranges from 6 psf to 8 psf and where natural vegetation alone will not provide long term stabilization. Products in the **TRM-IV** category have a maximum tensile strength in the machine direction of 1,500 lbs or greater. **TRM-IV** may be specified for use in stormwater management pond emergency spillways in lieu of riprap (up to a riprap size of R4) where infrequent flow will occur and grass is preferred over riprap. **TRM-IV** is not applicable as a replacement for riprap in areas of outlet protection where concentrated flow is anticipated. *Example Products: Pyramat High Performance TRM and East Coast Erosion Blanket T-RECS (all vegetated).*

Table 3. Manning's Roughness Coefficients.

Lining Category	Lining Type	n - value[1] Depth Ranges 0-0.5 ft (0-15 cm)	 0.5-2.0 ft (15-60 cm)	 >2.0 ft (> 60 cm)
Rigid	Concrete	0.015	0.013	0.013
	Grouted Riprap	0.040	0.030	0.028
	Stone Masonry	0.042	0.032	0.030
	Soil Cement	0.025	0.022	0.020
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.023	0.020	0.020
	Rock Cut	0.045	0.035	0.025
Temporary*	Woven Paper Net	0.016	0.015	0.015
	Jute Net	0.028	0.022	0.019
	Fiberglass Roving	0.028	0.021	0.019
	Straw with Net	0.065	0.033	0.025
	Curled Wood Mat	0.066	0.035	0.028
	Synthetic Mat	0.036	0.025	0.021
Gravel Riprap	1-inch (2.5-cm) D_{50}	0.044	0.033	0.030
	2-inch (5-cm) D_{50}	0.066	0.041	0.034
Rock Riprap	6-inch (15-cm) D_{50}	0.104	0.069	0.035
	12-inch (30-cm) D_{50}	--	0.078	0.040

[1] Based on data in (<u>5</u>, <u>8</u>, <u>13</u>, <u>14</u>, and <u>15</u>).

Note: Values listed are representative values for the respective depth ranges. Manning's roughness coefficients, n, vary with the flow depth. See Appendix B.

*Some "temporary" linings become permanent when buried.

Reference 5

Material Specifications. All vegetated channels shall require a biodegradable erosion control matting conforming to *Delaware Erosion and Sediment Control Handbook* that is durable enough to last at least 12 months. Recommended material specifications for vegetated channels are shown in **Table 8.3**.

Enhancement using Soil Amendments. Soil compost amendments serve to increase the runoff reduction capability of a vegetated channel. The following design criteria apply when soil amendments are used:

- The soil amendments should extend over the length and width of the channel bottom, and the compost should be incorporated to a depth as outlined in *Post Construction Stormwater BMP Standards and Specifications for Soil Amendments*.
- The amended area will need to be rapidly stabilized with perennial, salt tolerant grass species if adjacent to a roadway.
- For vegetated channels on steep slopes, it may be necessary to install a protective biodegradable stabilization matting to protect the compost-amended soils. Care must be taken to consider the erosive characteristics of the amended soils when selecting appropriate turf reinforcement matting.

Sizing. Unlike other stormwater practices, vegetated channels are designed based on a peak rate of flow. Designers must demonstrate channel conveyance and treatment capacity in accordance with the following guidelines:

- Hydraulic capacity should be verified using Manning's Equation or an accepted equivalent method, such as tractive forces and vegetal retardance.
  - Design storm flow depth based on 50% of RPv peak flow rate should be maintained at 4 inches or less.
  - Manning's "n" value for vegetated channels should be 0.2 for flow depths up to 4 inches, decreasing to 0.03 above 4 inches of flow depth.
  - Peak flow rates for the Cv and Fv storms must be non-erosive (less than 3 fps), or subject to a site-specific analysis of the channel lining material and vegetation. Examples of site-specific analysis ranges can be found in **Table 8.5** below (see ***Section 8.7 Vegetated Channel Landscaping Criteria***);
  - The Cv peak flow rate must be contained within the channel banks.
  - If the Fv storm event is not contained within the channel, the area of inundation must be shown.
- Calculations for peak flow depth and velocity should reflect any increase in flow along the length of the channel, as appropriate. If a single flow is used, the flow at the outlet should be used.
- Hydraulic residence times (the time for runoff to travel the full length of the channel) for both Bioswales and Grassed Channels are computed based upon 50% of the RPv peak flow rate.
  - For Bioswales, the hydraulic residence time should be a minimum of 9 minutes for the design storm (Mar et al., 1982; Barrett et al., 1998; Washington State Department of Ecology, 2005). If flow enters the channel at several locations, a 9 minute minimum

Appendix 5. Design of Stormwater Conveyance Systems

The Chezy-Manning formula is to be used to compute the system's transport capacities:

$$Q = \frac{1.486}{n} \times A \times R^{2/3} \times S^{1/2}$$

Where:

Q = channel flow (cfs)
n = Manning's roughness coefficient (Table A.1)
A = cross-sectional area of flow (ft^2)
R = hydraulic radius (ft)
S = channel slope (ft/ft)

Table A-5.1 Manning's Roughness Coefficient (n) Values for Various Channel Materials

Channel Materials	**Roughness Coefficient**
Concrete pipe and precast culverts	0.013
Monolithic concrete in boxes, channels	0.015
PVC pipes 24" to 36" 42" and larger	0.011 0.019 0.021
Sodded channel with water depth < 1.5'	0.050
Sodded channel with water depth >1.5'	0.035
Smooth earth channel or bottom of wide channels with sodded slopes	0.025
Rip-rap channels	0.035

Note: Where drainage systems are composed of more than one of the above channel materials, a composite roughness coefficient must be computed in proportion to the wetted perimeter of the different materials.

Culvert Calculations

Date:	12/27/19	**Made by:**	ZEG
Project No.:	19129265	**Checked by:**	JPG
Site Name:	Edge Moore Site II Ash Landfill	**Reviewed by:**	PAW 12/30/19
Subject:	**CULVERT CALCULATIONS**		

1.0 OBJECTIVE

Design a corrugate polyethylene (CPE) pipe culvert to convey flow from the northwest perimeter channel beneath the proposed perimeter access road at the Edge Moor Site II Ash Landfill (Site) in Wilmington, Delaware using the associated peak flow for the design storm within the channel at the inlet of the culvert. Determine an appropriate culvert outlet protection for the downstream channel reach.

2.0 REFERENCES

1) SCS Technical Release 55 (TR-55) Urban Hydrology for Small Watersheds, June 1986.

2) Rainfall Depths for Delaware, National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 2, Version 3, January 2014.

3) "Top of Final Grade Plan" drawing prepared by Golder Associates Inc., December 2019.

4) "Channel Calculations" report prepared by Golder Associates Inc., January 2020.

5) Pennsylvania Department of Environmental Protection, "Erosion and Sediment Pollution Control Program Manual," March 2012.

6) Bentley Systems Inc., Bentley FlowMaster V8i, November 2009.

7) Bentley Systems Inc., Bentley CulverMaster v.3.3, 2009.

8) HydroCAD Software Solutions LLC, HydroCAD 8.50, July 2011.

3.0 METHODOLOGY

Using the CulvertMaster software (Reference 7), evaluate the size and number of culvert pipes needed to:

- Convey the channel flows (Reference 3);
- Maintain an outlet velocity that is acceptable for the downstream channel lining; and
- Ensure the upstream channel does not overtop.

Using the FlowMaster Software (Reference 6), verify the outlet velocity in the downstream channel and select an outlet protection channel lining.

4.0 ASSUMPTIONS

1) Manning's "n" value of 0.012 will be used for corrugate polyethylene smooth pipe culvert as presented in Reference 7.

2) The stormwater calculations performed for the Channel Calculations (Reference 4) are valid and the contributing drainage areas and flows from the 25-year, 24-hour storm can be applied to the current calculation.

3) Reno mattresses, nine (9) inches thick, can adequately accept velocities up to 12.0 ft/sec (Reference 5).

4) The channel slopes were measured from Reference 3, the top of final grade plan.

5) The maximum allowable headwater for the culvert is the top elevation of the perimeter channel.

6) The V-ditch channel will widen upstream of the culvert inlet to allow for one foot between each pipe and one foot between a pipe and the edge of the channel side slopes (See Reference 3).

5.0 CALCULATION

1) The drainage subareas are shown in Reference 3. The northwest channel has a maximum flow rate of 17.59 cfs (Reference 4).

2) The northwest channel is lined with aggregate on the landfill side and vegetated on the opposing side, with a bottom slope of 0.25% and a minimum depth of 2.0 feet. Utilizing CulvertMaster, the culvert crossing was analyzed using the input elevations from the top of final grade plan (Reference 3). The upstream and downstream invert elevations are 7.55 feet and 7.45 feet, respectively, and the top elevation of the perimeter channel is 10.40 feet. The culvert will be 38 feet long.

3) The number and diameter of the culvert pipes were varied iteratively in CulvertMaster until the minimum acceptable configuration was determined. Once the size and number of culverts was approximately determined, the outlet velocity and headwater elevation were examined (See Table 1).

4) The headwater elevation was below the top elevation of the upstream perimeter channel. The outlet velocity for the pipe culverts was below eight (8) feet per second.

Table 1: Culvert Design Summary

Culvert Location	Culvert ID	Pipe Amount & Size	25-Yr, 24-Hr Peak Discharge (cfs)	Culvert Outlet Velocity (fps)	Allowable Channel Lining Velocity (fps)	Culvert Slope (ft/ft)	Channel Headwater / Freeboard (ft)
Northwest	1	Two 15”	17.59	7.45	12.0	0.0026	0.18

6.0 CONCLUSION

The culvert requires two (2) minimum 15-inch diameter CPE pipe culverts. Per Assumption 3 and the calculated culvert outlet velocity, 9-inch reno mattresses are sufficient at the culvert outlet invert.

Culvert Calculator Report
Northwest Culvert

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	10.40	ft	Headwater Depth/Height	2.13	
Computed Headwater Elev	10.22	ft	Discharge	17.59	cfs
Inlet Control HW Elev.	10.04	ft	Tailwater Elevation	7.45	ft
Outlet Control HW Elev.	10.22	ft	Control Type	Outlet Control	

Grades

Upstream Invert	7.55	ft	Downstream Invert	7.45	ft
Length	38.00	ft	Constructed Slope	0.002632	ft/ft

Hydraulic Profile

Profile	CompositeM2PressureProfile		Depth, Downstream	1.15	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	1.15	ft
Velocity Downstream	7.45	ft/s	Critical Slope	0.013722	ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.012	
Section Material	Corrugated HDPE (Smooth Interior)	Span	1.25	ft
Section Size	15 inch	Rise	1.25	ft
Number Sections	2			

Outlet Control Properties

Outlet Control HW Elev.	10.22	ft	Upstream Velocity Head	0.80	ft
Ke	0.20		Entrance Loss	0.16	ft

Inlet Control Properties

Inlet Control HW Elev.	10.04	ft	Flow Control	Submerged	
Inlet Type	Groove end projecting		Area Full	2.5	ft^2
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Worksheet for Perimeter Channel Cc4

Project Description

Friction Method	Manning Formula		
Solve For	Normal Depth		

Input Data

Roughness Coefficient		0.033	
Channel Slope		0.00250	ft/ft
Left Side Slope		3.00	ft/ft (H:V)
Right Side Slope		3.00	ft/ft (H:V)
Bottom Width		5.50	ft
Discharge		17.59	ft³/s

Results

Normal Depth		1.07	ft
Flow Area		9.36	ft²
Wetted Perimeter		12.29	ft
Hydraulic Radius		0.76	ft
Top Width		11.94	ft
Critical Depth		0.61	ft
Critical Slope		0.02076	ft/ft
Velocity		1.88	ft/s
Velocity Head		0.05	ft
Specific Energy		1.13	ft
Froude Number		0.37	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth		0.00	ft
Length		0.00	ft
Number Of Steps		0	

GVF Output Data

Upstream Depth		0.00	ft
Profile Description			
Profile Headloss		0.00	ft
Downstream Velocity		Infinity	ft/s
Upstream Velocity		Infinity	ft/s
Normal Depth		1.07	ft
Critical Depth		0.61	ft
Channel Slope		0.00250	ft/ft

Worksheet for Perimeter Channel Cc4

GVF Output Data

Critical Slope	0.02076	ft/ft

Reference 2

Rainfall Depths for Delaware* (NRCS Type II, 24-Hour Duration)			
	County		
Storm Event	*New Castle*	*Kent*	*Sussex*
Latitude	39.547 N	39.070 N	38.673 N
Longitude	75.681 W	75.602 W	75.417 W
6-MO (WQ)	2.0	2.0	2.0
1-YR (RPv)	2.7	2.7	2.7
2-YR	3.2	3.3	3.4
5-YR	4.1	4.3	4.4
10-YR (Cv)	4.8	5.2	5.3
25-YR	6.0	6.5	6.7
50-YR	6.9	7.6	7.9
100-YR (Fv)	8.0	8.9	9.2
500-YR	10.9	12.6	13.0

* Ref: NOAA Atlas 14 Volume 2, Version 3

EFFECTIVE DATE: January 1, 2014

Reference 5

TABLE 6.10
Maximum Permissible Velocities and Shear Stresses for Reno Mattress and Gabions

Type	n	Thickness Inches	Rock Fill Gradation (in)	Permissible Velocity (fps)	Permissible Shear Stress (lb/ft^2)
Reno Mattress	.026 - .030	6	3 - 6	6.0	4.27
	.026 - .030	9	3 - 6	12.0	4.58
Gabion	.026 - .030	12	3 - 6	15.0	4.73
	.028 - .030	18	4 - 6	18.0	5.20
	.029 - .032	36	5 - 9	22.0	8.35

Adapted from Maccaferri Gabions, Inc.

5. Calculate the Required Freeboard.

Determine whether stable or unstable flow conditions exist. Uniform flow at or near "critical depth" is unstable due to waves present at the water's surface. Since the height of the waves may exceed the top of the channel, sufficient freeboard should be provided to prevent channel failure. The procedure for determining whether channel flow conditions are stable or unstable is as follows:

Compute the channel's critical slope:

$$S_c = 14.56\ n^2 D_m / R^{4/3}$$

Where:
- S_c = critical slope (ft/ft)
- n = Manning's "n"
- D_m = mean depth of flow = A/T (ft)
- A = cross-sectional area of the channel (sq. ft.)
- T = channel top width at the water surface (ft)
- R = hydraulic radius = A/P (ft)
- P = wetted perimeter (ft)

Unstable flow occurs when $0.7S_c \leq S_o \leq 1.3S_c$

Where: S_o = channel bed slope.

Compute the minimum required freeboard.

If unstable flow conditions exist, compute the minimum required freeboard as follows:

$$F = (0.025\ V)\ (3\ D) = 0.075\ VD$$

Where:
- F = minimum freeboard in feet
- V = velocity in fps
- D = flow depth in feet

For stable flow conditions, the minimum freeboard should be 25% of the flow depth.

The minimum freeboard for any channel is 6".

6. Provide suitable outlet protection for all channels. See outlet protection section of this manual.

DrainTube Calculations

Date:	12/09/19 Revised February 2020 Revised April 2020	**Made by:** **Checked by:** **Reviewed by:**	ZEG JPG PAW
Project No.:	19129265	**Revised by:** **Checked by:**	JPG ANO
Site Name:	Edge Moor Site II Ash Landfill	**Reviewed by:**	PAW
		Revised by: **Checked by:** **Reviewed by:**	JPG ANO PAW 4/7/2020

Subject: **DRAINTUBE CALCULATIONS**

1.0 OBJECTIVE

To evaluate the flow within the soil on the plateau of the Edge Moor Site II Ash Landfill (Site) and the capacity necessary to transport the flow through DrainTube® down the Vertical Channels slopes of the landfill.

2.0 REFERENCES

1) SCS Technical Release 55 (TR-55) Urban Hydrology for Small Watersheds, June 1986.

2) Rainfall Depths for Delaware, National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 2, Version 3, January 2014.

3) "Construction Site Stormwater Management Plan" drawing prepared by Golder Associates Inc., January 2020.

4) Bentley Systems Inc., Bentley FlowMaster, V8i, November 2009.

3.0 METHODOLOGY

Calculate the percolation into the soil based on a given storm event and the expect CN for the landfill after construction and proper vegetation. Using the percolation and the area of rainfall on the plateau of the landfill, the subsurface flow that will contribute to each vertical channel is determined. These flows are compared to the flow capability of DrainTube® and a factor of safety is calculated at each vertical channel location, where the DrainTube® is located. If the factor of safety is less than 1.5, then additional 4" pipe(s) will be included to handle the flow sufficiently.

4.0 ASSUMPTIONS

1) The soil type is assumed to be a class C and the estimated curve number (CN) for the landfill is 86.

2) The subsurface flow on the plateau of the landfill (the crown) is directed, via grading and a small berm around the crown, to vertical channels along the steep slopes.

3) The steep slopes along the toe of the landfill range from 4H:1V to 7H:1V slopes, with a small bench at a 5% slope at the southeast toe.

4) A 25-year, 24-hour storm event is 6.0 inches for New Castle County, Delaware (Reference 2). This is required for surface water management, as specified by Delaware's Regulations Governing Solid Waste (DRGSW) § 6.6.2.2, and will also be used for subsurface water management.

5) The selected DrainTube will have 4 tubes per meter with a diameter of 25 mm per tube.

6) The hydraulic transmissivity used to calculate the flow capacity within DrainTube® will be 3.25×10^{-3} m^2/s (see the attached graph).

7) Each vertical channel is 10' wide, or approximately 3 meters, which will be the width necessary to calculate the flow capacity within DrainTube®.

8) Additional pipes will have a diameter of 4 inches and will be made of high-density polyethylene (HDPE) with a conservative Manning's n value of 0.015.

9) For conservatism, the capacity of the drainage layer below (in the vertical channel) is not considered.

5.0 CALCULATION

1) Contributing drainage areas were identified and measure for each vertical channel in which the DrainTube® is installed (Reference 3).

2) Darcy's formula was used to calculate the volumetric flow rate capacity within DrainTube®:

$$q = K \times i \times A$$

Which can also be written as follows:

$$q = \theta \times i \times W$$

Where:

q	=	Volumetric flow rate (m^3/s)
θ	=	Transmissivity (m^2/s)
i	=	Hydraulic gradient (dimensionless)
W	=	Width (m)

The volumetric flow rate should be calculated for the minimum gradient of each subarea. An example calculation is shown below, where the slope is 25%. The volumetric flow rate capacities for each DrainTube location is summarized in Table 1.

$$q = (3.25 \times 10^{-3}) \times (0.25) \times (3)$$

$$q = 2.44 \times 10^{-3} \ m^3/sec$$

3) These volumetric flow rates will be compared to the flows computed from percolation into the soil. With a 25-year, 24-hour storm event producing 6.0 inches of precipitation and a CN of 86, the surface runoff (SR) is 4.41 inches (calculated from Reference 1). Then the percolation (PERC) is calculated below:

$$PERC = P - SR = 6.0 - 4.41 = 1.59 \text{ in/day} = 4.7 \times 10^{-7} \text{ m/sec}$$

The flow within a given subarea contributing to each DrainTube® location is calculated by multiplying the percolation by the plateau area. An example calculation is given below for DrainTube® located below the vertical channel A3. All percolation flows are included in Table 1.

$$q_{PERC} = (PERC) \text{ X } (Area) = (4.7 \times 10^{-7} \ m^2/s) \times (3124 \ m^2) = 1.47 \times 10^{-3} \ m^3/s$$

4) An adequate factor of safety is necessary to ensure DrainTube® can properly manage the expected flow at each location. Any safety factor below 1.5 will require additional pipes to mitigate flooding issues. The safety factors for each DrainTube® location are shown in Table 1.

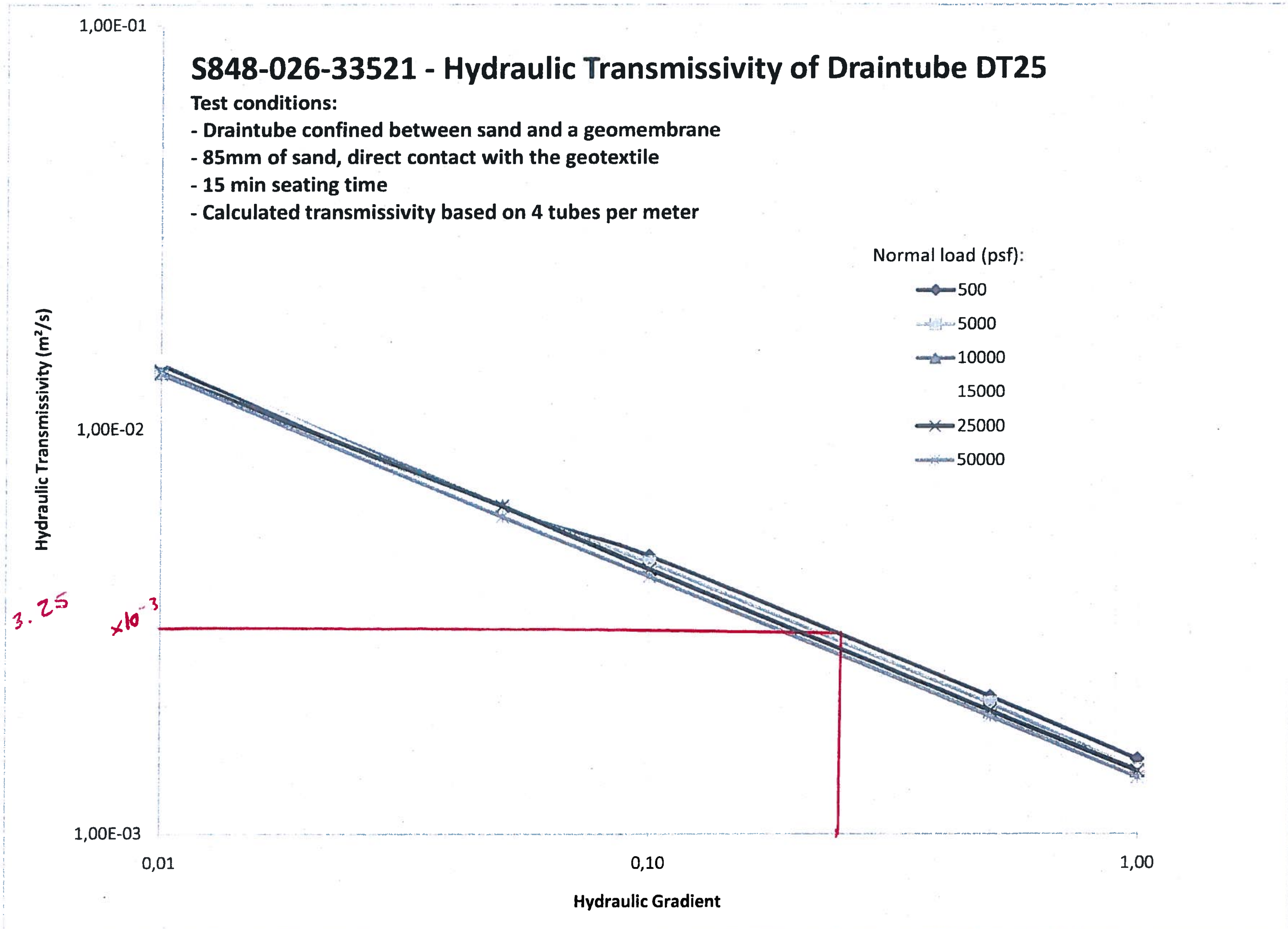
Table 1: Percolation flow within each plateau subarea and DrainTube's maximum flow capacity

DrainTube Location	Vertical Channel ID	Contributing Area (m^2)	Percolation Flow (m^3/s)	Minimum Slope	DrainTube Capacity (m^3/s)	Safety Factor
Southwest	VC1	3124	1.47×10^{-3}	25%	2.44×10^{-3}	1.66
Southeast	VC5	5341	2.51×10^{-3}	5%	4.88×10^{-4}	0.19(5)
Northwest	VC2	1343	6.31×10^{-4}	20%	1.95×10^{-3}	3.09
	VC3	1756	8.25×10^{-4}	20%	1.95×10^{-3}	2.36
Northeast	VC4	3088	1.45×10^{-3}	24%	2.34×10^{-3}	1.61

5) As seen in Table 1, DrainTube® can adequately handle the subsurface flow at all locations except at Vertical Channel VC5. This DrainTube® location is conservative since the entire slope is not 5%, only a portion of it is. However, even with an entire slope of 25% a pipe is still required. To analyze the capacity of a 4” pipe, the FlowMaster software was used (Reference 4). The pipe with full capacity can withstand a maximum flow of 0.36 ft^3/s, or 1.02×10^{-2} m^3/s. In addition to DrainTube®, this location can now accommodate a maximum flow of 1.07×10^{-2} m^3/s, with a new safety factor of 4.26. Attached is the FlowMaster report for reference.

6.0 CONCLUSION

Darcy's formula was used to calculate the flow capacity for DrainTube® at each location and was then compared to the percolation flow within each contributing subarea to determine the factor of safety. With one additional 4” pipe at Vertical Channel VC5, the factor of safety increases to over 4. All DrainTube® locations have acceptable safety factors. The lowest safety factor is 1.61 at Vertical Channel VC4.


S848-026-33521 - Hydraulic Transmissivity of Draintube DT25
Test conditions:
- Draintube confined between sand and a geomembrane
- 85mm of sand, direct contact with the geotextile
- 15 min seating time
- Calculated transmissivity based on 4 tubes per meter
Normal load (psf):
500
5000
10000
15000
25000
50000
Hydraulic Transmissivity (m²/s)
1,00E-01
1,00E-02
1,00E-03
3.25
x10^-3
0,01
0,10
1,00
Hydraulic Gradient

4" Pipe Capacity

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.05000	ft/ft
Normal Depth	0.33	ft
Diameter	0.33	ft

Results

Discharge	0.36	ft^3/s
Flow Area	0.09	ft^2
Wetted Perimeter	1.04	ft
Hydraulic Radius	0.08	ft
Top Width	0.00	ft
Critical Depth	0.31	ft
Percent Full	100.0	%
Critical Slope	0.04327	ft/ft
Velocity	4.20	ft/s
Velocity Head	0.27	ft
Specific Energy	0.60	ft
Froude Number	0.00	
Maximum Discharge	0.39	ft^3/s
Discharge Full	0.36	ft^3/s
Slope Full	0.05000	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s

4" Pipe Capacity

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	0.33	ft
Critical Depth	0.31	ft
Channel Slope	0.05000	ft/ft
Critical Slope	0.04327	ft/ft

Sediment Trap Calculations

Date:	12/11/19	**Made by:**	ZEG
Project No.:	19129265	**Checked by:**	ANO
Site Name:	Edge Moore Site II Ash Landfill	**Reviewed by:**	1/8/2020
Subject:	**SEDIMENT TRAP CALCULATION**		

1.0 OBJECTIVE

To evaluate the size of each sediment trap at the Edge Moor Site II Ash Landfill based on their contributing drainage areas and regulations specified by Delaware Department of Natural Resources and Environmental Control.

2.0 REFERENCES

1) Delaware Department of Natural Resources and Environmental Control (DNREC), "Delaware Erosion and Sediment Control Handbook," March 2013.

2) "Construction Site Stormwater Management Plan" drawing prepared by Golder Associates Inc., December 2019.

3.0 METHODOLOGY

The subareas that contribute to each sediment trap are identified (Reference 2) and the sediment traps can then be sized. Each sediment trap is computed to have a capacity of 3,600 cubic feet of stormwater runoff for each contributing acre (Reference 1).

4.0 ASSUMPTIONS

1) The sediment traps will be made of compost logs, which will have a minimum effective height (1H:1V) of at least three (3) feet as required by DNREC (Reference 1).

2) There shall be a freeboard of 1 foot as per DNREC's requirements for Compost Log Sediment Traps (Reference 1).

3) A check dam will be placed prior to a perimeter channel discharging into the sediment trap (Reference 1). An additional portion of the compost logs will extend past the check dam to ensure water flow is contained within the sediment trap.

4) Compost logs will meet the requirements as described in "3.1.7 Standards & Specifications for Compost Filter Log" of the Delaware Erosion and Sediment Control Handbook (Reference 1).

5) The maximum accumulation of sediment in each trap will be one half (1/2) of the trap's effective height (Reference 1).

6) A spillway will be incorporated into the sediment trap design, where the top of the freeboard is measured from the bottom of the spillway weir. A turf reinforcement mat will be extended past the spillway.

7) The weir height must be at least 6 inches.

5.0 CALCULATION

1) The contributing drainage area for each sediment trap was identified and is summarized in Table 1.

2) An effective height of four (4) feet from the base of the weir, with two (2) feet for sediment storage and one (1) foot as freeboard, allows for one (1) foot of water height capacity. For construction, the sediment traps will be five (5) feet in height. The weir will be six (6) inches in depth and, thus, the invert of the weir must be a 4.5 feet high from the base of the compost logs.

3) The resulting storage volume was then calculated, and example dimensions are provided in Table 1. The sediment traps are shown on the Construction Site Stormwater Management Plan (Reference 2). These dimensions are estimated and will be:

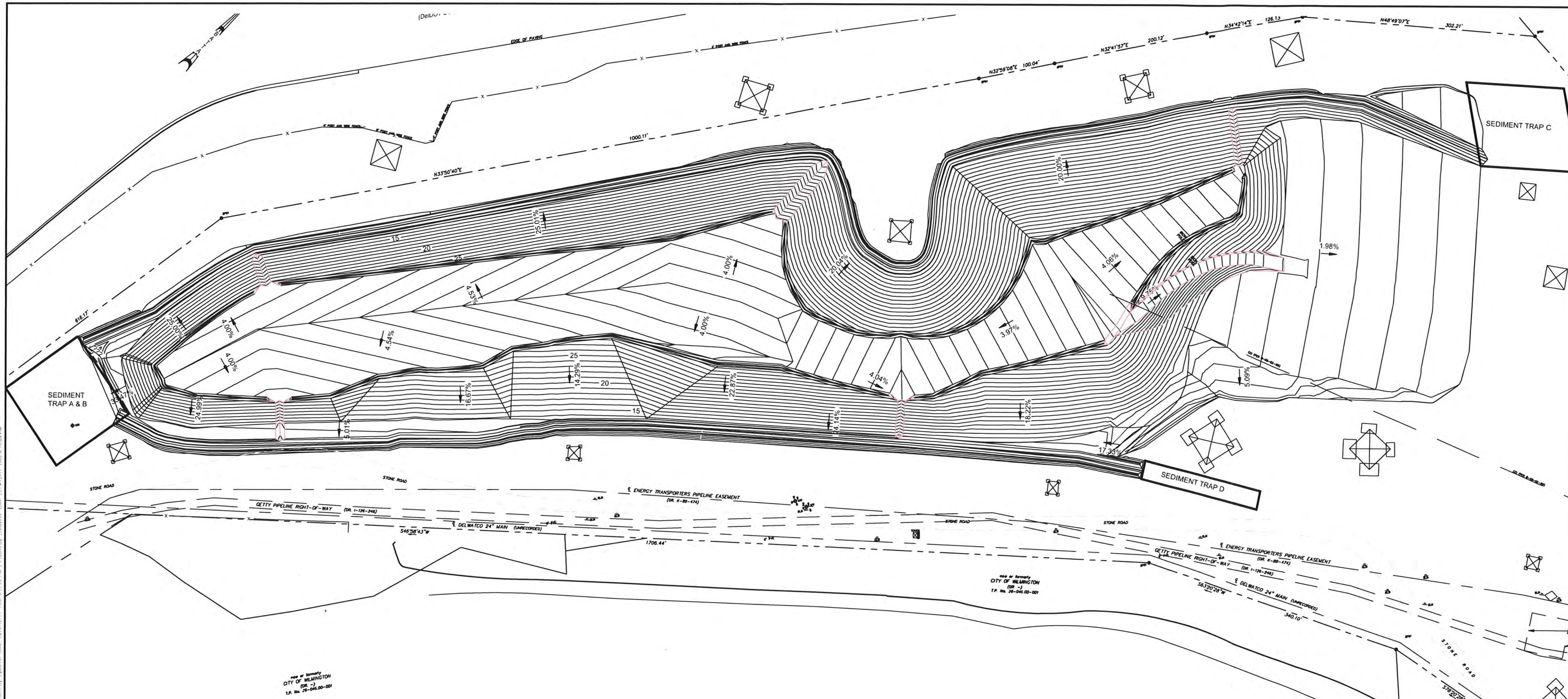
Table 1: Sediment Trap Flow Volume and Dimensions

Sediment Trap Location	Sediment Trap ID	Contributing Area (ac)	Volume (ft^3)	Dimensions*† (ft x ft)
South	A + B	3.801	13,684	115 x 120
Northwest	C	3.849	13,856	110 x 126
Northeast	D	1.732	6,235	40 x 156

*These dimensions are approximate and may be adjusted during placement.
†Dimensions are directly related to the effective height (e.g. shorter effective height results in a larger area).

6.0 CONCLUSION

The volume for each sediment trap was calculated and the approximate dimensions and location were given. With these dimensions and an effective height of four (4) feet, the sediment traps can adequately manage the expected volumes. This calculation conservatively assumes the sediment traps will sufficiently hold water when the sediment buildup is half the effective height, which is the maximum sediment height before maintenance is required. For construction, the sediment traps will be five (5) feet in height. The weir will be six (6) inches in depth and, thus, the invert of the weir must be a 4.5 feet high from the base of the compost logs.



Workins Figure 1

SEDIMENT TRAP CALCULATION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	####
####	####	####	####	####	####	####	####
####	####	####	####	####	####	####	####
####	####	####	####	####	####	####	####
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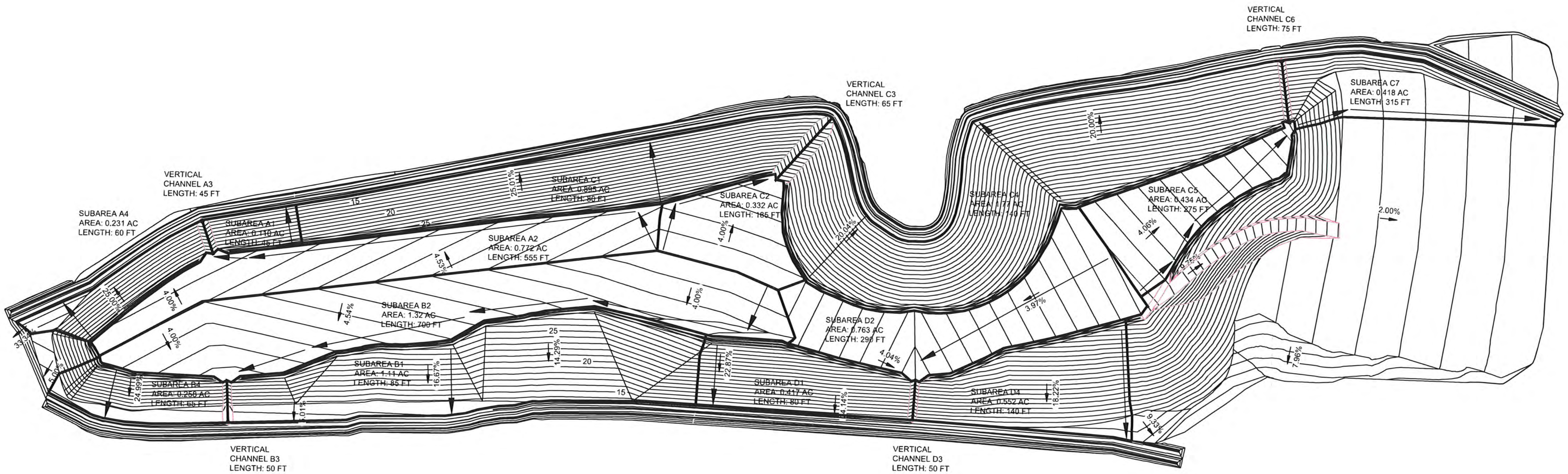

Working Figure 2
SEDIMENT TRAP CALCULATION

####	####	####	####	####	####	####	####	
####	####	####	####	####	####	####	####	
####	####	####	####	####	####	####	####	
####	####	####	####	####	####	####	####	
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REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	####	

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Date:	12/16/19 Revised February 2020	Made by:	ZEG
Project No.:	19129265	Checked by:	JPG
Site Name:	Edge Moor Site II Ash Landfill	Reviewed by:	PAW
		Revised by:	JPG
		Checked by:	ANO
		Reviewed by:	PAW 3/27/2020

Subject: **SLOPE STABILITY ANALYSIS FOR FINAL COVER**

1.0 OBJECTIVE

To evaluate the veneer stability, including geocomposite drainage layer capacity, during the placement of the 24-inch thick final cover as well as the long-term stability of the side slope cap system for the Edge Moor Site II Ash Landfill.

2.0 REFERENCES

1) The Design of Drainage Systems Over Geosynthetically Lined Slopes, GRI Report #19, by T.Y. Soong, R.M. Koerner, 1997.

2) Design of Lateral Drainage Systems for Landfills, Richardson, J.P. Giroud, and A. Zhao, 2000.

3) Peak Ground Acceleration (%g) with 2% Probability of Exceedance in 50 Years, USGS Map, April 2014.

4) Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces, G.R. Koerner, D. Narejo, GRI Report #30, 2005.

5) Rainfall Depths for Delaware, National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 2, Version 3, January 2014.

6) SCS Technical Release 55 (TR-55) Urban Hydrology for Small Watersheds.

7) Cover Soil Slope Stability Involving Geosynthetic Interfaces, GRI Report #18, by T.Y. Soong, R.M. Koerner, 1996.

8) "Final Grading Plan" drawing prepared by Golder Associates Inc. January 2020.

9) Caterpillar Performance Handbook, Caterpillar, Edition 48, June 2018.

10) GRI Standard GC-8

11) Actual 100 hour transmissivity testing for Agru MicroDrain®

3.0 METHODOLOGY

1) There are assumed reduction factors that will be used to determine the factor of safety for the geocomposite drainage layer capacity.

2) Using precipitation data from a reoccurring storm event, the surface runoff and percolation values will be determined.

3) The percolation value will be used to calculate the necessary transmissivity for the required factor of safety.

4) Based on further assumptions in the next section, these values can also be used to create a figure plotting the relationship between the slope length and the interface friction angle.

2) The interface friction angle can then be estimated based on the known slope length.

3) Using the assumptions and the estimated interface friction angle, an example calculation will illustrate that the assumed factors of safety are upheld.

4.0 ASSUMPTIONS

1. The cap system side slope ranges from 7H:1V to 4H:1V and the plateau ranges from 4% to 5%. For the transmissivity evaluation, a worst case for the sideslope condition will be used to asses one (1) common transmissivity value for all of the drainage layer to be used in the final cover system. This condition will assume the longest slope length for the shallowest of the varying sidelsopes. The shallower plateau slope will not be evaluated as the slope stability of this feature is of little concern. The following conditions will be evaluated to represent the worst-case condition for each:

   a) For slope stability: The steepest slope is 4H:1V. Conservatively the longest length is assumed to be 115 feet long, the same as the longest shallower slope, and will be used to calculate the slope stability.

   b) For transmissivity: The longest slope on the 7H:1V slope is 115 feet. Thus, transmissivity calculations and specification will use a minimum 7H:1V slope to simulate the worst-case transmissivity for the shallowest of the sideslope gradients.

2. The proposed side slope cap system will consist of the following components from top to bottom:

Primary Option	**Alternate Option #1**	**Alternate Option #2**
Vegetation	Vegetation	Vegetation
6-inch topsoil layer	6-inch topsoil layer	6-inch topsoil layer
18-inch soil layer	18-inch soil layer	18-inch soil layer
Geocomposite	10 oz/sy nonwoven geotextile	10 oz/sy nonwoven geotextile
40-mil LLDPE or HDPE textured geomembrane	50-mil LLDPE or HDPE Agru Super GripNet® combination geomembrane/drainage	50-mil LLDPE or HDPE Agru MicroDrain® combination geomembrane/drainage
6-inch grading fill layer	6-inch grading fill layer	6-inch grading fill layer

3. The final cover layer has a unit weight of 125 pcf, angle of internal friction of 32°, and no cohesion.

4. The final cover layer will adequately drain the anticipated storm; therefore, no seepage force is expected. Permeability of the cover soil is assumed to be $1x10^{-4}$ cm/sec = 1×10^{-6} m/sec, which is comparable to a silty sand.
5. From Reference 1, reduction factors for geocomposite capacity used for intrusion, chemical clogging, and biological clogging were 1.4, 1.2, and 1.75, respectively. Based on GRI GC8 (Reference 10), the reduction factor for creep can be eliminated if the transmissivity value for a 100-hour test is used. Since no trees or shrubs will be allowed on the cover soil once seeding has taken place, due to possible interference with nearby electrical towers, no reduction factor for root intrusion has been applied to this analysis.
6. The target DLC factor of safety incorporates both the drainage layer factor of safety and the reduction factors for the geocomposite transmissivity. The product of these safety factors must be greater than or equal to 6.0.
7. The target factors of safety against frictional veneer instability at the cover are 1.5, 1.3, and 1.0 against static (gravitational), construction and seismic loading, respectively.
8. Low ground pressure equipment will be used to place the final cover layer. Assume a typical CAT D6N LGP will be used.
9. The seismic coefficient is taken from Reference 3 and is based on the geographic location of the site. Based on 40 CFR § 257.63, the landfill shall be designed to resist the maximum horizontal acceleration with 2% probability of exceedance in 50 years (which is equivalent to 10% probability of exceedance in 250 years). This peak ground acceleration is typically found using the USGS Seismic Hazard Maps. The USGS Seismic Hazard Maps were updated in 2014 and can be found at the USGS National Seismic Hazard Mapping Project website (http://earthquake.usgs.gov/hazards/hazmaps/). The map for 10% probability of exceedance in 250 years was not published; therefore, the map for 2% probability of exceedance in 50 years is used, which is equivalent to the 10% probability in 250 years.

   The maximum horizontal acceleration for the site is 0.0986g. Based on the recommendation of Reference 2, the horizontal acceleration coefficient to be used for pseudo-static seismic slope analyses is as follows:

   $$k_{horizontal} = 0.5\ a_{horizontal\ (max)} / g$$

   $$= 0.5\ (0.0986g)/g$$

   $$= 0.0493$$

   The owner did not complete the necessary seismic impact zone demonstration by October 17, 2018, as stated in § 257.63(c)(1), since the landfill ceased placing coal combustion residuals (CCR) prior to this date. As a result, the site is in compliance with the requirement to cease placing CCR no later than October 31, 2020, as stated in § 257.101(b)(1)(i). This closure application is intended to close the CCR unit in accordance with the requirements of § 257.102.
10. The Curve Number (CN) for the final conditions is 86.
11. A 25-year, 24-hour storm event, as required by Delaware’s Regulations Governing Solid Waste (DRGSW) § 6.6.2.2, is 6.0 inches for New Castle County, Delaware (Reference 5).

5.0 DEFINITIONS

β	=	slope angle
δ	=	interface friction angle
ϕ_{req}	=	minimum required interface friction angle
ϕ_c	=	internal shear strength of cover soil
γ_w	=	unit weight of water = 62.4 pcf
γ_d	=	dry unit weight of cover soil
γ_{sat}	=	saturated unit weight of cover soil
γ_S	=	total unit weight of cover soil
γ_B	=	buoyant unit weight of cover soil = $\gamma_{sat} - \gamma_w$
c_a	=	adhesion
c	=	cohesion of cover soil
i	=	hydraulic gradient = sin β
W_S	=	weight of cover soil
W_W	=	weight of saturated cover soil
W_e	=	weight of construction equipment = equipment weight / contact area
W_e'	=	weight of construction equipment at interface
N_S	=	normal force of cover soil = $W_S \cos\beta$
N_W	=	normal force of saturated cover soil = $W_W \cos\beta$
N_e	=	normal force of construction equipment = $W_e \cos\beta$
N_e'	=	normal force of construction equipment at interface = $W_e' \cos\beta$
F_s	=	seepage force = $i\, \gamma_w\, z_W$
z_S	=	thickness of cover soil
z_W	=	saturated thickness

6.0 CALCULATIONS

6.1 Drainage Layer Capacity

A 25-year, 24-hour storm for the site will produce 6.0 inches of precipitation (Reference 5). A curve number of 86 will be used, which corresponds to a surface runoff (SR) of 4.41 inches (calculated from Reference 6). Then, the percolation (PERC) is calculated below:

$$\text{PERC} = \text{P} - \text{SR} = 6.0 - 4.41 = 1.59 \text{ in/day} = 4.7 \times 10^{-7} \text{ m/sec}$$

Let k_c be the smaller value of PERC and cover soil rate of percolation, k_s. Based on Assumption 4, the calculated value of PERC is smaller than the assumed cover soil rate of percolation.

Then, the quantity of water, FLUX $_{req'd}$, infiltrated per unit width of drainage geocomposite is:

$$\text{FLUX}_{req'd} = k_c \times L \times \cos(\beta) \times w$$

Where:

L = Slope length (m)

w = 1.0 = Unit width of drainage slope (m)

$$\text{FLUX}_{req'd} = (4.7 \times 10^{-7} \text{m/sec}) \times (36.6 \text{ m}) \times \cos(9.5) \times 1.0 \text{ m}$$

$$\text{FLUX}_{req'd} = 1.7 \times 10^{-5} \text{ m}^3\text{/sec}$$

The allowable geocomposite transmissivity is:

$$\theta_{all} = \theta_{ult} / \Pi RF$$

Where:

θ_{all} = Allowable geocomposite transmissivity (m^2/sec)
θ_{ult} = Ultimate geocomposite transmissivity (m^2/sec)
ΠRF = Combination of reduction factors for intrusion, chemical clogging and biological clogging (no creep RF due to 100-hr testing)

The flow capacity, $FLUX_{allow}$, for geocomposite is:

$$FLUX_{allow} = \theta_{all} \times i \times w$$

Where:

i = Flow gradient

Then the factor of safety of the geocomposite drainage capacity is

$$FS = FLUX_{allow} / FLUX_{req'd} = (\theta_{all} \times i \times w)/(k_c \times L \times \cos(\beta) \times w)$$

If the available geocomposite is not able to drain, head buildup, h (m), will be,

$$h = [Q_{in} /i) - t(k_d - k_s)] / k_s$$

Where:

Q_{in} = Flow of infiltration into the cover system (m^3/sec)
k_d = Permeability of geocomposite (m^2/sec)
k_s = Permeability of cover soil (m^2/sec)
t = Thickness of geocomposite core (m)

The calculation spreadsheets are attached. For the 7H:1V slope and PERC less than 4.7 x 10^{-7} m/s, a minimum transmissivity of 8.0 x 10^{-4} m^2/sec is required for the geocomposite. Since this is the worst-case condition, a minimum transmissivity of 8.0 x 10^{-4} m^2/sec for all slopes on the final cover system is required. The specification will require that this value be met for the shallowest of the sideslopes (i.e., gradient = 0.14 ft/ft). This equates to a drainage layer capacity factor of safety of at least 1.5.

6.2 Veneer Stability

The calculation spreadsheets and equations used for the calculation are attached. Stability factors of safety were evaluated under three (3) loading conditions: static forces, equipment forces, and seismic forces. Based on the longest 4H:1V side slope length, 115 feet, an interface friction angle of 19 degrees is required to achieve the prescribed factors of safety. The attached plot, Figure 1, indicated the maximum distance final cover could be advanced up the slope for varying interface friction angles while maintaining the prescribed factors of safety. The calculation using an interface friction angle of 19 degrees has been included as an example.

Based on the longest 4H:1V side slope length, 115 feet, an interface friction angle of 19 degrees is required to achieve the prescribed factors of safety. The calculation using an interface friction angle of 19 degrees has been included.

7.0 CONCLUSION

Based on the analysis presented herein, a minimum geocomposite transmissivity of 8.0 x 10^{-4} m^2/sec is required for the geocomposite is required for all slopes. An interface friction angle of 19 degrees is required to construct a 4H:1V side slope.

Laboratory interface friction testing will be performed as part of the landfill closure construction. The results of this testing can be used in conjunction with Figure 1 to determine the maximum distance final cover can be advanced while maintaining the prescribed factors of safety for static, operational and seismic conditions (1.5, 1.3 and 1.0, respectively).

Edge Moor Site II Ash Landfill Cap Geocomposite Capacity at 7H:1V Slope

Slope Information		
Slope length, L	115	ft, horizontal
	35.1	m
Slope, V:H	0.14	
Slope angle, β	8.1	degree
sinβ = Flow Gradient for Geocomposite	0.141	
cosβ = Flow Gradient for Infiltration	0.990	
Water Infiltration Quantity		
Rate of percolation of cover soil, PERC*	**4.7E-07**	m/sec
Unit width of drainage slope, w	1.0	m
Water infiltration through cover soil, $FLUX_{required}$	1.6E-05	m^3/sec
Geocomposite Capacity		
Geocomposite ultimate transmissivity, θ_{ult}	**8.00E-04**	m^2/sec
Reduction factor for intrusion, RFin	1.0	
Reduction factor for creep deformation, RFcr	1.4	
Reduction factor for chemical clogging, RFcc	1.2	
Reduction factor for biological clogging, RFbc	1.75	
Total reduction factor, ΠRF	2.94	
Geocomposite allowable transmissivity, θ_{all}	2.721E-04	m^2/sec
Flow gradient, i	0.141	
Flow capacity of the geocomposite, $FLUX_{allow}$	3.85E-05	m^3/sec
FS for Drainage Layer Capacity, DLC	**2.36**	

*PERC = $k_{cover\ soil}$; when P(1-RC) > $k_{cover\ soil}$

PERC = P(1-RC); when P(1-RC) ≤ $k_{cover\ soil}$

Edge Moor Site II Ash Landfill Cap Geocomposite Capacity at 6H:1V Slope

Slope Information		
Slope length, L	115	ft, horizontal
	35.1	m
Slope, V:H	0.17	
Slope angle, β	9.5	degree
sinβ = Flow Gradient for Geocomposite	0.164	
cosβ = Flow Gradient for Infiltration	0.986	
Water Infiltration Quantity		
Rate of percolation of cover soil, PERC*	**4.7E-07**	m/sec
Unit width of drainage slope, w	1.0	m
Water infiltration through cover soil, $FLUX_{required}$	1.6E-05	m^3/sec
Geocomposite Capacity		
Geocomposite ultimate transmissivity, θ_{ult}	**8.00E-04**	m^2/sec
Reduction factor for intrusion, RFin	1.0	
Reduction factor for creep deformation, RFcr	1.4	
Reduction factor for chemical clogging, RFcc	1.2	
Reduction factor for biological clogging, RFbc	1.75	
Total reduction factor, ΠRF	2.94	
Geocomposite allowable transmissivity, θ_{all}	2.721E-04	m^2/sec
Flow gradient, i	0.164	
Flow capacity of the geocomposite, $FLUX_{allow}$	4.47E-05	m^3/sec
FS for Drainage Layer Capacity, DLC	**2.75**	

*PERC = $k_{cover\ soil}$; when P(1-RC) > $k_{cover\ soil}$

PERC = P(1-RC); when P(1-RC) ≤ $k_{cover\ soil}$

Edge Moor Site II Ash Landfill Cap Geocomposite Capacity at 5H:1V Slope

Slope Information		
Slope length, L	115	ft, horizontal
	35.1	m
Slope, V:H	0.20	
Slope angle, β	11.3	degree
sinβ = Flow Gradient for Geocomposite	0.196	
cosβ = Flow Gradient for Infiltration	0.981	
Water Infiltration Quantity		
Rate of percolation of cover soil, PERC*	**4.7E-07**	m/sec
Unit width of drainage slope, w	1.0	m
Water infiltration through cover soil, $FLUX_{required}$	1.6E-05	m^3/sec
Geocomposite Capacity		
Geocomposite ultimate transmissivity, θ_{ult}	**8.00E-04**	m^2/sec
Reduction factor for intrusion, RFin	1.0	
Reduction factor for creep deformation, RFcr	1.4	
Reduction factor for chemical clogging, RFcc	1.2	
Reduction factor for biological clogging, RFbc	1.75	
Total reduction factor, ΠRF	2.94	
Geocomposite allowable transmissivity, θ_{all}	2.721E-04	m^2/sec
Flow gradient, i	0.196	
Flow capacity of the geocomposite, $FLUX_{allow}$	5.34E-05	m^3/sec
FS for Drainage Layer Capacity, DLC	**3.30**	

*PERC = $k_{cover\ soil}$; when P(1-RC) > $k_{cover\ soil}$

PERC = P(1-RC); when P(1-RC) ≤ $k_{cover\ soil}$

Edge Moor Site II Ash Landfill Cap Geocomposite Capacity at 4H:1V Slope

Slope Information		
Slope length, L	115	ft, horizontal
	35.1	m
Slope, V:H	0.25	
Slope angle, β	14.0	degree
sinβ = Flow Gradient for Geocomposite	0.243	
cosβ = Flow Gradient for Infiltration	0.970	
Water Infiltration Quantity		
Rate of percolation of cover soil, PERC*	**4.7E-07**	m/sec
Unit width of drainage slope, w	1.0	m
Water infiltration through cover soil, $FLUX_{required}$	1.6E-05	m^3/sec
Geocomposite Capacity		
Geocomposite ultimate transmissivity, θ_{ult}	**8.00E-04**	m^2/sec
Reduction factor for intrusion, RFin	1.0	
Reduction factor for creep deformation, RFcr	1.4	
Reduction factor for chemical clogging, RFcc	1.2	
Reduction factor for biological clogging, RFbc	1.75	
Total reduction factor, ΠRF	2.94	
Geocomposite allowable transmissivity, θ_{all}	2.721E-04	m^2/sec
Flow gradient, i	0.243	
Flow capacity of the geocomposite, $FLUX_{allow}$	6.60E-05	m^3/sec
FS for Drainage Layer Capacity, DLC	**4.13**	

*PERC = $k_{cover\ soil}$; when P(1-RC) > $k_{cover\ soil}$

PERC = P(1-RC); when P(1-RC) ≤ $k_{cover\ soil}$

Edge Moor Landfill Side Slope Stability

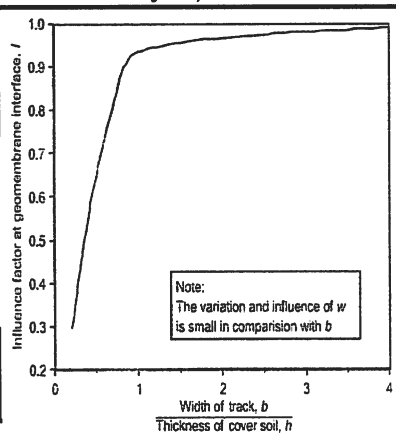
1. GRAVITY ONLY

Interface Friction Angle, δ	19	degrees	$\sin\beta =$ 0.24	$W_A =$	26,688	lb/ft
Interface Adhesion, c_a	0	psf	$\tan\beta =$ 0.25	$W_P =$	1,063	lb/ft
Soil Friction Angle, ϕ	32	degrees	$\cos\beta =$ 0.97	$N_A =$	25,891	lb/ft
Soil Cohesion, c	0	psf	$\sin 2\beta =$ 0.47	$C_a =$	0	lb/ft
Slope	4	H:1V	$\tan\phi' =$ 0.62	C =	0	lb/ft
Soil Unit Weight, γ	125	pcf	$\tan\delta' =$ 0.34			
Cover Depth, h	2	ft		a =	1,523	lb/ft
Slope Length, L	115	ft		b =	-2,497	lb/ft
				c =	328	lb/ft

FACTOR OF SAFETY = **1.50**

2. EQUIPMENT PUSHING SOIL UP COVER SLOPE (NOTE: CAT D6N LGP used in analysis)

Weight of Equipment, W_b	40,446	lb	$W_e =$ 6,986	psf
Length of Equipment Track, w	10.3	ft	$N_e =$ 6,778	psf
Width of Equipment Track, b	2.75	ft		
Width-to-Thickness Ratio, b/h	1.4			
Influence Factor, I	0.95	(from figure to right)		
			a = 7,923	lb/ft
			b = -12,814	lb/ft
			c = 1,705	lb/ft

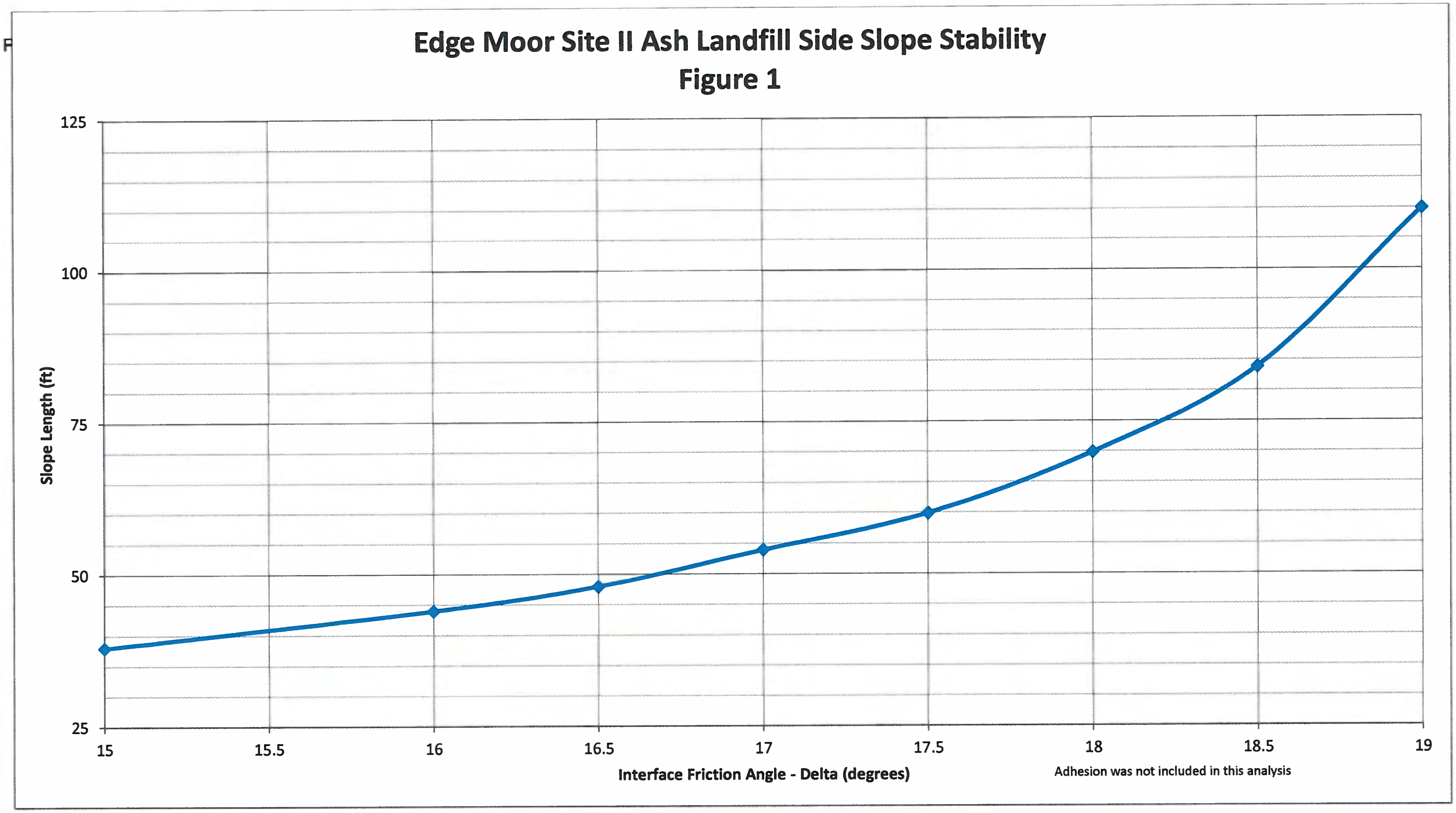


FACTOR OF SAFETY = **1.47**

3. SEISMIC FORCES

Seismic Coefficient, C_S	0.05	a =	7,438	lb/ft
		b =	-10,188	lb/ft
		c =	1,311	lb/ft

FACTOR OF SAFETY = **1.23**


Edge Moor Site II Ash Landfill Side Slope Stability
Figure 1
Slope Length (ft)
125
100
75
50
25
15
15.5
16
16.5
17
17.5
18
18.5
19
Interface Friction Angle - Delta (degrees)
Adhesion was not included in this analysis

EQUATIONS USED IN DESIGN CALCULATIONS
FROM REFERENCE 2

GRAVITY ONLY

$$W_A = \gamma_{moist} \cdot h^2 \cdot \left[\frac{L}{h} - \frac{1}{\cos\beta \cdot \sin\beta} + \frac{\tan\beta}{2}\right]$$

$$W_P = \frac{h^2 \cdot \gamma_{moist}}{\sin 2\beta}$$

$$N_A = W_A \cdot \cos\beta$$

$$C_a = c_a \cdot \left(L - \frac{h}{\tan\beta}\right)$$

$$C = \frac{c \cdot h}{\sin\beta}$$

$$a = (W_A - N_A \cdot \cos\beta) \cdot \cos\beta$$

$$b = -[(W_A - N_A \cdot \cos\beta) \cdot \sin\beta \cdot \tan\phi + (N_A \cdot \tan\delta + C_a) \cdot \sin\beta \cdot \cos\beta + \sin\beta \cdot (C + W_P \cdot \tan\phi)]$$

$$c = (N_A \cdot \tan\delta + C_a) \cdot \sin^2\beta \cdot \tan\phi$$

$$FS = \frac{-b + \sqrt{b^2 - 4a \cdot c}}{2a}$$

EQUIPMENT PUSHING SOIL UP COVER SLOPE

$$q = \frac{W_b}{(2 \cdot w \cdot b)}$$

$$W_e = q \cdot w \cdot I$$

$$N_e = W_e \cdot \cos\beta$$

$$a = [(W_A + W_e) \cdot \sin\beta] \cdot \cos\beta$$

$$b = -\{[(N_e + N_A) \cdot \tan\delta + C_a] \cdot \cos\beta + [(W_A + W_e) \cdot \sin\beta] \cdot \sin\beta \cdot \tan\phi + (C + W_P \cdot \tan\phi)\}$$

$$c = [(N_e + N_A) \cdot \tan\delta + C_a] \cdot \sin\beta \cdot \tan\phi$$

- Wa, Wp, Na, Ca, C, and FS same as gravity only

EQUIPMENT PUSHING SOIL DOWN COVER SLOPE

$$F_e = W_e \cdot \left(\frac{a}{g}\right)$$

$$a = [(W_A + W_e) \cdot \sin\beta + F_e] \cdot \cos\beta$$

$$b = -\{[(N_e + N_A) \cdot \tan\delta + C_a] \cdot \cos\beta + [(W_A + W_e) \cdot \sin\beta + F_e] \cdot \sin\beta \cdot \tan\phi + (C + W_P \cdot \tan\phi)\}$$

$$c = [(N_e + N_A) \cdot \tan\delta + C_a] \cdot \sin\beta \cdot \tan\phi$$

- Wa, Wp, Na, Ca, C, and FS same as gravity only
- We, q, and Ne same as equipment pushing soil up cover slope

HORIZONTAL SEEPAGE BUILD-UP

$$W_A = \gamma_{moist} \cdot \left[h \cdot \left(\frac{H - Hw}{\sin\beta} \right) - \left(\frac{h^2}{2 \cdot \tan\beta} \right) \right] + \gamma_{sat} \cdot \left[h \cdot \left(\frac{2 \cdot Hw \cdot \cos\beta - h}{\sin 2\beta} \right) \right]$$

$$W_P = \frac{h^2 \cdot \gamma_{sat}}{\sin 2\beta}$$

$$U_v = \frac{h^2 \cdot \gamma_w}{\sin 2\beta}$$

$$U_h = \frac{h^2 \cdot \gamma_w}{2 \cdot \cos^2 \beta}$$

$$U_N = \gamma_w \cdot h \cdot \left(\frac{2 \cdot Hw \cdot \cos\beta - h}{\sin 2\beta \cdot \cos\beta} \right)$$

$$N_A = W_A \cdot \cos\beta + U_h \cdot \sin\beta - U_N$$

$$E_A = W_A \cdot \sin\beta - U_h \cdot \cos\beta - \frac{N_A \cdot \tan\delta + C_a}{FS}$$

$$E_P = \frac{U_h \cdot FS - (W_P - U_v) \cdot \tan\phi - C}{\sin\beta \cdot \tan\phi - \cos\beta \cdot FS}$$

$$a = U_h + W_A \cdot \sin\beta \cdot \cos\beta - U_h \cdot \cos^2 b$$

$$b = -W_A \cdot \sin^2 b \cdot \tan\phi + U_h \cdot \cos\beta \cdot \sin\beta \cdot \tan\phi - (N_A \cdot \tan\delta + C_a) \cdot \cos\beta - [(W_P - U_v) \cdot \tan\phi - C]$$

$$c = (N_A \cdot \tan\delta + C_a) \cdot \sin\beta \cdot \tan\phi$$

- Ca, C, and FS same as gravity only

SEEPAGE PARALLEL TO THE SLOPE

$$W_P = \frac{\gamma_{moist} \cdot (h^2 - h_w^2) + h_w^2 \cdot \gamma_{sat}}{\sin 2\beta}$$

$$W_A = \gamma_{moist} \cdot \left[L \cdot h - \frac{h^2}{\cos\beta \cdot \sin\beta} + \frac{h^2 \cdot \tan\beta}{2} \right] + \gamma_{sat} t \cdot \left[\left(h_w \cdot \frac{2H \cdot \cos\beta - 2h}{\sin 2\beta} \right) + \left((h - h_w) \cdot h_w + \frac{h_w^2}{2} \right) \cdot \tan\beta \right]$$
$$- \gamma_{moist} \cdot \left[\left(h_w \cdot \frac{2H \cdot \cos\beta - 2h}{\sin 2\beta} \right) + \left((h - h_w) \cdot h_w + \frac{h_w^2}{2} \right) \cdot \tan\beta \right]$$

$$U_N = \left(\frac{H}{\sin\beta} - \frac{h}{\tan\beta} \right) \cdot \frac{\gamma_w \cdot h_w}{\cos\beta^*}$$

$$U_h = \frac{\gamma_w \cdot h_w^2}{2 \cos^2 \beta}$$

- Ca, C, and FS same as gravity only
- a, b, c, NA, EA, and EP same as horizontal seepage

SEISMIC FORCES

$$a = (C_s \cdot W_A + N_A \cdot \sin\beta) \cdot \cos\beta + C_s \cdot W_P \cdot \cos\beta$$

$$b = -[(C_s \cdot W_A + N_A \cdot \sin\beta) \cdot \sin\beta \cdot \tan\phi + (N_A \cdot \tan\delta + C_a) \cdot \cos^2 b + (C + W_P \cdot \tan\phi) \cdot \cos\beta]$$

$$c = (N_A \cdot \tan\delta + C_a) \cdot \cos\beta \cdot \sin\beta \cdot \tan\phi$$

- Wa, Wp, Na, Ca, C, and FS same as gravity only

Reference 3

U.S. Geological Survey - Earthquake Hazards Program

Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Input

Edition

Conterminous U.S. 2014 (v4.0.x)

Spectral Period

Peak Ground Acceleration

Latitude

Decimal degrees

39.739

Time Horizon

Return period in years

2475

Longitude

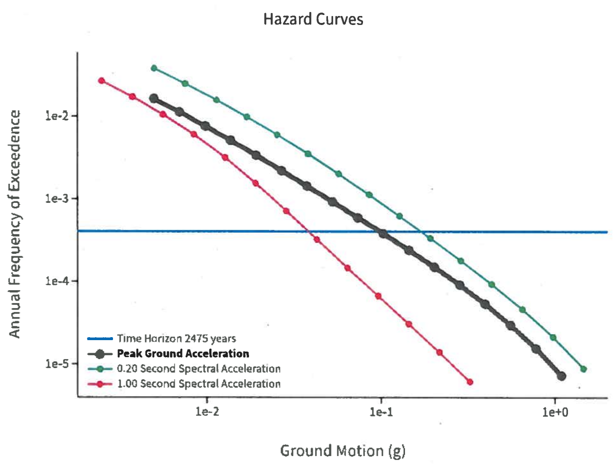
Decimal degrees, negative values for western longitudes

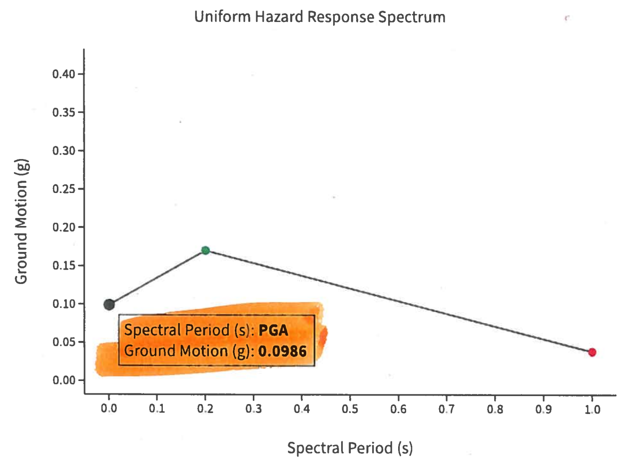
-75.517

Site Class

760 m/s (B/C boundary)

Hazard Curve





View Raw Data

Reference 5

Rainfall Depths for Delaware* (NRCS Type II, 24-Hour Duration)			
	County		
Storm Event	*New Castle*	*Kent*	*Sussex*
Latitude	39.547 N	39.070 N	38.673 N
Longitude	75.681 W	75.602 W	75.417 W
6-MO (WQ)	2.0	2.0	2.0
1-YR (RPv)	2.7	2.7	2.7
2-YR	3.2	3.3	3.4
5-YR	4.1	4.3	4.4
10-YR (Cv)	4.8	5.2	5.3
25-YR	6.0	6.5	6.7
50-YR	6.9	7.6	7.9
100-YR (Fv)	8.0	8.9	9.2
500-YR	10.9	12.6	13.0

* Ref: NOAA Atlas 14 Volume 2, Version 3

EFFECTIVE DATE: January 1, 2014

Reference 6

Chapter 2 Estimating Runoff

SCS runoff curve number method

The SCS Runoff Curve Number (CN) method is described in detail in NEH-4 (SCS 1985). The SCS runoff equation is

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{[eq. 2-1]}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. I_a is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

$$I_a = 0.2S \qquad \text{[eq. 2-2]}$$

By removing I_a as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation 2-2 into equation 2-1 gives:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{[eq. 2-3]}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = \frac{1000}{CN} - 10 \qquad \text{[eq. 2-4]}$$

Figure 2-1 and table 2-1 solve equations 2-3 and 2-4 for a range of CN's and rainfall.

Factors considered in determining runoff curve numbers

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Figure 2-2 is provided to aid in selecting the appropriate figure or table for determining curve numbers.

CN's in table 2-2 (*a* to *d*) represent average antecedent runoff condition for urban, cultivated agricultural, other agricultural, and arid and semiarid rangeland uses. Table 2-2 assumes impervious areas are directly connected. The following sections explain how to determine CN's and how to modify them for urban conditions.

Hydrologic soil groups

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. Appendix A defines the four groups and provides a list of most of the soils in the United States and their group classification. The soils in the area of interest may be identified from a soil survey report, which can be obtained from local SCS offices or soil and water conservation district offices.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbanization, native soil profiles may be mixed or removed or fill material from other areas may be introduced. Therefore, a method based on soil texture is given in appendix A for determining the HSG classification for disturbed soils.

Reference 9

Caterpillar Performance Handbook (Edition 48, June 2018)

Model	Unit	D3K LGP	D4G LGP Hystat	D6R	D6R LGP	**D6N LGP**	D7R LGP Series II	D8R	D9R	D10R
Weight of Equipment, W_b	lb	17842	17877	40400	45600	**40446**	60300	82850	107670	144200
Length of Equipment Track, w	in	83	80.9	103	128	**123**	125	126	137	153
	ft	6.9	6.7	8.6	10.7	**10.3**	10.4	10.5	11.4	12.8
Width of Equipment Track, b	in	25	25	22	36	**33**	36	22	24	24
	ft	2.1	2.1	1.8	3.0	**2.75**	3.0	1.8	2.0	2.0
Ground contact area, calculated	in^2	4150	4045	4532	9216	**8118**	9000	5544	6576	7344
	ft^2	28.8	28.1	31.5	64.0	**56.4**	62.5	38.5	45.7	51.0
Ground contact area, from book	in^2	4124	4045	4518	9194	**8122**	9029	5565	6569	7321
	ft^2	28.6	28.1	31.4	63.8	**56.4**	62.7	38.6	45.6	50.8
Ground pressures, from book	psi	4.3	4.11	8.82	4.94	**4.98**	6.55	14.67	16.08	19.63
	psf	619	592	1270	711	**717**	943	2112	2316	2827
Ground pressures, calculated	psi	4.30	4.42	8.91	4.95	**4.98**	6.70	14.94	16.37	19.64
	psf	619	636	1284	713	**717**	965	2152	2358	2827

Reference 11

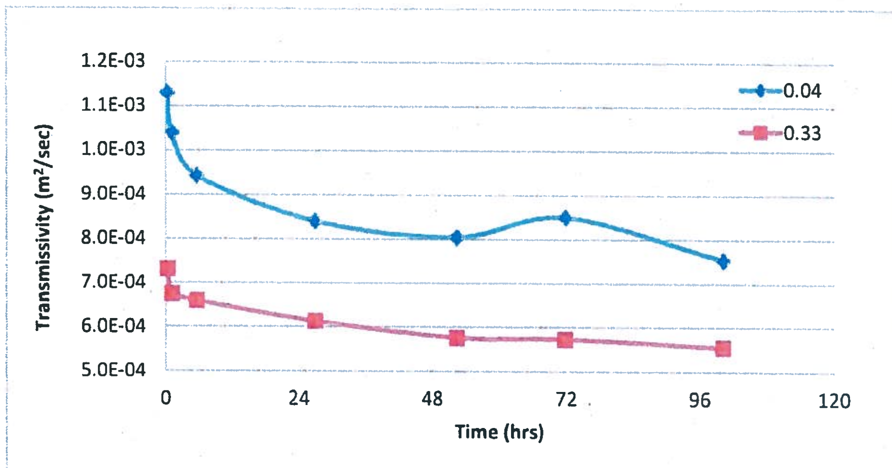
SEPTEMBER 2019 | 1404534

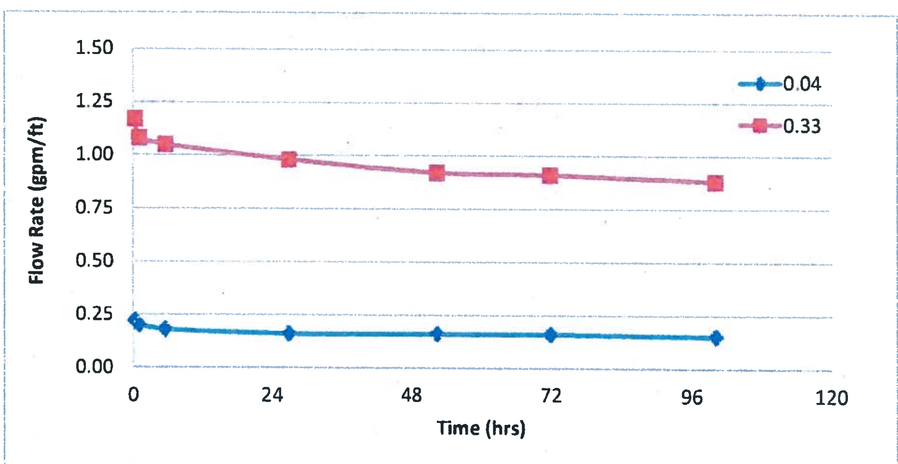
TRANSMISSIVITY TEST RESULTS
ASTM D4716

PROJECT NAME: [redacted]
SAMPLE NUMBER: GTB0042710002

Configuration: Plate / Geotextile / Geomembrane (nub side up) / Plate
(top to bottom)
Seat Time: 100 hours
Normal Load: 500 psf
Gradient:

	0.04		0.33	
Time (hours)	Transmissivity (m^2/sec)	Flow Rate (gpm/ft)	Transmissivity (m^2/sec)	Flow Rate (gpm/ft)
0.25	1.13E-03	0.22	7.31E-04	1.17
1	1.04E-03	0.20	6.75E-04	1.08
6	9.43E-04	0.18	6.59E-04	1.05
27	8.40E-04	0.16	6.13E-04	0.98
52	8.04E-04	0.16	5.76E-04	0.92
72	8.50E-04	0.16	5.73E-04	0.91
100	7.53E-04	0.15	5.55E-04	0.88





APPENDIX 5-C

TECHNICAL SPECIFICATIONS

SECTION 01562

DUST CONTROL

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall employ means and methods that keep airborne particulates to the minimum during construction. This includes providing all labor, equipment, machinery, and materials for the application of water or other appropriate preventative means or methods to maintain dust control and to minimize the potential for complaints from the public.

B. The CONTRACTOR shall comply will all applicable codes, ordinances, rules, regulations and laws of local, State, and Federal authorities having jurisdiction.

C. The CONTRACTOR shall provide a Competent Person to implement, supervise, and inspect all Work. The Quality Assurance Consultant (QAC) shall monitor implementation of the Work.

1.02 HEALTH AND SAFETY

A. Site workers shall not be exposed to respirable particulates caused by the performance of the Work in excess of applicable Federal and State standards.

B. Airborne particulates shall be monitored in accordance with the Site-specific Health and Safety Plan.

1.03 RELATED SECTIONS

A. 02100 - Site Preparation

B. 02110 - Site Clearing and Grubbing

C. 02125 - Erosion and Sediment Control

D. 02210 - Site Grading

E. 02223 – Backfill and Fill

F. 02233 – Aggregate

G. 02235 – Vegetative Support Layer

PART 2 - PRODUCTS

2.01 GENERAL

A. Clean water shall be used for dust control. The CONTRACTOR is required to provide equipment to apply water for dust control that shall be obtained from locations designated by the OWNER.

B. Dust control shall be applied immediately when conditions warrant and as directed by the OWNER or the QAC. A sufficient quantity of clean water and appropriate equipment shall be maintained on-site for immediate dust control use.

C. The use of calcium chloride or other chemical dust suppressants for dust control is not permitted on the Site.

PART 3 - EXECUTION

3.01 GENERAL

A. Watering equipment shall be used to minimize airborne particulate concentrations and shall consist of pipelines, tanker trucks, or other devices acceptable to the OWNER. This equipment shall be capable of applying a uniform spread of water over the ground surface. A suitable device for a positive shut-off and for regulating the flow rate of water shall be located so as to afford unhindered operator control.

B. The CONTRACTOR shall implement strict dust control whenever possible, including all temporary and permanent routes used for access to the work area. All haul roads used during execution of the Work shall be maintained by the CONTRACTOR.

C. Soil stockpiles shall be watered as necessary to prevent dust.

*****END OF SECTION*****

SECTION 01562

DUST CONTROL

PART 1 - GENERAL

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A. The CONTRACTOR shall employ means and methods that keep airborne particulates to the minimum during construction. This includes providing all labor, equipment, machinery, and materials for the application of water or other appropriate preventative means or methods to maintain dust control and to minimize the potential for complaints from the public.

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C. Soil stockpiles shall be watered as necessary to prevent dust.

*****END OF SECTION*****

SECTION 02070

MONITORING WELL PROTECTION AND MODIFICATION

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all permits, materials, labor, equipment, tools and appurtenances required to complete the Work as described herein. Comply with all applicable codes, ordinances, rules, regulations and laws of local, State, and Federal authorities having jurisdiction.

B. This Section describes the general requirements for the protection of the existing monitoring wells, as indicated in the Contract Documents.

C. This Section describes the general requirements for the replacement of any existing monitoring wells damaged during Construction due to insufficient protection by the CONTRACTOR.

D. All monitoring well work shall be conducted by a Delaware Licensed Driller (DRILLER) subcontracted by the CONTRACTOR.

E. The term "well" refers to monitoring wells and/or piezometers, unless specifically noted.

1.02 SUBMITTALS

A. Two (2) weeks prior to construction at or near a well, the CONTRACTOR shall submit to the Quality Assurance Consultant (QAC) the following documentation:

1. Method to protect each well during construction;
2. Method to excavate the existing soils around each well (as appropriate); and,
3. Proposed well modifications necessary to meet the proposed grading plan elevations (as appropriate);

B. As needed, the DRILLER shall provide a Delaware Department of Natural Resources and Environmental Conservation (DNREC) well sealing report at the completion of each monitoring well abandonment. The DRILLER will submit copies of the well abandonment report to the QAC.

C. The DRILLER shall provide the necessary well construction log to document well modifications and submit copies to the QAC, for submission to DNREC.

D. DRILLER shall be responsible for obtaining required permits for well installation and providing documentation of permits to the QAC.

1.03 QUALITY ASSURANCE

A. Observation: All well protection and modification operations shall be conducted under the observation of the RESIDENT MANAGER (RM) or other representative of the QAC.

B. All Work is to be performed in accordance with all applicable State and Federal regulations.

1.04 SCHEDULING

A. Schedule Work prior to other activities that might damage the wells.

PART 2 - PRODUCTS

2.01 MATERIALS

A. All materials shall be in accordance with applicable local, State, and Federal requirements.

B. GROUT

1. Neat cement grout:

Neat Cement Grout:
1 bag Portland cement concrete (94 pounds (lbs)
6.3-7 gallons (gal) clean water

2. A mud balance shall be used to verify slurry weight. Slurry weight shall be 13.4 to 14.5 lbs/gal

3. Mix design, method of mixing, and consistency of grout shall be approved by QAC.

4. Cement grout admixtures may be used to increase fluidity, reduce shrinkage or control time of set. Use of admixtures shall be approved by QAC.

a. No more than 5 lbs of bentonite may be added per bag (94 lb) of cement.

PART 3 - EXECUTION

3.01 GENERAL

A. The wells to be protected are as indicated on the Contract Documents.

3.02 MONITORING WELL TO BE ABANDONED

In the event of abandonment, due to damage during construction, of any water well, or other type of well, as indicated in the Contract Documents, the following procedure and materials shall be used:

A. The well shall be plugged to prevent the entrance of surface water, circulation of water between or among producing zones, or any other process resulting in the contamination or pollution of groundwater resources.

B. The well shall be checked from land surface to the entire depth of the well before it is sealed, to ensure against the presence of any obstruction that will interfere with sealing operations. Silt deposit shall be removed from silted-in wells, to ensure an adequate seal. Any materials removed from a well prior to abandonment shall be containerized, transported to the area identified in the Contract Documents, and staged for subsequent characterization and disposal by the CONTRACTOR at the appropriate approved off-site disposal facility.

C. The grout material shall be placed through a tremie pipe extending to the bottom of the well, which shall be raised as the well is filled.

D. Any well or boring shall be abandoned in such a manner that it does not become a channel for the vertical movement of water or other substance to potable groundwater resources.

3.03 MONITORING WELL TO BE MODIFIED

A. As shown in the Contract Documents, existing wells in locations receiving additional fill may need to be extended to maintain access above the new ground surface.

B. Wells shall be extended incrementally such that a “stick-up” above the final ground surface is maintained and a new protective casing is installed at the new ground surface.

C. Where applicable, geomembrane boots or sleeves shall be installed around extended wells that penetrate the low permeability cover system.

D. Remove existing protective casings, taking care not to damage the well casing, and install new protective outer casings, as indicated on the Contract Documents.

E. Waste materials generated during well modification including, but not limited to, concrete debris, protective casings, PVC well casing, and soils shall be disposed of off-site by the CONTRACTOR at the appropriate approved disposal facility.

F. The CONTRACTOR shall repair or replace any damage caused to the existing well casing during modifications at the CONTRACTOR’s expense.

*****END OF SECTION*****

SECTION 02100

SITE PREPARATION

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all permits, materials, labor, equipment, tools and appurtenances required to complete the Work as described herein. The CONTRACTOR shall provide a "Competent Person" to implement, supervise, and inspect all Work.

B. This Section describes materials and equipment to be utilized, and requirements for their use in preparing the Site for construction.

C. The CONTRACTOR shall comply with applicable codes, ordinances, rules, regulations and laws of local, State or Federal authorities having jurisdiction.

D. The CONTRACTOR shall remove, transport, and dispose of cleared and grubbed materials at on-Site areas designated by the OWNER. The CONTRACTOR shall provide all equipment, materials, and personnel necessary to remove and transport these materials to the designated areas.

E. Protect and maintain existing monitoring wells, vents, structures, fences, benchmarks, monuments, and other reference points. Re-establish, at no cost to the OWNER, any such reference points if disturbed or destroyed. The CONTRACTOR's surveyor shall conduct a survey of all monuments and property markers within proposed Work areas prior to any disturbance so that they can be re-established if disturbed by the CONTRACTOR as part of this Contract.

F. Protect and maintain all existing groundwater monitoring wells, electrical transmission towers and foundations, stormwater control features, and all other facilities to remain in place as indicated on the Contract Documents.

G. Protect any existing facilities, utilities, and structures from damage due to construction.

1.02 RELATED SECTIONS

A. 02110 – Site Clearing and Grubbing
B. 02125 – Erosion and Sediment Control
C. 02210 – Site Grading
D. 02223 – Backfill and Fill

PART 2 – PRODUCTS

Not Used.

PART 3 - EXECUTION

Not Used.

*****END OF SECTION*****

SECTION 02110

SITE CLEARING AND GRUBBING

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all materials, labor, equipment, tools and appurtenances required to complete the work as described below. The CONTRACTOR shall provide a “Competent Person” to implement, supervise, and inspect all Work.

B. Site clearing includes, but is not limited to, removing from the construction area, hauling to disposal areas approved by the OWNER, and disposing of trees, stumps, roots, brush, structures, abandoned utilities, trash, debris and all other materials found on or near the surface of the ground within construction areas. Precautionary measures that prevent damage to existing features to remain are part of the Work.

C. The CONTRACTOR shall comply with applicable codes, ordinances, rules, regulations and laws of local, State, and Federal authorities having jurisdiction.

D. No clearing and grubbing shall be allowed without adequate erosion and sedimentation control measures in-place to the satisfaction of the OWNER, and as described in the Contract Documents.

1.02 RELATED SECTIONS

A. 02100 - Site Preparation

B. 02125 – Erosion and Sediment Control

C. 02210 - Site Grading

1.03 JOB CONDITIONS

A. Location of Work: Areas to be cleared and grubbed include all areas designated for final cover installation, laydown area(s), designated access roads, construction of stormwater management system, and all areas identified in the Contract Documents associated with the construction.

PART 2 - PRODUCTS

A. The CONTRACTOR shall furnish equipment of the type normally used in clearing and grubbing operations including, but not limited to, dozers, shears, skidders, loaders, root rakes, chipping equipment and stump grinders.

PART 3 - EXECUTION

3.01 SCHEDULING OF CLEARING

A. Clearing and grubbing shall not commence prior to the CONTRACTOR installing erosion and sedimentation control measures to the satisfaction of the OWNER, and as described in the Contract Documents.

B. The OWNER may permit clearing of additional areas provided that temporary erosion and sedimentation controls are in-place in accordance with Section 02125 of these Specifications.

3.02 CLEARING AND GRUBBING PROCEDURES

A. Materials to be cleared, grubbed, and removed from the construction areas include, but are not limited to, trees, stumps, roots, brush, trash, organic matter, and debris.

B. Grubbing shall consist of completely removing roots, stumps, trash and other debris from all graded areas, so that surface material is free of roots and debris. Surface material is to be left sufficiently clean so that further picking and raking will not be required.

C. Stumps, roots, foundations and planking embedded in the ground shall be removed for off-site disposal at an approved disposal facility.

D. Surface rocks and boulders greater than 6 inches in diameter shall be grubbed from the soil and removed to a designated on-Site location approved by the OWNER.

E. Where tree limbs interfere with utility wires, or where trees to be felled are in proximity to utility wires, these trees shall be taken down in sections to reduce the possibility of damage to the utility wires. The CONTRACTOR shall be responsible for damages to utilities and consequential damages to the OWNER and third parties, and shall replace or repair damaged utilities at no cost to the OWNER.

F. Any Work pertaining to utility poles and guy wires shall comply with the requirements of the appropriate utility.

G. Stumps and roots shall be grubbed and removed to a depth not less than two (2) feet below ground as indicated on the Contract Documents. All holes or cavities which extend below the subgrade elevation of the proposed work shall be backfilled with soil or other suitable material, compacted to a similar density as the surrounding material. Roots ½-inch in diameter and greater shall be removed to a depth not less than 6 inches below subgrade.

H. The CONTRACTOR shall be held liable for any direct or consequential damage to property outside of the designated Work area(s).

I. The CONTRACTOR shall be responsible for all damages to existing structures and/or improvements resulting from the Work.

J. The CONTRACTOR shall protect existing wells and fencing, and any other facilities or structures to remain from damage due to construction activities. Damaged items shall be repaired or replaced at no cost to the OWNER.

3.03 DISPOSAL OF DEBRIS

A. Debris (i.e., stumps, roots, branches, leaves etc.) resulting from the Site clearing and grubbing operations shall be removed for off-site disposal at an approved disposal facility.

B. All trees and shrubs from the clearing operation shall be removed for off-site disposal at an approved disposal facility.

C. Large debris (i.e., stumps, etc.) shall be cut, shredded, or crushed into pieces no greater than 6 inches in any dimension, and removed for off-site disposal at an approved disposal facility.

*****END OF SECTION*****

SECTION 02125

EROSION AND SEDIMENT CONTROL

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. CONTRACTOR shall furnish all labor, materials, tools, supervision, transportation, installation equipment, and incidentals required to install the erosion and sediment control features shown on the drawings, including: (i) erosion control mat; (ii) compost filter sock; and (iii) temporary stabilization, as specified herein and as shown in the Contract Documents.

B. CONTRACTOR shall furnish all labor, material, tools, supervision, transportation, installation equipment, and incidentals required to install erosion and sediment controls not shown in the Contract Documents but required to prevent sedimentation or pollution to waters of the State or Federal waterways.

C. CONTRACTOR shall furnish all labor, materials, tools, supervision, transportation, installation equipment, and incidentals required to maintain all soil erosion and sediment control features and structures throughout the duration of the Project and removal of temporary measures and structures, where and when necessary, as directed by OWNER or Quality Assurance Consultant (QAC).

D. CONTRACTOR shall furnish all labor, materials, tools, supervision, transportation, installation equipment, and incidentals required to construct and maintain soil stockpiles on site.

E. CONTRACTOR shall not disturb wetland areas.

1.02 SUBMITTALS

A. At least ten days prior to the Preconstruction Meeting, CONTRACTOR shall submit to QAC the proposed product material data sheets, and manufacturer recommended method of installation for:
   1. Erosion control mat; and
   2. Silt fence.

B. At least seven days prior to applying any temporary stabilization, CONTRACTOR shall submit to QAC information of:
   1. Seed mixture, quantity, and application rate;
   2. Mulch type and application rate;
   3. Fertilizer type and application rate; and
   4. Seed bed preparation.

C. At least seven days prior to installing a sediment control feature not addressed in this Section, CONTRACTOR shall submit to QAC Shop Drawings and/ or product information on the proposed feature, along with calculations necessary to verify the proper functioning of the feature for the intended purpose.

1.03 CONSTRUCTION QUALITY ASSURANCE

A. The installation, use, and maintenance of the erosion and sediment control feature shall be monitored by the QAC as outlined in the CQA Plan.

B. CONTRACTOR shall be aware of the activities outlined in the CQA Plan and shall account for these when preparing the project schedule.

C. At the discretion of OWNER or QAC, the Work of this Section may be subjected to CQA monitoring.

PART 2 - PRODUCTS

2.01 TEMPORARY EROSION CONTROL BLANKET

A. Temporary Erosion Control Blanket (ECB) shall have an allowable tractive stress of 2 Ibs/ft^2 and an allowable velocity of 8 ft/sec.

B. Temporary ECB shall be North American Green's SC150 or alternate as favorably reviewed by the DESIGNER.

C. In accordance with the Erosion and Sediment Control Details in the Contract Documents.

2.02 TURF REINFORCEMENT MAT

A. Permanent Turf Reinforcement Mat (TRM) shall have an allowable tractive stress of 6 Ibs/ft^2 and an allowable velocity of 16 ft/sec.

B. Permanent TRM shall be North American Green's P300 or alternate as favorably reviewed by the DESIGNER.

C. In accordance with the Erosion and Sediment Control Details on the Contract Documents.

2.03 SILT FENCE

A. Silt fence shall meet the requirements for Silt Fence as described in the Delaware Erosion and Sediment Control Handbook, most recent version, and as shown in the Contract Documents.

2.04 COMPOST FILTER LOG

A. Compost filter log shall meet the requirements as described in the Delaware Erosion and Sediment Control Handbook, most recent version, and as shown in the Contract Documents.

B. Compost filter log shall be multi-filament polypropylene or approved equal.

2.05 STABILIZED CONSTRUCTION ENTRANCE

A. In accordance with Delaware Erosion and Sediment Control Handbook, most recent version, and as shown in the Contract Documents.

2.06 TEMPORARY STABILIZATION

A. Temporary stabilization shall consist of placing seed, mulch, fertilizer, and/or soil amendments as needed, for the area to be stabilized.

B. Seed, mulch, fertilizer, and soil amendments shall comply with the material requirements specified in Sections 734 and 735 of the August 2001 edition of the State of Delaware Department of Transportation *"Standard Specifications for Road and Bridge Construction"* (DELDOT Standard Specifications), as appropriate.

2.07 SEEDING, FERTLIZIER, MULCH

A. In accordance with Section 02936 of these Specifications and the most recent version of Delaware Erosion and Sediment Control Handbook.

2.08 DUST CONTROL

A. In accordance with Section 01562 of these Specifications and the most recent version of Delaware Erosion and Sediment Control Handbook.

2.09 OTHER EROSION AND SEDIMENT CONTROL FEATURES

A. CONTRACTOR shall select appropriate erosion and sediment control features from Delaware Erosion and Sediment Control Handbook, most recent version, and DELDOT Division 200.

B. CONTRACTOR may use erosion and sediment control features presented in other published erosion and sediment control guidance documents or manufacturers recommendations as approved by QAC.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the Work described in this Section, CONTRACTOR shall become thoroughly familiar with all portions of the Work falling within this Section.

B. Prior to implementing any of the Work in this Section, CONTRACTOR shall carefully inspect the installed Work of all other Sections and verify that all Work is complete to the point where the installation of this Section may properly commence without adverse impact. If CONTRACTOR has any concerns regarding the installed Work of other Sections, then CONTRACTOR shall notify QAC in writing within 48 hours of its site inspection. Failure to inform QAC in writing or installation of the Work of this Section will be construed as CONTRACTOR's acceptance of the related Work of all other Sections.

3.02 EROSION CONTROL MAT

A. Temporary and Permanent erosion control blanket/mat shall be installed either prior to or within 48 hours after seeding operations have been completed in the work areas.

B. Temporary erosion control blankets will be installed in all perimeter channels and on all landfill slopes less than 5H:1V.

C. Permanent TRM will be installed within all vertical channels and on landfill slopes 5H:1V and steeper.

D. The mat shall be placed on a smooth surface that is free of trash, ruts, and rocks.

C. TRM/ECB shall be placed flat and shall conform to the contours of soil surface.

D. Placement on Slopes;
   1. Anchor trenches shall be located at the crest and the toe of the terrace. Anchor trenches shall be a minimum of 6 inches deep. The anchor trench at the crest shall be located at 1 foot from the edge of the slope. The geometry of the anchor trench, type of fastener, fastener spacing, and method of construction of the anchor trenches shall be in accordance with the manufacturer's instructions.
   2. TRM/ECB shall be unrolled as directed by the manufacturer. Adjacent panels of TRM/ECB shall be installed with a minimum overlap of 4 inches. Fastening of the erosion mat shall begin in the toe anchor trench and shall progress upslope to the crest anchor trench. Spacing of fasteners shall be in intervals of 3 to 5 feet vertically upslope. Horizontal spacing of fasteners shall be in accordance with the manufacturer's instructions. Backfill shall be placed in anchor trenches over fasteners as construction proceeds.

3.03 SILT FENCE

A. CONTRACTOR shall install silt fence on a level grade downslope of all disturbed areas as shown on the Drawings. Both ends of the silt fence section must extend at least 8 feet upslope at 45 degrees to the main fence alignment.

B. Sediment accumulated against the silt fence shall be removed when it reaches one-half of the above ground height of the fence.

3.04 COMPOST FILTER LOG/ COMPOST FILTER LOG SEDIMENT TRAP

A. CONTRACTOR shall install compost filter log on a level grade downslope of all disturbed areas as shown on the Drawings. Both ends of the compost filter log must extend at least 10 feet upslope at 30 degrees to the main alignment.

B. Where multiple logs are needed, CONTRACTOR shall overlap the ends of each adjacent log at least 12 inches prior to filling. Placing filled logs end-to-end is not permitted.

C. Compost filter log sediment traps shall be constructed in accordance with the most recent version of Delaware Erosion and Sediment Control Handbook and as shown in the Contract Documents.

D. Sediment accumulated against the compost filter log and/or compost log sediment trap shall be removed when it reaches one-half of the above ground height of the log/trap.

3.05 TEMPORARY STABILIZATION

A. CONTRACTOR shall install temporary stabilization over disturbed areas, as needed, to minimize the potential for erosion.

B. The selection of temporary stabilization shall be agreed to between CONTRACTOR and QAC based on season, weather conditions, and anticipated time area will be left undisturbed.

C. Temporary stabilization shall be applied over any disturbed area that will be left bare for more than fourteen days.

D. CONTRACTOR shall prepare a seedbed prior to seeding and shall apply soil amendments and fertilizers to the seedbed.

E. CONTRACTOR shall apply mulch and mulch binding immediately after placing seed, soil amendments, and fertilizer.

3.06 OTHER EROSION AND SEDIMENT CONTROL FEATURES

A. CONTRACTOR shall install, operate, and maintain erosion and sediment control features in accordance with published literature and/or manufacturers recommendations throughout the duration of the Contract and direction by OWNER and QAC.

3.07 STOCKPILING

A. Stockpiles sideslopes shall be no steeper than 3H: 1V (horizontal: vertical), graded to drain, sealed by tracking parallel to the slope with a dozer or other means, and dressed daily during periods when material is taken from the stockpile. CONTRACTOR shall stabilize stockpiles as described in Part 3.05 of this Section.

*****END OF SECTION*****

SECTION 02210

SITE GRADING

<u>PART 1 - GENERAL</u>

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the Work of rough and finished site grading for areas to receive fill, temporary stormwater management structures, site drainage, site access roads, and general grading necessary for restoration of the overall Site. The CONTRACTOR shall provide a "Competent Person" to implement, supervise, and inspect the Work.

B. The CONTRACTOR shall comply with applicable codes, ordinances, rules, regulations and laws of local, State, and Federal authorities having jurisdiction.

1.02 SUBMITTALS

A. Submittals shall be made by the CONTRACTOR in accordance with the Specifications.

1.03 RELATED SECTIONS

A. 01562 - Dust Control

B. 02100 - Site Preparation

C. 02110 - Site Clearing and Grubbing

D. 02223 - Backfill and Fill

1.04 GENERAL

A. Notify corporations, companies, individuals or authorities owning above- or below-ground conduits, wires, pipes, or other utilities running to the property prior to the start of the Work in order to verify their locations and protect them from damage. CONTRACTOR should arrange for underground utility mark-outs prior to any excavation or grading work.

B. Cap, or remove and relocate, utility services in accordance with instructions by the OWNER and/or utility company.

C. Protect, support, and maintain conduits, wires, pipes or other utilities that are to remain in accordance with the requirements of the Contract Documents, and/or as required by the OWNER, and/or utility company.

1.05 QUALITY ASSURANCE

A. Testing shall be provided by the CONTRACTOR in accordance with applicable Sections of these Specifications as outlined in Article 1.03.

B. Tolerances in accordance with those specified in individual Sections of these Specifications as outlined in Article 1.03 herein.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Materials shall be in accordance with applicable Sections of these Specifications as outlined in Article 1.03 herein.

PART 3 - EXECUTION

3.01 PREPARATION

A. Examine surfaces to receive fill to determine existence of areas loosened by frost action, softened by precipitation or flooding, or of unsuitable materials.

B. Fill settled areas that were previously filled and where excavations or trenches were backfilled and holes made by demolition, tree removal, and other Site preparation work.

C. Natural soils or compacted fill softened by frost, precipitation or flooding shall be removed, replaced with soils of similar characteristics, and compacted.

D. Remove unsuitable material discovered during grading activities and backfill with compacted structural fill material as outlined in Section 02223.

E. Maintain adequate drainage of the Site. Remove ponded water prior to grading.

3.02 FILLING AND GRADING

A. Perform in accordance with Section 02223 of these Specifications.

B. Stockpile material suitable for backfill where indicated on the Contract Drawings or designated by the OWNER.

C. Place and grade materials not suitable for backfilling or grading, and unsuitable materials in designated relocation areas or as directed by the OWNER.

D. Grade to the elevations specified by the Contract Documents.

3.03 CLEANING

A. Excess materials shall be removed, stockpiled, or otherwise be removed for off-site disposal at an approved disposal facility. Excess excavation beyond the Contract limits, shall be discussed and approved by the OWNER prior to proceeding.

***** END OF SECTION *****

SECTION 02223

BACKFILL AND FILL

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of fill placement, including structural fill over excavated subgrade areas and in the existing sedimentation basin, general fill for backfill of anchor trenches, grading fill for placement on the top of ash prior to geosynthetic installation, cover soil above the geosynthetic components of the cap, and other fill placement related and incidental to the work within the designated area and as required for the construction of other work, as shown specified, or required. CONTRACTOR shall provide a "Competent Person" to implement and supervise all work.

B. Comply with applicable codes, ordinances, rules, regulations, and laws of local, municipal, State, or Federal authorities having jurisdiction.

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. ASTM D422 - Standard Method for Particle Size Analysis of Soils.
2. ASTM D698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
3. ASTM D1587- Standard Practice for Thin-Walled Tube Geotechnical Sampling of Soils.
4. ASTM D2216 - Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock.
5. ASTM D2487 - Standard Test Method for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
6. ASTM D6938 – Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow/Depth)
7. ASTM D4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
8. ASTM D2166 - Standard Test Method for Unconfined Compressive Strength of Cohesive Soil
9. ASTM D3080 - Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions

1.03 DEFINITIONS

A. Structural Fill – Material used to fill for over-excavated subgrade areas and backfill of the existing sedimentation basin, as applicable.

B. General Fill – Material used to backfill anchor trenches.

C. Grading Fill – Material used on top of the ash immediately beneath the geosynthetic components of the ash landfill cover system.

D. Cover Soil – Eighteen (18)-inch layer used directly over the geosynthetic cover system to provide protection to geosynthetics, and rooting depth and moisture for plant growth.

E. Vegetative Support Layer - Six (6)-inch thick topsoil layer placed directly on top of the cover soil layer on which permanent vegetation is established.

F. Ash – Material from the existing ash mound to be excavated and placed and compacted in the designated fill zones.

PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Fill and cover materials, unless otherwise specified, shall consist of suitable soil from selected off-Site borrow areas, approved by the OWNER.

B. No frozen earth shall be used for backfill and fill, and no backfill or fill shall be placed over frozen surfaces. All backfill and fill materials shall be free from all perishable and objectionable (as described below) materials. All fill shall be protected from frost.

C. All required fill and cover materials shall be free from organic materials, wood, trash, and other objectionable materials that may be compressible or cannot be properly compacted. Fill and cover materials shall not contain broken concrete, masonry rubble, or other similar materials that could damage geosynthetics. Fill and cover materials shall have physical properties such that it can be readily spread and compacted. Snow, ice, and frozen soil shall be removed from fill and cover material prior to placement.

D. All fill is to be in accordance with the applicable Delaware Department of Natural Resources and Environmental Control (DNREC) regulations.

E. All soil delivered to the Site shall be clean fill from a virgin borrow source or excavation project and not from a contaminated or remediated site.

F. All imported materials shall be tested prior to use according to Table 02223-1

G. All imported materials approved for use on Site shall be tested during construction according to Table 02223-1.

2.02 STRUCTURAL FILL:

Borrow materials shall have a USCS classification of GM, GW, GC, SM, SW, SC, ML, or CL in accordance with ASTM D2487. The maximum particle size shall not exceed 4-inches unless otherwise specified. The plasticity index shall be less than, or equal to, 25. The required testing is provided in Table 02223-1.

2.03 GENERAL FILL

Material proposed to use as general fill shall be approved by the QUALITY ASSURANCE CONSULTANT (QAC) and shall meet the general requirements listed in Section 2.01. The maximum particle size shall not exceed 3-inches unless otherwise specified.

2.04 GRADING FILL

Material proposed to use as grading fill shall be approved by the QAC and shall meet the general requirements listed in in Table 02223-1. Grading fill shall have a maximum particle size of 1 inch.

2.05 COVER SOIL

A. Material proposed to use as cover soil shall have a USCS classification of GM, GW, GC, SM, SW, SC, ML, or CL in accordance with ASTM D2487. The maximum particle size shall not exceed 1.5-inches, unless otherwise specified. The plasticity index shall be less than, or equal to, 25.

B. Soils containing organic debris or stone larger than 1.5-inches shall not be used in the construction of the cover system layers above the geomembrane.

C. The internal friction angle (ASTM D 3080) of the cover soil shall be 32 degrees.

PART 3 – INSTALLATION

3.01 STRUCTURAL FILL

3.01.01 Construction Quality Assurance (CQA) Pre-construction Testing

The QAC shall conduct CQA pre-construction sampling/testing to verify compliance with the specifications listed in in Table 02223-1

3.01.02 Placement

3.01.02.01 General Specifications

A. Areas on which fill will be constructed, shall be cleared of all vegetation. Immediately prior to filling, the subgrade shall be proof-rolled, unless otherwise specified. All unsuitable material, ponded water, and soft disturbed soils, as determined by the QAC, shall be removed prior to filling and filled with compacted structural fill.

B. Structural fill shall be placed in an approximate 12 inch thick loose lifts. Lift thickness may be increased to bridge over saturated areas at the discretion of the QAC.

C. Compaction shall be accomplished using a penetrating-foot compactor (e.g., Caterpillar 815 peg-foot compactor, or equal) or a vibratory smooth-drum roller (Caterpillar 563 roller, or equal) depending on the type of soil used and subject to the approval of the QAC and/or RESIDENT MANAGER (RM).

D. Structural fill shall be compacted to at least 95% of its maximum dry density determined by Standard Proctor (ASTM D698). Field testing for dry density and compaction moisture content shall be performed using a nuclear gauge (ASTM D-2922/3017). During the construction of each lift of structural fill, field moisture-density tests shall be performed at the frequency listed in in Table 02223-1. The frequency of testing may be increased at the discretion of the QAC when visual observations indicate a potential problem.

E. The surface of each compacted lift shall be scarified prior to the placement of subsequent lifts to ensure homogeneous bonding.

F. Areas exhibiting “pumping” or “rolling” shall be rejected by the QAC. All locations shall be competent and unyielding prior to placement of subsequent overlying layers of material.

3.01.02.02 Over-excavated Areas

Structural fill placed in over-excavated areas shall be placed in accordance with general specifications listed in Section 3.01.02.01.

3.01.02.03 Access Road Construction

In addition to the general specifications listed in section 3.01.02.01, the construction of the access road shall meet the following specifications:

A. Access Road Subgrade structural fill shall have a maximum particle size of 3-inches. Borrow materials shall be free of organic matter.

B. Any Temporary Access Roads required by the CONTRACTOR shall be at least 12-feet wide at the crest.

C. Access Road Subgrade structural fill shall have side slopes no steeper than 2(H):1(V). The CONTRACTOR shall design and maintain the road surface and side slopes, as necessary, to maintain the original grades and conditions specified in the Contract Documents. The road shall be passable at all times with construction traffic and passenger automobiles. At the end of the work, the CONTRACTOR shall repair the road to achieve a well maintained condition to the satisfaction of the OWNER.

D. A woven geotextile followed by coarse aggregate shall be place over the final surface of the access road. The ends of the woven geotextile shall be over lapped a minimum of 2-feet. Refer to Sections 02233 “Aggregate” and 02595 “Geotextile”, of these Specifications and Contract Drawings for placement and quality assurance requirements.

3.01.03 Construction Quality Assurance (CQA) Testing

The QAC shall monitor the placement of structural fill on a full-time basis and conduct CQA construction sampling/testing to verify compliance with the specifications at the frequencies outlined in Table 02223-1.

3.02 GENERAL FILL

3.02.01 Construction Quality Assurance (CQA) Pre-construction Testing

The QAC shall conduct CQA pre-construction sampling/testing to verify compliance with the specifications listed in section 2.01 at the frequencies noted above.

3.02.02 Placement

3.02.02.01 Backfill for Geomembrane Anchor Trenches

A. General fill approved by the QAC shall be placed in the anchor trench.

B. Backfill shall not be placed until the geosynthetics have been inspected in place and approved by the QAC. The extent of anchor trenches left open shall be kept to a minimum.

C. Unless otherwise directed, excavations shall be backfilled as soon as possible after geosynthetics are installed, tested (as required) and accepted, and permission to backfill has been given by the QAC.

D. Fill shall be brought up in essentially horizontal uniform lifts throughout the area. The loose lift thickness shall not exceed 12-inches, unless otherwise noted.

E. The backfill shall be compacted with the compaction effort acceptable to the QAC. The method of compaction shall not damage the geosynthetics. A minimum of 12-inches of fill must exist over geosynthetics prior to compaction.

F. Hand-operated plate type vibratory or other suitable equipment may be used in areas not accessible to larger rollers or compactors, and to avoid damaging geosynthetics.

3.02.03 Construction Quality Assurance (CQA) Testing

The CONTRACTOR shall allow the QAC to perform testing for general fill during construction, which shall consist of the following activities:

A. The QAC shall monitor placement of general fill on a full-time basis; and conduct CQA construction sampling/testing to verify compliance with the specifications.

B. Observe compaction at the discretion of the QAC where insufficient compaction is suspected and in areas where the uniformity of the material is not maintained based on visual observation.

3.03 GRADING FILL

3.03.01 Construction Quality Assurance (CQA) Pre-Construction Testing

The QAC shall conduct CQA pre-construction sampling/testing to verify compliance with the specifications listed in section 2.01 at the frequencies noted above.

3.03.02 Placement

A. The final grading layer on the impacted soils shall consist of at least 6-inches of soil, to attain the final slope and provide a stable base for the subsequent geosynthetic capping system. The surface of the final grading layer shall contain no particles larger than 1-inch in their greatest dimension.

3.03.03 Construction Quality Assurance (CQA) Construction Testing

The CONTRACTOR shall allow the QAC to testing for grading fill during construction, which shall consist of the following activities:

A. The QAC shall conduct four (4) depth checks per acre to ensure a minimum depth of 6-inches;

B. The QAC shall conduct laboratory gradation analyses of four separate samples per acre (one each obtained at the four depth check locations) to ensure conformance with the maximum particle size requirements.; and,

C. Inspect the surface of the final layer prior to the installation of the geosynthetic capping system.

All survey grade stakes are to be accounted for and removed prior to placement of the geosynthetic capping system.

3.04 COVER SOIL

3.04.01 Construction Quality Assurance (CQA) Pre-Construction Testing

A. Prior to the placement of the cover soil, the QAC shall test each source to determine whether the material meets the requirements outlined in in Table 02223-1. This testing may be decreased at the discretion of the QAC, if the material is relatively uniform.

B. The pre-construction laboratory testing must be completed and approved by the QAC before use.

3.04.02 Placement Testing

A. No material shall be placed until the QAC has approved the installation of the underlying geosynthetics.

B. No material shall be placed until the QAC has approved the pre-construction laboratory testing as described in Table 02223-1.

C. Cover soil shall be placed directly over the geocomposite (or geotextile) in one (1) 18-inch thick lift. No compaction is required for this layer. Should the QAC have reason to suspect that the material delivered to the Site has changed from that previously tested and approved, he shall immediately notify the CONTRACTOR's on-Site representative and arrange for additional laboratory testing.

D. The CONTRACTOR shall use extreme care in the placing of the cover soil over the geosynthetics. The material shall be spread up slope in a manner that will maintain a minimum thickness of 18-inches of material between the geomembrane liner and low ground pressure (LGP) (less than or equal to 5 pounds per square inch (psi)) spreading equipment. A minimum distance of 36-inches shall be maintained between geosynthetics and heavy equipment transporting protective cover material. Additional procedures for the placement of soils above the geosynthetic cap system are as follows:
   a. Placement of soils on the geomembranes shall not proceed at an ambient temperature below 32 degrees F (0 degrees C) nor above 104 degrees F (40 degrees C) unless otherwise specified. Fill placement will not be allowed during weather conditions that do not allow for the proper control of moisture and density.

b. Placement of soil on the geomembrane should be done during the coolest part of the day to minimize the development of wrinkles in the geomembrane.
c. Equipment used for placing soil shall not be driven directly on the geosynthetics.
d. In any areas traversed by any vehicle other than low ground pressure vehicles approved by the QAC, the soil layer shall have a minimum thickness of 3-feet (0.9m).
e. Soil cover material shall be placed at the toe of slope and advanced upslope. Traversing cross slope or spinning by track equipment shall not be permitted. Placement of soil downslope is strictly prohibited.

E. Cover soil shall be transported over constructed temporary haul roads or benches to the toe of the slope. Material shall be placed at the toe of the slope by transporting equipment and pushed up slope by LGP spreading equipment. Transporting equipment shall not be allowed on slopes of the capping system under any circumstances. All equipment to be used on the slope shall be LGP, and be approved by the OWNER.

F. The CONTRACTOR shall take care to ensure that:

1. No foreign material is mixed into the cover soil that may damage the under lying geosynthetics.
2. No vehicles shall drive on the uncovered geosynthetics.
3. All grade stakes used for survey control during protective cover placement are removed in their entirety.

3.04.03 Construction Quality Assurance (CQA) Testing

A. The QAC shall perform quality control assurance outlined in in Table 02223-1.

B. The QAC will submit copies of daily field reports, including results of field and laboratory testing, on a daily basis.

3.05 ASH

3.05.01 Placement

The excavated ash shall be relocated to the fill area and placed in maximum 12-inch loose lifts and compacted with a vibratory smooth-drum roller (Caterpillar 563 roller, or equal). Compaction shall be made with four (4) complete passes of the roller to ensure proper bonding between lifts

3.05.02 Construction Assurance Testing

The QAC will witness and document the compactive effort and will direct the Contractor to proof-roll suspect areas with a loaded triaxial truck to ensure there is no pumping or deflection. Any substandard areas will be excavated and recompacted to the satisfaction of the QAC.

*****END OF SECTION*****

TABLE 02223-1
GEOTECHNICAL LABORATORY CONFORMANCE TESTING SUMMARY
EDGE MOOR SITE II ASH LANDFILL CLOSURE
EDGE MOOR, DELAWARE

Test	Method	Frequency		Specification Requirement
		Conform.	Construct.	
Structural Fill				
Soil Classification	ASTM D2487	1/source	-	
Sieve Analysis (w/ hydrometer)	ASTM D422	1/source	1/5,000cy	≤4 in
Atterberg Limits	ASTM D4318 (B)	1/source	1/5,000cy	≤25 PI
Moisture Content	ASTM D2216	1/source	1/5,000cy	
Field Density	ASTM D2922/2937	-	1/lift on 100' x 100' grid	≥ 95% of max. dry density
Field Mositure	ASTM D3017	-	1/lift on 100' x 100' grid	
Proctor Test	ASTM D698	1/source	1/5,000cy	
General Fill				
Soil Classification	ASTM D2487	1/source	-	
Sieve Analysis (w/ hydrometer)	ASTM D422	1/source	1/5,000cy	≤3 in
Atterberg Limits	ASTM D4318 (B)	1/source	1/5,000cy	
Moisture Content	ASTM D2216	1/source	1/5,000cy	
Grading Fill				
Soil Classification	ASTM D2487	1/source	-	
Sieve Analysis (w/ hydrometer)	ASTM D422	1/source	1/5,000cy	≤1 in
Atterberg Limits	ASTM D4318 (B)	1/source	1/5,000cy	
Moisture Content	ASTM D2216	1/source	1/5,000cy	
Thickness	Not listed	-	4/acre	≥6 in
Cover Soil				
Soil Classification	ASTM D2487	1/source	-	
Sieve Analysis (w/ hydrometer)	ASTM D422	1/source	1/5,000cy	≤1.5 in (Cover)
Atterberg Limits	ASTM D4318 (B)	1/source	1/5,000cy	≤25 PI
Moisture Content	ASTM D2216	1/source	1/5,000cy	
Thickness	Not listed	-	4/acre	≥18 in
Internal Angle of Friction	ASTM D3080	1/source/project	-	32 degrees
Vegetative Support Layer				
Grain Size (w/ hydrometer)	ASTM D422	1/source	1/5,000 cy	≤1.5 in
Internal Angle of Friction	ASTM D3080	1/source/project	-	32 degrees
Atterberg Limits	ASTM D4318	1/source	1/5,000 cy	≤25 PI
pH	ASTM D4972	1/source	1/5,000 cy	<7.6
Organic Matter	ASTM D2974	1/source	1/5,000 cy	
Soil Fertility	Mehlich 3 Test	1/source	1/5,000 cy	
Total Nitrogen	ASTM D2973	1/source	1/5,000 cy	
Aggregate				
Particle Size Testing	ASTM C136	1/source	-	≤2.5 in (AASHTO No. 3)
				≤1.5 in (AASHTO No. 57)
				≤1.5 in (Dense Grade)
Sodium Sulfate Soundness	ASTM C88	1/source	-	≤20% weight loss
Stone Riprap				
Sodium Sulfate Soundness	ASTM C88	1/source	-	≤20% weight loss

Notes: (1) Based on 16.0 acres.

SECTION 02230

ANCHOR TRENCH

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, equipment, tools and appurtenances required to complete portions of the Work required for the excavation and backfilling of the anchor trench and for the placement of the anchor trench, as shown, specified, or required by the Contract Documents.

B. The CONTRACTOR shall comply with applicable codes, ordinances, rules, regulations and laws of local, State, and Federal authorities having jurisdiction. The CONTRACTOR shall provide a “Competent Person” to implement, supervise, and inspect the Work.

C. The CONTRACTOR is responsible for following all health and safety precautions applicable to trenches during backfilling of trenches.

D. The QUALITY ASSURANCE CONSULTANT (QAC) will perform quality assurance testing in accordance with these Specifications and Construction Quality Assurance (CQA) Plan for the placement and testing of anchor trench backfill. CONTRACTOR shall cooperate fully with QAC in obtaining the required samples.

1.02 RELATED SECTIONS

A. 02210 – Site Grading

B. 02223 – Backfill and Fill

1.03 SUBMITTALS

A. Submittals shall be made by the CONTRACTOR in accordance with the Specifications.

PART 2 - PRODUCTS

2.01 GENERAL

A. Fill for the anchor trench backfill/plug and shall consist of general fill material supplied by the CONTRACTOR in accordance with Section 02223

B. The anchor trench backfill/plug shall have a maximum particle size of 1 inch. The OWNER will endeavor to provide material which will generally meet these maximum particle size requirements. However, the CONTRACTOR may be required to remove occasional particles exceeding these maximum dimensions. Such particles will be removed when observed and stockpiled outside the fill area at a location designated by the OWNER.

PART 3 - EXECUTION

3.01 STORAGE

A. Stockpile excavated and imported materials where directed by the OWNER until required for backfill and fill placement. Place, grade, and shape stockpiles to provide proper drainage. Seal stockpiles with a smooth drum roller to avoid excessive moisture retention. Install appropriate erosion and sediment control devices around stockpiles.

B. Do not combine stockpiles of fill for the anchor trench backfill/plug with other soil stockpiles on-site. Stockpiles should be clearly separated in the field to prevent mixing.

C. Locate and retain stockpiled soil materials in a location where the weight of the stockpiled materials will not create surcharge loading conditions on the edges of excavations as specified in Section 02223.

D. Material not suitable for backfilling or site grading and other unsuitable materials shall be placed in designated spoil stockpiles. Spoil stockpiles shall be graded and have erosion control measures in place as outlined in Section 02125.

3.02 PREPARATION

A. Do not excavate within the influence zone of existing footings or foundations, or similar structures such as monitoring wells without prior approval of the QAC.

B. Excavate the subgrade to provide smooth surface free from loose soil, stones, rocks, and construction related debris.

C. CONTRACTOR shall excavate anchor trenches, unless otherwise specified, to the lines and grades shown on the Contract Drawings, prior to geomembrane placement. Anchor trench shall be drained to prevent ponding or softening of adjacent soils while the trench is open.

D. Provide slightly rounded corners in anchor trenches to avoid sharp bends in the geosynthetic liner.

E. If the anchor trench is excavated in material susceptible to desiccation, minimize the amount of trench open at any time.

3.03 PLACEMENT OF FILL

A. Fill materials shall not be placed until the subgrade has been inspected in place, surveyed, and favorably reviewed by the QAC.

B. Employ a placement method that does not disturb or damage other completed Work.

C. Make gradual grade changes. Blend slope into surrounding areas.

D. Place fill in relatively uniform horizontal lifts not exceeding 9 inches before compaction, or as shown on the Contract Drawings.

E. Do not place material below air temperature of 32° F, unless the CONTACTOR can demonstrate fill material temperature is above freezing. No frozen materials shall be used for backfill, fill, or any other materials specified herein. Snow, ice, and frozen soil shall be removed from fill and backfill material prior to placement.

F. All fill and backfill materials shall be free from organic materials, wood, trash, broken concrete, masonry rubble, and all deleterious and objectionable materials that may be degradable or cannot be properly compacted. Backfill and fill materials shall have physical properties such that they can be readily spread and compacted.

G. CONTRACTOR shall backfill the anchor trench as soon as practical after the geosynthetic liner installation is completed. The compacted material plug above the anchor trench will be constructed immediately after the liner installation is completed.

H. The tolerance for layers having a specified minimum thickness shall be -0.0 to +0.1 feet of the specified thickness. The CONTRACTOR shall ensure that materials placed meet or exceed the minimum specified thickness but do not exceed maximum thicknesses as required by the Contract Documents.

3.04 COMPACTION REQUIREMENTS

A. Backfill and fill shall be placed and compacted as required in Section 02223.

3.05 FIELD QUALITY ASSURANCE

A. The QAC observe compaction of soils in accordance with the CQA Plan.

B. Any areas that show visible signs of softness or rutting shall be reworked by the CONTRACTOR by providing additional compaction effort until acceptable results are obtained. The CONTRACTOR shall not proceed with a new lift of material until the QAC has confirmed that the previous lift has attained the required compaction. The CONTRACTOR shall rework by wetting, drying, or recompacting backfill/fill material that is not in compliance with the requirements of this section. At his sole expense, the CONTRACTOR may remove and replace fill materials with prior approval from the QAC.

C. In areas where the degree of compaction is not obtained or the uniformity of materials is not maintained in the opinion of the QAC, additional tests and/or compactive effort will be made as directed by the QAC at no additional cost to the OWNER.

D. The QAC shall verify the thickness of each lift after the compaction and prior to the placement of the next lift.

E. The CONTRACTOR shall be responsible for conducting any and all quality control testing necessary for the CONTRACTOR's purposes to satisfy the Contract Documents.

*****END OF SECTION*****

SECTION 02233

AGGREGATE MATERIALS

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of furnishing and placing aggregate materials for access roads, toe drains, stabilized construction entrances and as otherwise shown on the Contract Drawings or approved by the QUALITY ASSURANCE CONSULTANT (QAC).

B. The CONTRACTOR shall comply with applicable codes, ordinances, rules, regulations and laws of local, municipal, State or Federal authorities having jurisdiction. The CONTRACTOR shall provide a "Competent Person" to implement, supervise and inspect the Work.

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM):
   1. ASTM C136 – Standard Method for Sieve Analysis of Fine and Coarse Aggregates

PART 2 - PRODUCTS

2.01 MATERIAL

A. The materials shall be environmentally clean, sound, tough, durable, crushed stone or gravel as required by this Section, not lumpy, and free from slag, cinders, ashes, rubbish, ice, recycled concrete, and deleterious and organic materials.

B. All aggregate materials shall be obtained from an environmentally clean off-site borrow source that is favorably reviewed by the QAC. The QAC may at any time collect samples of imported materials for testing at the OWNER's expense. Any contaminated materials from off-site sources that are placed shall be removed and replaced with suitable materials at the CONTRACTOR's expense.

C. Aggregate materials shall be stored in designated clean areas approved by the QAC. The CONTRACTOR shall be responsible for maintaining the aggregate materials to be free of contamination, and any aggregate materials determined to be contaminated shall not be used for the required construction activities.

D. Aggregate material referred to DelDOT No. 3 (AASHTO No. 3) on the Construction Drawings shall be crushed stone conforming to the following gradation requirements:

US Standard Sieve Size	Percent Passing By Weight
2 ½ inch	100
2 inch	90-100
1 ½ inch	35-70
1 inch	0-15
1/2 inch	0-5

E. Aggregate material referred to AASHTO No. 57 on the Construction Drawings shall be crushed stone conforming to the following gradation requirements:

U.S. Standard Sieve Size	Percent Passing by Weight
1-1/2 inch	100
1 inch	95-100
1/2 inch	25-60
No. 4	0-10
No. 8	0-5

F. Where required by the Contract Drawings, aggregate material commonly referred to as Dense Graded Aggregate (DGA), shall be non-plastic, broken or crushed stone, and shall conform to the following gradation requirements:

US Standard Sieve Size	Percent Passing By Weight
1½ inch	100
¾ inch	55-90
No. 4	25-60
No. 5	5-25
No. 200	3-12

2.02 TESTING

A. The CONTRACTOR shall submit to the QAC a certification that the materials proposed for use as aggregate materials meet the requirements of Article 2.01 herein. This certification shall include, at a minimum, particle size testing in accordance with ASTM C136 for each type of aggregate material and each material source.

B. The CONTRACTOR shall be responsible submitting testing results. Testing shall be performed by a specialized laboratory that has been favorably reviewed by the QAC. The frequency of testing shall be once per every 5,000 tons of each material delivered or once per each material source, whichever is greater.

C. The CONTRACTOR shall not proceed with the use of the materials until the QAC has favorably reviewed the proposed materials.

D. The QAC may at any time request the collection of samples of imported materials for additional analytical and/or index property testing at the OWNER's expense. Any imported materials from off-site sources found to not be in accordance with the Specifications, or found to be contaminated, shall immediately be removed and replaced with suitable materials at the CONTRACTOR's expense with no time extensions in the Construction Schedule granted.

PART 3 - EXECUTION

3.01 STORAGE

A. Stockpile imported materials in clean areas approved by the QAC until required for placement.

B. Locate and retain stockpiled materials in a location where the weight of the stockpiled materials will not create surcharge loading conditions on the excavation edges.

3.02 PLACEMENT

A. Aggregate materials shall be placed in uniform layers to the lines, depths, and grades in areas as shown on the Contract Drawings or where approved in the field by the QAC.

B. Placement of aggregate materials shall be performed by the CONTRACTOR in a manner such that the material is kept clean and free of foreign materials.

C. Placement of aggregate materials for access roads shall be performed by the CONTRACTOR in a manner such that the material is graded to blend in with existing grades to prevent surface water ponding or erosion. In particular, the aggregate materials for the access roads and benches shall be confined on the edges to prevent push-out of the material.

D. When backfilling with aggregate materials, the CONTRACTOR shall employ a placement method that does not disturb or damage other work.

E. Aggregate materials shall be placed in maximum 12-inch thick loose lifts. Each lift shall be compacted to form a hard dense mass as approved by the QAC.

*****END OF SECTION*****

SECTION 02235

VEGETATIVE SUPPORT LAYER

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. CONTRACTOR shall furnish all labor, materials, equipment and incidentals necessary to place the vegetative support layer as shown on the Contract Drawings and specified herein. The work shall include, but not necessarily be limited to, the earthwork required for vegetative support layer placement, and all related work. CONTRACTOR shall provide a "Competent Person" to implement and supervise all work.

B. Comply with applicable codes, ordinances, rules, regulations, and laws of local, municipal, State, or Federal authorities having jurisdiction.

1.02 TOLERANCES

A. The minimum thickness of the vegetative support layer is as shown on the Contract Drawings. Tolerances for the thickness of vegetative support layer are 0.0 to +0.1 feet.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Soil material used as vegetative support layer shall be loamy fine sand, loamy sand, sandy clay, sandy clay loam, fine sandy loam, clay loam, silty clay, or sandy loam as defined by the U.S. Department of Agriculture textural classification chart, and shall be suitable to support vegetative growth.

B. Soil shall meet the requirements set forth in Section 02223 Backfill and Fill Article 2.01 E.

C. The vegetative support layer shall not contain trash, debris, stones, lumps, roots, or similar objects larger than 1½ inches in any dimension.

D. The vegetative support layer shall be free of weeds and invasive plant material.

E. The vegetative support layer shall have a pH between 5.8 and 7.6.

F. Soil material used as the vegetative support layer must be capable of sustaining vegetation, as specified in Section 02936 “Seeding”.

G. The internal friction angle (ASTM D 3080) of the cover soil shall be 32 degrees.

2.02 TESTING

A. The CONTRACTOR shall submit, to the QUALITY ASSURANCE CONSULTANT (QAC) for approval, laboratory test results indicating that the material proposed for use as vegetative support layer meets the requirements of Section 2.01. Testing shall include, but not necessarily be limited to, the following methods (or QAC approved equivalent methodology):

1.	Grain Size w/ Hydrometer	ASTM D422
2.	Atterberg Limits	ASTM D4318
3.	pH	ASTM D4972

4.	Organic Matter (OM)	ASTM D2974
5.	Soil fertility	Mehlich 3 Test
6.	Total Nitrogen	ASTM D2973
7.	Direct Shear	ASTM D3080

B. The testing above should be completed at a frequency of one (1) test per source pre-construction testing and one (1) test per 5,000 CY during construction. The pre-construction testing, if approved, applies for the first 5,000 CY. See Table 02223-1 for more detail on testing requirements.

C. No material shall be placed unless approved by the QAC.

D. If, in the opinion of the QAC, the proposed vegetative support layer is unsuitable for the proposed application, the CONTRACTOR shall submit to the QAC the required suitable testing, as specified in (A) above, for soil from a different source.

PART 3 - EXECUTION

3.01 INSTALLATION

A. This item shall consist of the placement of the vegetative support layer as the final cover system layer or other areas as approved by the QAC.

B. The CONTRACTOR shall provide all the required materials, labor, and equipment to perform the Work in accordance with these Specifications.

C. No vegetative support layer soils shall be placed until subgrade is prepared and approved by the QAC.

D. The vegetative support layer shall be installed in 6-inch thick uncompacted lifts.

E. The CONTRACTOR shall take care to ensure that underlying soil remains intact and does not become mixed with the vegetative support layer during installation.

F. In applying vegetative support material, no equipment can drive directly across the prepared subgrade areas. The vegetative support layer shall be placed from the bottom of the slope proceeding upwards and in a manner that prevents instability of the underlying soils. Unless otherwise specified by the QAC, all equipment for spreading vegetative support layer overlying the subgrade shall comply with the following:

Maximum Equipment Ground Pressure (psi)	Minimum Separation Thickness (inches)
<5	12
5 – 10	36
>10	48

*****END OF SECTION*****

SECTION 02271

STONE RIPRAP

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall provide all labor, materials, equipment, tools and appurtenances required to complete the work of furnishing and placing stone riprap in the areas shown on the Construction Drawings. CONTRACTOR shall provide a "Competent Person" to implement and supervise all work.

B. Comply with applicable codes, ordinances, rules, regulations, and laws of local, municipal, State, or Federal authorities having jurisdiction.

PART 2 - PRODUCTS

2.01 MATERIAL

A. The materials shall be environmentally clean, sound, tough, durable, crushed stone or gravel as required by this Section, not lumpy, and free from slag, cinders, ashes, rubbish, ice, recycled concrete and deleterious and organic materials.

B. The riprap sizes specified for the Site are:

Type	Graded Rock Size (in.)			Min. Blanket Thickness (in.)
	Max.	d_{50}**	Min.	
R-3	6	3	2	9
R-4	12	6	3	18

** 50% of pieces, by weight, should be larger than this size

C. All riprap materials shall be obtained from an environmentally clean off-site borrow source that is favorably reviewed by the DESIGNER. The DESIGNER may at any time collect samples of imported materials for testing at the OWNER’s expense. Any contaminated materials from off-site sources that are placed shall be removed and replaced with suitable materials at the CONTRACTOR’s expense.

D. Riprap materials shall be stored in designated clean areas approved by the DESIGNER. The CONTRACTOR shall be responsible for maintaining the riprap materials to be free of contamination, and any riprap materials determined to be contaminated shall not be used for the required construction activities.

E. Stone riprap shall be utilized as shown on the construction drawings and consist of R-3 or R-4 lining, hard, durable, sub-angular material in accordance with Delaware Department of Natural Resources and Environmental Control (DNREC) specifications. It shall be free from any considerable amount of flat, laminated or elongated particles; and shall be free from cracks, overburden shells, clay, organic matter, or other deleterious matter.

F. The stone riprap shall have a minimum Specific Gravity of 2.50, as defined by ASTM C127.

G. Weight loss shall not be more than 20% after 5 cycles when tested by sodium sulfate test methods as defined by ASTM C88.

H. The stone riprap shall be composed of an evenly distributed mixture of particle sizes. Fifty (50) percent of the mixture by weight shall be larger than the d50 size shown on the Contract Drawings. The largest stone size in this mixture shall be 2.0 times the d50 size. The diameter of the smallest stone size in this mixture shall be 0.5 times the d50 size.

I. The minimum blanket thickness to be 1.5 times the dmax or as required on the Contract Drawings.

J. The breadth or thickness of a single stone shall not be less than 1/3 its length.

2.02 TESTING

A. The CONTRACTOR shall provide a written certification letter from the supplier to the DESIGNER stating that the riprap meets the requirements of Article 2.01 herein.

PART 3 – EXECUTION

3.01 INSTALLATION

A. Stone riprap shall be placed in the indicated areas to thicknesses as indicated on Construction Drawings.

B. Stone riprap shall be placed in a manner that will not damage the geotextile placed above any subgrade areas, utilities, or other facilities. Riprap shall not be dropped from a height exceeding three (3) feet.

C. The tolerance in riprap thickness in place shall be 0.0 to +0.3 feet.

D. No material shall be placed unless approved by the DESIGNER.

*****END OF SECTION*****

SECTION 02275

RENO MATTRESS

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of furnishing, placing the reno mattress baskets, and backfilling with reno mattress rock as shown, specified, or required. The CONTRACTOR shall provide a "Competent Person" to implement, supervise, and inspect all work.

1.02 SUBMITTALS

A. The CONTRACTOR shall, at least 15 calendar days prior to use on-site, submit to the QUALITY ASSURANCE CONSULTANT (QAC) for favorable review supplier's information the type of reno mattress baskets to be used.

B. The CONTRACTOR shall submit manufacturer's catalog sheets and installation information.

C. Submittals shall be made in accordance with the Specifications.

1.03 RELATED SECTIONS

A. 02223 - Backfill and Fill

B. 02271 - Stone Riprap

C. 02595 - Geotextile

PART 2 - PRODUCTS

2.01 MATERIAL

A. Reno Mattress Baskets shall be galvanized cages as manufactured by Maccaferri Inc., or approved equal and conform to ASTM A975-97.

1. Galvanized (zinc coated) wire:
   a. Tensile strength shall a minimum of 75,000 psi, in accordance with ASTM A641/A641M-03.
   b. Elongation shall be a minimum of 12% in accordance with ASTM A370-97a.
   c. Zinc coating shall be in accordance with ASTM A641/A641M-03, Class III soft temper coating.
   d. Adhesion of zinc coating shall be in accordance with ASTM A641/A641M-03.

2. Galvanized (zinc coated) woven mesh wire reno mattress (6 x 8 mesh):
   a. Wire mesh: 0.087 inches (2.20 mm) diameter.
   b. Selvedge wire: 0.120 inches (3.00 mm) diameter.

c. Mesh opening: 2.5 inches (64 mm) nominal.

3. Galvanized (zinc coated) lacing wire:
   a. lacing wire: 0.087 inches (2.2 mm) diameter.

4. Steel Mesh
   a. Mesh tensile strength: 2,300 lb/ft in accordance with ASTM A975.
   b. Punch test resistance: 4,000 lbs. in accordance with ASTM A975.
   c. Connection to selvedges resistance: 700 lb/ft in accordance with ASTM A975.

B. Reno Mattress Rock
   1. The rock shall be clean, sound, tough, and durable, subangular or subrounded stone, not lumpy, and free from slag, cinders, ashes, rubbish, or other deleterious material.
   2. Rock shall meet the requirements for riprap in Article 2.01 of Section 02271.
   3. The CONTRACTOR shall maintain a uniform gradation of rock with a minimum diameter of 3 inches and a maximum diameter of 6 inches.
   4. Rock shall be stored in designated areas approved by the OWNER. The CONTRACTOR is responsible for maintaining the rock free of contamination, and any rock determined by the QAC to be contaminated, shall not be incorporated into the work.

PART 3 - EXECUTION

3.01 PLACEMENT

A. Reno mattresses shall be placed to the lines, depths and grades as shown on the Contract Drawings and shall be in strict accordance with the manufacturer's recommendations and/or these Specifications, whichever is more stringent.

B. The subgrade should be rolled smooth before the geotextile is installed. Install the geotextile flat with proper overlaps and sewn seams before installing the baskets. Anchor the geotextile accordingly prior to the placement of the first basket.

C. All tying of the Reno mattress in each step of construction shall be done in the following manner:

   1. Cut a length of tie wire approximately 5 feet long, secure the wire at one end by looping and twisting together, then proceed tying with a double loop (made at the same point) every 4 to 5 inches apart, pulling the basket pieces tightly together. Secure the end of the wire by again looping and twisting.
   2. Reno mattress baskets are assembled by unfolding the baskets on a hard flat surface and stamping out all kinks. Fold up the front, back and end panels and fasten together with the projecting heavy gauge wire by twisting it around the selvedge wire two (2) complete turns. Fold the diaphragms up and secure in the same manner. All end panels and diaphragms are then tied to the sides.
   3. Reno mattress baskets shall be placed in position empty and shall be tied together each to its neighbor along all contacting edges in order to form a continuous connecting structural unit before filling with rock. The use of fasteners is acceptable <u>ONLY</u> when used in addition to the lacing wire.

4. Selvedge perimeter edges of mesh forming basket so joints formed by tying selvedges have at least the same strength as the body of the mesh.
5. When the assembled empty baskets have been installed and secured, the rock shall then be placed in the following manner. The baskets may be filled by machine in 6-inch maximum layers; however, the rock must be manipulated by hand to accomplish a maximum density and a minimum amount of voids. Care shall be taken when placing the stone into the baskets to ensure that the baskets are not damaged or bent. Edges of baskets and diaphragms may be protected by tying steel reinforcement to the baskets or other suitable means. Care shall be taken that the individual cells do not bulge outward and that the rows are straight, level and have square corners.
6. When each basket has been filled to its maximum capacity, which is slightly higher than the sides, and the surface leveled with a minimum amount of voids, the lids shall be pried down and over with a bar or lid closing tool until the edge of the lid and the edge of the basket are together. It should require a light stretching in order to bring the two basket pieces together. The heavy projecting wire on the lid shall then be twisted around the heavy wire on the sides, two complete turns and the lid shall then be tied to the sides and tops of the diaphragms in the same manner as the baskets are assembled. The lids of the reno mattress baskets shall also be tied together, each to its adjoining basket along all contacting edges to ensure the formation of a continuous connecting structural unit. Special attention shall be given such that all projecting sharp ends are turned in.
7. Reno mattress baskets may be cut to form curves or bevels. Re-tying shall be in a manner to produce a closed cell and re-tying of the basket shall be in a manner as the assembly. Excess mesh wire shall be cut off or be tightly and neatly laced down.

3.02 QUALITY CONTROL

A. Install reno mattresses in strict conformance with the manufacturer's installation instructions, tying of all joints and filling of the baskets to the maximum density with a minimum amount of voids. The QAC shall visually inspect the construction of all reno mattresses.

B. Reno mattresses that are not constructed and filled in accordance with the manufacturer's instructions and to the satisfaction of the QAC shall be repaired or removed and replaced by the CONTRACTOR at no cost to the OWNER.

*****END OF SECTION*****

SECTION 02595

GEOTEXTILE

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. CONTRACTOR shall furnish all geotextile, labor, incidental materials, tools supervision, transportation, and installation equipment necessary for the installation of geotextile, and as specified herein, as shown on the Drawings, and in accordance with the Construction Quality Assurance (CQA) Plan.

B. CONTRACTOR shall obtain the geotextile from a Geotextile Manufacturer that has the demonstrated experience with geotextile manufacturing as stated in Part 1.02.A of this Section.

C. CONTRACTOR shall install all geotextile and shall be responsible for field handling, storing, deploying, seaming or connecting, temporary restraining, anchoring, and other site aspects of geotextile installation.

1.02 QUALIFICATIONS

A. The Geotextile Manufacturer shall have successfully manufactured a minimum of 20,000,000 ft^2 of the same type of geotextile a specified for this Project.

B. At Geotextile Manufacturer shall have sufficient manufacturing capacity and qualified personal to meet the requirements of this Section and the demands (e.g., quantity production and quality control) of this Project.

1.03 SUBMITTALS

A. At least 14 days prior to shipping any geotextile, the CONTRACTOR shall provide the QUALITY ASSURANCE CONSULTANT (QAC) with the following documentation on the proposed geotextile:

1. manufacturer and product name;
2. minimum property values of the proposed geotextile and corresponding test procedures;
3. proposed geotextile delivery dates; and,
4. a statement from the Geotextile Manufacturer that the geotextiles will retain their structure during handling, placement, and long-term service; and be capable of withstanding direct exposure to sunlight for a minimum of 30 days with no measurable deterioration.

B. At least seven (7) days prior to deploying the geotextile, the CONTRACTOR shall submit to the QAC the following documentation on geotextile production:

1. a list of geotextile roll numbers delivered to the Site;
2. lot, batch and/or roll numbers and identification; and,
3. results of quality control tests, including a description of the test methods, signed by a responsible party employed by the Geotextile Manufacturer (e.g., Production Manager).

1.04 CONSTRUCTION QUALITY ASSURANCE

A. The installation of the geotextile shall be monitored by the QAC as outlined in the CQA Plan.

B. CONTRACTOR shall be aware of the activities in the CQA Plan and shall account for these CQA activities in the construction schedule.

PART 2 - PRODUCTS

2.01 NONWOVEN GEOTEXTILE PROPERTIES

A. Non-woven geotextile shall be as indicated on the Contract Drawings. The geotextile shall meet the following minimum average required value (MARV) minimum properties:

Test Name	Test Standard	Value	MQC Testing Frequency by Manufacturer	CQA Testing Frequency
Mass per Unit Area	ASTM D5261	10.0 oz/sy	1 test per 100,000 SF	1 test per 250,000 SF*
Grab Tensile Strength	ASTM D4632	270 lbs	1 test per 100,000 SF	1 test per 250,000 SF*
Grab Tensile Elongation	ASTM D4632	50 %	1 test per 100,000 SF	1 test per 250,000 SF*
Trapezoidal Tear Strength	ASTM D4533	105 lbs	1 test per 100,000 SF	1 test per 250,000 SF*
CBR Puncture Strength	ASTM D6241	120 lbs	1 test per 500,000 SF	1 test per 250,000 SF*
Apparent Opening Size	ASTM D4751	100 sieve	1 test per 500,000 SF	1 test per 250,000 SF*
Permittivity	ASTM D4491	1.0 Sec^{-1}	1 test per 500,000 SF	1 test per 250,000 SF*
UV Resistance	ASTM D4355	70 %	Certified by Manufacturer	-

* Minimum one (1) per lot.

B. The geotextile provided shall be stock products. Products specifically manufactured to meet the Specifications of the Project shall not be used unless authorized by the OWNER and QAC.

2.02 WOVEN GEOTEXTILE PROPERTIES

A. Geotextile for stabilized construction entrance shall be as indicated in the Delaware Erosion and Sediment Control Handbook and on the Contract Drawings. The geotextile meet the following minimum average required value (MARV) minimum properties:

Test Name	Test Standard	Value	MQC Testing Frequency by Manufacturer	CQA Testing Frequency
Grab Tensile Strength	ASTM D4632	315 lbs (min.)	1 test per 100,000 SF	1 test per 250,000 SF*
Grab Tensile Elongation	ASTM D4632	15% (max.)	1 test per 100,000 SF	1 test per 250,000 SF*
Trapezoidal Tear Strength	ASTM D4533	120 lbs (min.)	1 test per 100,000 SF	1 test per 250,000 SF*
CBR Puncture Strength	ASTM D6241	900 lbs (min.)	1 test per 500,000 SF	1 test per 250,000 SF*
Apparent Opening Size	ASTM D4751	40-80 sieve	1 test per 500,000 SF	1 test per 250,000 SF*
Flow-thru Rate	ASTM D4491	5 gal/min/SF (max.)	1 test per 500,000 SF	1 test per 250,000 SF*
UV Resistance	ASTM D4355	70 %	Certified by Manufacturer	-

* Minimum one (1) per lot.

B. The geotextile provided shall be stock products. Products specifically manufactured to meet the Specifications of the Project shall not be used unless authorized by the OWNER and QAC.

2.03 MANUFACTURING QUALITY CONTROL

A. The Geotextile Manufacturer shall sample and test the geotextile as indicated above.

B. Sampling shall, in general, be performed on sacrificial portions of the material such that repair of the material is not required.

C. Any geotextile sample that does not comply with the requirements of this Section shall result in the rejection of the roll from which the sample was obtained. The Geotextile Manufacturer shall replace any rejected rolls at no cost to the OWNER.

D. If a geotextile sample fails to meet the quality control requirements of this Section, then the CONTRACTOR shall require that the Geotextile Manufacturer sample and test each roll manufactured in the same lot, or at the same time, as the failing roll, at no cost to the OWNER. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established.

E. Additional sample testing may be performed at the Geotextile Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

F. The Geotextile Manufacturer shall comply with the certification and submittal requirements of this Section.

2.04 PACKING AND LABELING

A. Geotextile shall be supplied by the Geotextile Manufacturer in rolls wrapped in relatively waterproof and opaque protective covers.

B. Geotextile rolls shall be marked or tagged with the following information:
1. manufacturer's name;

2. product identification;
3. lot number
4. roll number; and,
5. rill dimensions.

2.05 TRANSPORTATION

A. Transportation of geotextile is the responsibility of the Geotextile Manufacturer. The Geotextile Manufacturer shall be liable for all damage to the materials incurred prior to and during transportation.

B. Geotextile shall be delivered to the Site at least seven (7) days before the scheduled date of deployment to allow the QAC adequate for taking inventory and obtaining additional conformance samples, if needed.

2.06 HANDLING AND STORAGE

A. The CONTRACTOR shall be responsible for handling, unloading, storage, and care of the geotextile prior to, during, and following installation. The CONTRACTOR shall be liable for all damages to the geotextile incurred prior to final acceptance by the OWNER and QAC.

B. The CONTRACTOR shall be responsible for storage of the geotextile at the Site after the material is delivered and shall protect the geotextile from moisture, long-term direct exposure to sunlight, puncture, or other damaging or deleterious conditions (e.g., mud, dirt, dust). The CONTRACTOR shall be responsible for any additional storage procedures required by the Geotextile Manufacturer.

C. The CONTRACTOR shall ensure the geotextile is stored in a well-drained area prior to deployment.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any Work described in this Section, the CONTRACTOR shall become thoroughly familiar with all portions of the Work falling within this Section.

B. Prior to implementing any of the Work of this Section, the CONTRACTOR shall carefully inspect the installed Work of all other Sections and verify that all such Work is complete to the point where the Work of this Section may properly commence without adverse impact.

C. If the CONTRACTOR has any concern regarding the installed Work of other Sections, then the CONTRACTOR shall notify the QAC in writing prior to the start of the Work of this Section. Failure to inform the QAC in writing prior placing any geotextile will be constructed as the CONTRACTOR's acceptance of the related Work of all other Sections.

3.02 HANDLING AND PLACEMENT

A. The geotextile shall be handled in such a manner as to ensure that it is not damaged in anyway.

B. Precautions shall be taken to prevent damage to underlying materials during placement of the geotextile.

C. After unwrapping the geotextile from its opaque cover, the geotextile shall not be left exposed for a period in excess of 30 days unless a longer exposure period is approved by the QAC. Approval may be based on a formal demonstration from the Geotextile Manufacturer that the geotextile is stabilized against ultraviolet degradation for a period in excess of 30 days.

D. If white colored geotextile is used, then precautions shall be taken against "snow blindness" of personnel.

E. The CONTRACTOR shall examine the surfaces to be covered with geotextile before deployment to ensure there are no potentially harmful foreign objects. Foreign objects shall be removed prior to deploying the geotextile.

F. The geotextile shall be laid to minimize tension, stress, folds, and wrinkles.

G. All geotextile shall be anchored with ballast during windy conditions. Such ballast shall be installed during placement and shall remain until the geotextile is covered.

H. The QAC shall examine the deployed geotextile surface after installation to ensure that no potentially harmful foreign objects are present either above or below the geotextile.

I. Geotextile shall not be placed on saturated or frozen subgrade or standing water.

3.03 SEAMS AND OVERLAPS

A. All geotextile shall be continuous down the slope; that is, no horizontal seams are allowed. Horizontal seams shall be considered as any seam having an alignment exceeding 20 degrees from being perpendicular to the slope contour lines, unless otherwise approved by the QAC. No horizontal seams shall be allowed within 5-feet of the top or toe of the slopes.

B. Geotextiles shall be overlapped as indicted on the Contract Drawings.

C. When specified on the Contract Drawings, geotextile shall be continuously sewn (i.e., spot sewing is not allowed) using a "single prayer" seam, with the stitching a minimum of 1.5-inches from the edge of the geotextile. Stitching shall be two-thread, double-locked, 7 stitched per inch.

D. Geotextile shall be sewn with polymeric thread, having similar strength characteristics as the geotextile.

3.04 REPAIR

A. Any holes or tears in the geotextile shall be repaired using a patch made from the same geotextile. The patch shall overlap the defect for a minimum of 3 feet in each direction. Geotextile patches will be sewn into place no closer than 1-inch from any panel edge. Should any tear exceed 50 percent of the width of the roll, that roll shall be removed and replaced.

B. Where geosynthetic materials underlie the geotextile being placed, care shall be taken to remove any soil or other material that may have penetrated the torn geotextile.

3.05 MATERIALS IN CONTACT WITH GEOTEXTILE

A. The CONTRACTOR shall place all soil or aggregate on top of geotextile such that:
   1. the geotextile and underlying materials are not damaged;
   2. minimum slippage occurs between the geotextile and underlying layers; and,
   3. excess stresses are not induced in the geotextile.

B. Equipment shall not be driven directly on the geotextile. Unless otherwise specified by the QAC, all equipment operating on the earthen materials overlying the geotextile shall comply with the following:

Allowable Equipment Ground pressure (psi)	**Thickness of Overlying Compacted Soils (ft)**
<5	1.0
<10	1.5
<20	2.0
>20	3.0

3.06 PRODUCT PROTECTION

A. The CONTRACTOR shall use all means necessary to protect all prior Work and materials and completed Work of other Sections.

B. IN the event of damage, the CONTRACTOR shall immediately make all repairs and replacements necessary to the approval of the QAC and at no cost to the OWNER.

*****END OF SECTION*****

SECTION 02596

HIGH DENSITY POLYETHYLENE (HDPE) GEOMEMBRANE

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. CONTRACTOR shall furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for the installation of geomembrane as specified herein, as shown on the Drawings, and in accordance with the Construction Quality Assurance (CQA) Plan.

B. Textured high-density polyethylene (HDPE) geomembrane shall be used as the geomembrane for this Project. The approved geomembrane will have properties that comply with the requirements specified on Table 02596-1.

C. CONTRACTOR shall obtain the specified geomembrane from a qualified Geomembrane Manufacturer that has the demonstrated experience with geomembrane manufacturing as stated in Part 1.02.A of this Section.

D. CONTRACTOR shall retain the services of a Geosynthetics Installer to install the approved geomembrane in conjunction with the other components of the Project. The Geosynthetics Installer shall be approved by the Geomembrane Manufacturer and have the demonstrated experience with installation of the geomembrane as stated in Part 1.02.B of this Section.

1.02 QUALIFICATIONS

A. Geomembrane Manufacturer:
1. The Geomembrane Manufacturer shall be capable of manufacturing geomembrane rolls from resin and shall have sufficient production capacity and qualified personnel to meet the requirements of this Section and the demands (e.g., quantity production and quality control) of this Project.
2. The Geomembrane Manufacturer shall have successfully manufactured a minimum of 20,000,000 ft^2 of HDPE geomembrane for use in at least ten landfill projects in the past five years.

B. Geomembrane Installer:
1. The Geosynthetics Installer shall be responsible for field handling, storing, deploying, seaming, temporarily restraining (against wind), and other site aspects of the geomembrane and other components of the liner system, and shall provide qualified installation personnel, as outlined in this Section. The Geosynthetics Installer may also be responsible for anchoring systems.
2. As a firm, the Geosynthetics Installer shall have successfully installed a minimum of 10,000,000 ft^2 of HDPE geomembrane for at least ten landfill projects in the past five years.
3. The superintendent assigned to this project shall have supervised the installation of a minimum of 2,000,000 ft^2 of HDPE geomembrane on at least ten different landfill liner systems.
4. All personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests.

a. At least one seamer shall have experience seaming a minimum of 1,000,000 lineal ft of HDPE geomembrane seams using the same type of seaming apparatus to be used at this Site. Seamers with such experience will be designated "master seamers" and shall provide direct supervision over less experienced seamers.

b. Seaming personnel shall have seamed at least 100,000 lineal ft of HDPE geomembrane seams using the same type of seaming apparatus to be used at this Site.

C. CONTRACTOR shall accept and retain full responsibility for all materials and installation and shall be held responsible for any defects.

1.03 WARRANTY

A. CONTRACTOR shall provide a written warranty from the Geomembrane Manufacturer to OWNER and QUALITY ASSURANCE CONSULTANT (QAC) for a 20-year period against defects in material from the date the installation of the geomembrane is accepted.

B. CONTRACTOR shall provide a written warranty from the Geosynthetics Installer to OWNER and QAC for a one-year period against defects in workmanship from the date the installation of the geomembrane is accepted.

C. Warranty conditions concerning limits of liability will be evaluated and must be acceptable to OWNER and QAC.

1.04 SUBMITTALS

A. At least 14 days prior to shipping any geomembrane to the Site, CONTRACTOR shall provide QAC with the following documentation concerning the Geomembrane Manufacturer that will supply the geomembrane.

1. Corporate background and information.
2. Manufacturing capabilities, including:
    a. information on plant size, equipment, personnel, number of shifts per day, and capacity per shift;
    b. daily production quantity available for this Contract;
    c. manufacturing quality control procedures; and
    d. list of material properties, including certified test results, to which are attached liner samples.
3. A list of at least ten landfill projects within the last five years that the Geomembrane Manufacturer has manufactured a minimum of 20,000,000 ft^2 of HDPE geomembrane. The following information shall be provided for each facility:
    a. name, location, and purpose of facility, and date of installation;
    b. names of OWNER, QAC, and CONTRACTOR; and
    c. thickness and surface area of geomembrane manufactured.
4. Origin (resin supplier's name, resin production plant) and identification (brand name, number) of the resin.

B. At least 14 days prior to shipping any geomembrane to the Site, CONTRACTOR shall provide QAC with the following documentation on the resin used to manufacture the geomembrane.

1. Copies of quality control certificates issued by the resin supplier including the production dates, brand name, and origin of the resin used to manufacture the geomembrane for the Project.
2. Results of tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the Project.
3. Certification that no reclaimed polymer is added to the resin during the manufacturing of the geomembrane to be used for this Project, or, if recycled polymer is used, then the Geomembrane Manufacturer shall submit a certificate signed by the Production Manager documenting the quantity of recycled material, including a description of the procedure used to measure the quantity of recycled polymer.

C. Prior to the shipping the geomembrane rolls, CONTRACTOR shall provide QAC with the following documentation on geomembrane roll production.
1. Manufacturing certificates for each shift's production of geomembrane, signed by responsible parties employed by the Geomembrane Manufacturer (such as the Production Manager).
2. The quality control certificate shall include:
    a. roll numbers and identification;
    b. sampling procedures; and
    c. results of quality control tests, including descriptions of the test methods used.
3. The Geomembrane Manufacturer quality control tests to be performed are outlined in Part 2.03 of this Section.

D. At least 14 days prior to the scheduled date of geomembrane installation, the Geosynthetics Installer shall submit to QAC the following:
1. Corporate background and information.
2. Copy of Geomembrane Installer's letter of approval or license by the Geomembrane Manufacturer.
3. Installation capabilities, including:
    a. information on equipment and personnel;
    b. average daily production anticipated for this Project; and
    c. quality control procedures;
4. A list of at least ten landfill projects within the last five years that the Geomembrane Installer has installed a minimum of 10,000,000 ft^2 of HDPE geomembrane. The following information shall be provided for each facility:
    a. the name and purpose of the facility, its location, and dates of installation;
    b. the names of OWNER, QAC, and CONTRACTOR;
    c. name and qualifications of the installer's supervisor(s);
    d. thickness and surface area of installed geomembrane;
    e. type of seaming and type of seaming apparatus used; and
    f. duration of installation.
5. Resumes of all personnel who will perform seaming operations on this Project, including dates and duration of employment.
6. A drawing showing the installation layout identifying field seams, as well as any variance or additional details that deviate from the Drawings. The layout shall be adequate for use as a construction plan and shall include dimensions, details, etc.
7. Installation schedule
8. A Certificate. of Calibration less than 12 months old for the field tensiometer referenced in Parts 3.05.I and K of this Section.

E. At least 14 days prior to transporting welding rod to the Site, the Geosynthetic Installer shall submit the following documentation on welding rod to QAC:
  1. quality control documentation, including lot number, welding rod spool number, and results of quality control tests on the welding rod; and
  2. certification that the welding rod is compatible with the geomembrane and this Section.

F. During the installation, the Geosynthetics Installer shall be responsible for the timely submission to QAC the following:
  1. quality control documentation; and
  2. subgrade acceptance certificates, signed by the Geosynthetics Installer, for each area to be covered by geomembrane.

G. Upon completion of the installation, CONTRACTOR shall submit to QAC the following:
  1. required warranties as specified in Part 1.03 of this Section; and
  2. record drawings of the installation.

1.05 CONSTRUCTION QUALITY ASSURANCE

A. The installation of geomembrane shall be monitored by the QAC as outlined in the CQA Plan.

B. CONTRACTOR and the Geosynthetics Installer shall be aware of the activities in the CQA Plan and shall account for these CQA activities in the installation schedule.

C. CONTRACTOR shall provide the QAC the opportunity to obtain conformance samples at the geomembrane manufacturing facility in order to expedite the conformance testing and approval process.

<u>PART 2 - PRODUCTS</u>

2.01 RESIN

A. The geomembrane shall be manufactured from new, first-quality resin, and shall be designed and manufactured specifically for use in geomembrane. Reclaimed polymer shall not be added to the resin. However, the use of polymer recycled during the manufacturing process shall be permitted if performed with appropriate cleanliness and if the recycled polymer does not exceed 2 percent by weight of the total polymer weight.

2.02 GEOMEMBRANE PROPERTIES

A. The manufacturer shall furnish geomembrane with properties that comply with the required property values provided below and on Table 02596-1.

B. In addition to the property values listed on Table 02596-1, the geomembrane shall:
  1. contains a maximum of 1 percent by weight of additives, fillers, or extenders (not including carbon black);
  2. not have striations, pinholes, or bubbles on the surface or in the interior;

3. be produced so as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter; and
4. are manufactured in a single layer (thinner layers shall not be welded together to produce the final required thickness).

2.03 MANUFACTURING QUALITY CONTROL

A. Rolls.

1. The Geomembrane Manufacturer shall continuously monitor the geomembrane during the manufacturing process for inclusions, bubbles, or other defects. Geomembrane that exhibits any defects will not be accepted.
2. The Geomembrane Manufacturer shall continuously monitor the geomembrane thickness during the manufacturing process. Geomembrane that fails to meet the specified minimum thickness will not be accepted.
3. The Geomembrane Manufacturer shall sample and test the geomembrane in accordance with the test frequency stated in GRI Test Method GM13 for HDPE geomembrane to demonstrate that its properties conform to the values specified on Table 02596-1.
4. Samples of the geomembrane shall be taken across the entire width of the roll.
5. At a minimum, the following manufacturing quality control tests shall be performed:

TEST	PROCEDURE
Thickness	ASTM D5994
Asperity Height	ASTM D7466
Density	ASTM D792 or ASTM D1505
Tensile Properties	ASTM D638
Puncture Resistance	ASTM D4833
Carbon Black Content	ASTM D1603
Carbon Black Dispersion	ASTM D5596

6. Any geomembrane sample that does not comply with the requirement of this Section shall result in rejection of the roll from which the sample was obtained. The Geomembrane Manufacturer shall replace any rejected rolls at no additional cost to OWNER.
7. In the case of the rejection of a roll of geomembrane, the Geomembrane Manufacturer shall sample and test each roll manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established.
8. Additional testing may be performed at the Geomembrane Manufacturer's discretion and expense, to more closely identify the non-complying rolls and/or to qualify individual rolls.
9. In addition to the tests listed under Paragraph 2.03.B.5 of this Section, CONTRACTOR and/or Geomembrane Manufacturer must provide laboratory test data that demonstrates that the geomembrane supplied meets the specifications for environmental stress crack (ASTM D5397) and direct shear (ASTM D5321) as listed on Table 02596-1. This testing shall be performed on geomembrane manufactured at the same time, from the same type of resin, and exhibiting the same material properties as the geomembrane to be used for this Project. The Geomembrane

Manufacturer shall provide the test results as part of his quality control documentation.

B. Manufacturing Plant Visit
   1. The Geomembrane Manufacturer shall allow OWNER and QAC to visit the manufacturing plant for project specific visits. If possible, then the visits will be prior to or during the manufacturing of the geomembrane rolls for this Project.
   2. During the visit, OWNER or QAC may:
      a. review the manufacturing process, quality control procedures, laboratory facilities, and testing procedures;
      b. verify that properties guaranteed by the manufacturer comply with these Specifications;
      c. verify that the measurements of properties by the manufacturer are properly documented and the test methods used are acceptable;
      d. check select geomembrane rolls for evidence of holes, blisters, or any sign of contamination by foreign matter;
      e. review packaging and transportation procedures to verify that these procedures are not damaging the geomembrane; and
      f. verify that roll packages are labeled in compliance with Part 2.05 of this Section.

2.04 GEOMEMBRANE SUPPLY

A. The geomembrane shall be supplied to the Site in rolls or as factory panels. A factory panel is comprised of one or more rolls that have been seamed together in a factory.

2.05 LABELING

A. Geomembrane and fabricated panels shall be labeled with the following information:
   1. thickness of the material;
   2. length and width of the roll or factory panel;
   3. names of manufacturer;
   4. directions to unroll the material;
   5. product identification;
   6. lot number; and
   7. roll or factory panel number.

2.06 TRANSPORTATION

A. Transportation of the geomembrane is the responsibility of the Geomembrane Manufacturer. The Geomembrane Manufacturer shall be liable for all damages to the geomembrane incurred prior to and during transportation to the Site.

B. Geomembrane shall be delivered to the Site at least seven days before the scheduled date of installation to allow the QAC adequate time for taking inventory and obtaining additional conformance samples, if needed.

2.07 HANDLING AND STORAGE

A. CONTRACTOR shall be responsible for handling, storage, and care of the geomembrane prior to and following installation at the Site. CONTRACTOR shall be liable for all damages to the materials incurred prior to final acceptance by OWNER and QAC.

B. CONTRACTOR shall be responsible for storage of the geomembrane at the Site. Geomembrane storage shall be in a clean, well-drained area. During storage, the geomembrane shall be protected from excessive heat or cold, puncture, cutting, or other damaging or deleterious conditions. The geomembrane shall be stored in accordance with any additional requirements of the Geomembrane Manufacturer.

2.08 CONFORMANCE TESTING

A. Samples of the geomembrane will be removed by the QAC at the factory and sent to an independent geosynthetics laboratory (i.e., different than the Geomembrane Manufacturer) for testing to ensure conformance with the requirements of this Section.

B. Conformance sampling and testing will be performed in accordance with the CQA Plan.

C. Samples will be taken at a minimum frequency of one sample per 250,000 ft^2 with a minimum of one sample per lot. If the Geomembrane Manufacturer provides material that requires sampling at a frequency (due to lot size, shipment size, etc.) higher than necessary, then CONTRACTOR shall pay the cost for all.

D. The QAC may direct CONTRACTOR to increase the frequency of sampling in the event that test results do not comply with requirements of Part 2.02 of this Section until passing conformance test results are obtained for all material that is received at the Site. This additional testing shall be performed at the expense of CONTRACTOR.

E. Any geomembrane roll or panel that is not certified in accordance with Part 1.04 of this Section, or that conformance testing indicates do not comply with Part 2.02 of this Section, will be rejected by the QAC. The Geomembrane Manufacturer shall replace the rejected material with new material, at no additional cost to OWNER.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any Work described in this Section, the Geomembrane Installer shall become thoroughly familiar with all portions of the Work required by Section.

B. The Geosynthetic Installer shall carefully inspect the installed Work of all other Sections and verify that all Work is complete to the point where the Work of this Section may properly commence without adverse impact to the project.

C. If the Geosynthetic Installer has any concerns regarding the installed Work of other Sections, then he should notify QAC in writing prior to the start of the Work of this Section. Failure to inform QAC in writing or commencing geomembrane installation will be construed as the Geosynthetic Installer's acceptance of the related Work of other Sections.

3.02 SURFACE PREPARATION

A. The Geosynthetics Installer shall provide certification in writing that the surface on which the geomembrane will be installed is acceptable. The surface shall be free of stones, litter, organic matter, irregularities, protrusion, loose soil, and any abrupt changes in grade that could damage the geomembrane. The certification of acceptance shall be given to the QAC prior to commencement of geomembrane installation in the area under consideration.

B. Special care shall be taken to maintain the prepared subgrade.

C. No geomembrane shall be placed onto an area which has been softened by precipitation or which has cracked due to desiccation. The soil surface shall be observed daily to evaluate the effects of desiccation cracking and/or softening on the integrity of the subgrade.

D. Any damage to the soil surface caused by installation activities shall be repaired at the CONTRACTOR's expense.

E. The CONTRACTOR or Geosynthetics Installer shall be responsible for dewatering areas that have been accepted for geomembrane deployment, including anchor trenches.

3.03 ANCHORAGE

A. The anchor trench shall be excavated prior to geomembrane placement to the lines, grades, and configuration shown on the Contract Drawings and as specified in the Specifications.

B. No loose soil shall be allowed in the anchor trench beneath the geomembrane.

C. The anchor trench shall be backfilled and compacted after the geomembrane has been installed in the trench. Care shall be taken when backfilling the trenches to prevent any damage to the geomembrane.

D. Slightly rounded corners shall be provided in the trench where the geomembrane adjoins the trench to avoid sharp bends in the geomembrane.

3.04 GEOMEMBRANE DEPLOYMENT

A. The Geosynthetics Installer shall prepare a geomembrane installation layout drawing(s) prior to geomembrane deployment. These drawings shall indicate the geomembrane configuration, dimensions, details, locations of seams, etc. Field seams shall be differentiated from factory seams (if any) on the drawings. Field seams shall be oriented up or down slope and not across slope. QAC must approve the layout drawings prior to the installation of any geomembrane. The layout drawings, as modified and/or approved by QAC, shall become part of the Contract Documents.

B. Field Panel Identification
   1. A geomembrane field panel is defined as follows:
      a. If the geomembrane is not fabricated into factory panels, then a field panel is a roll or a portion of roll cut in the field.

b. If the geomembrane is fabricated into factory panels, then a field panel is a factory panel or a portion of factory panel cut in the field.

2. Each field panel must be given an identification code (number or letter-number). This identification code shall be agreed upon by the QAC and Geosynthetics Installer. The field panel identification code shall be related, through a table or chart, to the original resin, and the constituent rolls and factory panels.

C. Field Panel Placement

1. Field panels shall be installed as approved or modified at the location and positions indicated in the layout drawings.
2. Field panels shall be placed one at a time, and each field panel shall be seamed to adjacent panels the same day that it is placed.
3. Geomembrane may only be deployed daylight hours between one hour after sunrise and one hour before sunset.
4. Geomembrane shall not be placed when the ambient temperature is below 32°F or above 104°F, unless otherwise authorized by QAC.
5. Geomembrane shall not be placed during any precipitation, in the presence of excessive moisture (e.g., frost, ice, fog, dew), in an area of ponded water, or in the presence of winds exceeding 20 miles per hour.
6. The Geosynthetics Installer shall employ placement methods consistent with the following:
    a. no vehicular traffic shall be allowed on the geomembrane.
    b. equipment used shall not damage the geomembrane by handling, trafficking, leakage of hydrocarbons, or other means.
    c. personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in other activities that could damage the geomembrane.
    d. the method used to unroll the panels shall not scratch or crimp the geomembrane and shall not damage the supporting soil.
    e. the prepared surface underlying the geomembrane shall not be allowed to deteriorate after acceptance of the surface and shall remain acceptable up to the time of geomembrane placement.
    f. the method used to place the panels shall minimize wrinkles (especially differential wrinkles between adjacent panels).
    g. temporary loads and/or anchors (e.g., sand bags, tires), not likely to damage the geomembrane, may be placed on the geomembrane to prevent uplift by wind (in high winds, continuous loading is recommended along panel edges to minimize the risk of wind flow under the panels).
7. Any field panel or portion thereof that becomes seriously damaged (tom, twisted, or crimped) shall be replaced with new material at no cost to OWNER. Less serious damage may be repaired at the QAC's sole discretion and at no cost to OWNER. Damaged panels or portions of damaged panels that have been rejected shall be removed from the work area.

3.05 FIELD SEAMING

A. In general, seams shall be oriented parallel to the line of maximum slope, (i.e., oriented down, not across, the slope). In corners and at odd-shaped geometric locations, the number of field seams shall be minimized. No horizontal seam shall be made within 5 ft of any toe of the slope, except where approved by QAC. No seams shall be located in an area of potential stress concentration, as defined by QAC.

B. All personnel performing seaming operations shall be qualified as indicated in the CQA Plan and in this Section. No seaming shall be performed unless a "master seamer" (as defined in the CQA Plan and in this Section) is present.

C. The geomembrane shall have field seams that equal or exceed the strength requirements presented on Table 02596-2.

D. Weather Conditions for Seaming:
   1. Seaming shall not be attempted at ambient temperatures below 32°F or above 104°F or when wind velocity exceeds 20 miles per hour. At ambient temperatures between 32°F and 50°F, seaming shall be allowed if the geomembrane is preheated either by the sun or a hot air device, and if there is no excessive cooling from wind. At ambient temperatures above 50°F, no preheating will be required. In all cases, the geomembrane shall be dry and protected from excessive wind.
   2. If the Geosynthetics Installer wishes to use methods that allow seaming at ambient temperatures below 32°F or above 104°F, then he shall demonstrate that the seam so produced is equivalent to those produced under normally approved conditions, and that the overall quality of the geomembrane is not adversely affected. In addition, an addendum to the Contract between OWNER and the Geosynthetics Installer shall be required that specifically states that the seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short- or long-term damage to the geomembrane.
   3. To minimize geomembrane contraction stresses, seaming should ideally be carried out in the morning and late evening when the geomembrane is relatively contracted and during the middle of the day if overcast conditions prevail. If the geomembrane must be seamed in the middle of a sunny day, then the Geosynthetics Installer shall ensure that the panels to be seamed are at the same temperature and that there is sufficient slack in the geomembrane to prevent the generation of excessive stresses or trampolining when the geomembrane contracts as cooler temperatures prevail. The Geosynthetics Installer shall determine the required amount of slack and it should not be so much so as to cause significant wrinkling of the geomembrane. If trampolining of the geomembrane is observed, then the Geosynthetics Installer will be required to make repairs so that the problem is eliminated.
   4. Ambient temperatures shall be measured within 6 inches above the geomembrane surface.

E. Overlapping and Temporary Bonding
   1. Geomembrane panels shall be overlapped a minimum of 3 inches for extrusion welding and 5 inches for fusion welding, but in any event, sufficient overlap shall be provided to allow peel tests to be performed on the seam.

2. The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane. The temperature of the air at the nozzle of spot welding apparatus shall be controlled such that the geomembrane is not damaged.
3. No solvent or adhesive shall be used unless OWNER has approved the product in writing. Samples of any proposed solvent or adhesive shall be submitted to CONTRACTOR for testing and evaluation at the Geosynthetics Installer's expense.

F. Seam Preparation

1. Prior to seaming, the seam area shall be cleaned and made free of moisture, dust, dirt, debris of any kind, and foreign material.
2. If seam overlap grinding is required, then the process shall be completed according to the Geomembrane Manufacturer's instructions within 20 minutes of the seaming operation and in a manner that does not damage the geomembrane. The grind depth shall not exceed ten percent of the geomembrane thickness. Grinding marks shall not appear beyond 0.25 inches of the extrudate after it is placed.
3. Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths".

G. General Seaming Requirements

1. Seaming shall extend to the outside edge of panels, including those panels placed in the anchor trench.
2. If required to provide a firm substrate, then a board, or similar hard surface, placed directly under the seam overlap may be used to achieve proper support.
3. Fishmouths or wrinkles at the seam overlaps shall be removed by cutting the geomembrane along the ridge of the wrinkle. At the end(s) of the cut, cut a circle in the geomembrane to achieve a flat overlap. The cut shall be seamed as described in the Section. Any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane that extends a minimum of 6 inches beyond the cut in all directions.

H. Seaming Process

1. Approved processes for field seaming are extrusion welding and fusion welding. Seaming equipment shall be operated in a manner that does not cause damage to the geomembrane. Only apparatus that QAC has specifically approved by make and model shall be used. Proposed alternate seaming processes shall be documented and submitted to QAC.
2. Extrusion Equipment and Procedures:
   a. The Geosynthetics Installer shall maintain at least one spare operable extrusion seaming apparatus on site at all times.
   b. Extrusion welding apparatus shall be equipped with gauges giving the temperature in the apparatus.
   c. Prior to beginning a seam, the extruder shall be purged until all heat- degraded extrudate has been removed from the barrel.

d. The electric generator used for power supply to the welding machines shall he placed outside the area to be lined or mounted on soft tires such that no damage occurs to the geomembrane. The electric generator shall be equipped with a grounding rod that is driven into the ground outside the lined area. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

3. Fusion Equipment and Procedures:
   a. The Geosynthetics Installer shall maintain at least one spare operable seaming apparatus on site at all times.
   b. Fusion-welding apparatus shall be automated vehicular-mounted devices equipped. with gauges giving the instantaneous temperatures and pressures of the machine.
   c. The edges of cross seams shall be abraded to a smooth incline (top and bottom) prior to welding.
   d. A movable protective layer may be used directly below each geomembrane overlap to be seamed to prevent the buildup of moisture between the sheets.
   e. The electric generator used for power supply to the welding machines shall be placed outside the area to be lined or mounted on soft tires such that no damage occurs to the geomembrane. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

I. Trial Seams

1. Trial seams shall be made prior to production seaming by all seamers and by all equipment to be used during production seaming. The trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period, and at least once each five hours, for each seaming apparatus used that day. In addition, each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual production field seams. The trial seam sample shall be at least 3.5-feet long by 1-foot wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as specified in Part 3.05.E of this Section.
2. Four adjoining specimens, each 1.0-inch wide, shall be cut from the trial seam sample by the Geosynthetics Installer. The specimens shall be tested in peel (both tracks for fusion welds) using an electronic readout field tensiometer and the specimen shall fail by film tear bond (FTB) (i.e., failure in the parent material) rather than in the seam. The Geosynthetics Installer shall test the specimens in the presence of the QAC. Testing using the field tensiometer shall be performed in accordance with ASTM D 6392, at a strain rate of 2 inches/minute. Ideally, the samples shall be conditioned at 73°F at a relative humidity of 50 percent for two hours prior to testing. If test conditions vary from this requirement, then a 1 inch wide specimen of the parent geomembrane (no weld) shaII be tested in the same manner as the seam specimens to determine the break strength at this condition. At no time shall the specimens be soaked in water.

3. If a specimen fails to comply with the properties stated on Table 02596-2, then the entire operation shall be repeated. If the additional specimen fails to meet these requirements, then the seaming apparatus or seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved.
4. After completion of the above described tests, the remaining portion of the trial seam sample can be discarded. If a trial seam sample fails a test, then a destructive test seam sample may be taken from the seams completed by the seamer during the shift related to the considered trial seam at the discretion of the QAC. These samples shall be forwarded to CQA geosynthetics laboratory and, if they fail the tests, the procedure indicated in Part 3.05.K.5 of this Section shall apply. The results of all testing shall be reported to the QAC. The conditions of this paragraph shall be considered as met for a given seam if a destructive seam test sample has already been taken from the considered seam.

J. Nondestructive Seam Continuity Testing
1. The Geosynthetics Installer shall nondestructively test all field seams over their full length using a vacuum test, air pressure test (for double fusion seams only), or other approved method. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. The installer shall complete any required repairs in accordance with Part 3.05.L of this Section. The following procedures shall apply to locations where seams cannot be nondestructively tested:
   a. If the seam is accessible to testing equipment prior to final installation, then the seam shall be nondestructively tested prior to final installation.
   b. If the seam cannot be tested prior to final installation, then the seaming operations must be observed in their entirety by the QAC for uniformity and completeness.
2. Vacuum testing of extrusion field seams and repairs shall be performed in accordance with ASTM D 5641.
3. Air pressure testing shall be performed on double fusion seams only, and shall be performed in accordance with ASTM D 5820 and the following:
   a. Energize the air pump to a pressure between 25 and 30 psi, close valve, allow two minutes for pressure to stabilize, and sustain the pressure for not less than 5 minutes.
   b. If loss of pressure exceeds 4 psi, or if the pressure does not stabilize, then locate faulty area and repair in accordance with Part 3.05.L of this Section.
   c. Cut opposite end of air channel from pressure gauge and observe release of pressure to ensure that the entire channel is not blocked.
   d. Remove needle, or other approved pressure feed device, and seal repair in accordance with Part 3.05.L of this Section.
4. QAC may allow spark testing in accordance with ASTM D 6365 if the seam cannot be tested using other nondestructive methods.

K. Destructive Testing
1. Destructive testing of field seams shall be performed on samples collected from selected locations to evaluate seam strength and integrity according to the requirements for seam strength presented on Table 02596-2. Destructive testing shall be carried out as the geomembrane installation progresses, not at the completion of all field seaming.

2. Sampling
   a. Field seam samples shall be collected for destructive testing at a minimum average frequency of one test location per 500 ft of seam length. Test locations shall be determined during seaming, and may be prompted by suspicion of excess crystallinity, contamination, offset seams, or any other potential cause of imperfect seaming. The QAC will be responsible for choosing the locations. The Geosynthetics Installer shall not be informed in advance of the locations where the seam samples will be taken. QAC reserves the right to increase the sampling frequency.
   b. Samples of the field seams shall be cut with rounded corners by the Geosynthetics Installer at the locations designated by the QAC as the seaming progresses. Passing laboratory test results must be obtained before the field seams are covered by another material. All holes in the geomembrane resulting from the field seam sampling shall be immediately repaired in accordance with the repair procedures described in Part 3.05.L of this Section. The continuity of the new seams in the repaired areas shall be tested according to Part 3.05.J of this Section.
   c. Two strips, 1-inch wide and 12-inch long with the seam centered parallel to the width, shall be taken. The strips shall be spaced a clear distance of 42- inches apart. These samples shall be tested using the field tensiometer in accordance with Part 3.05.I.2 of this Section. If these samples pass the field test, then a laboratory sample shall be taken. The laboratory sample shall be at least 1-foot wide by 42-inches long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:
      i. one 1-foot long portion to the Geosynthetics Installer.
      ii. one 1-foot long portion to OWNER for archiving;
      iii. one 1.5-feet long portion to the QAC for laboratory testing.
3. If any field test sample fails to meet the required seam strength properties presented on Table 02596-2, then the procedures outlined in Part 3.05.K.5 of this Section shall be followed.
4. Samples shall be tested in the laboratory in accordance with the requirements of this Section and the CQA Plan.
5. Destructive Test Failure
   a. The following procedures shall apply whenever a sample fails a destructive test, whether the test is conducted by the CQA laboratory, the Geosynthetics Installer's laboratory, or by a field tensiometer. The Geosynthetics Installer shall have two options, as described in b and c below.
   b. The Geosynthetics Installer can reconstruct the seam (e.g., remove the old seam and reseam) between two passing destructive test locations. The welding path of the seaming apparatus shall be tracked (in each direction).

c. The Geosynthetics Installer can trace the welding path to an intermediate location, a minimum of 10 feet from the location of the failed test (in each direction) and take a small sample for an additional field test at each location. If these additional samples pass the tests, then full laboratory samples shall be taken. If these laboratory samples pass the tests, then the seam shall be reconstructed between these locations. If either sample fails, then the process shall be repeated to establish the zone in which the seam should be reconstructed. In any case, all acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. In cases where the length of reconstructed seam exceeds 150 feet, a destructive sample taken from within the reconstructed zone must pass destructive testing. Whenever a sample fails, the QAC may require additional tests for seams that were formed by the same seamer and/or seaming apparatus or seamed during the same time shift.

L. Defects and Repairs

1. All seams and non-seam areas of the geomembrane will be examined by the QAC and the Geosynthetic Installer for evidence of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be swept or washed by the Geosynthetics Installer if surface contamination inhibits examination. The Geosynthetics Installer shall ensure that this examination of the geomembrane precedes any seaming of that section.
2. Each suspect location, both in seam and non-seam areas, shall be nondestructively tested using the methods described Part 3.05.J of this Section, as appropriate. Each location that fails nondestructive testing shall be marked by the QAC and repaired by the Geosynthetics Installer. Work shall not proceed with any materials that will cover the defective area until the suspect location is repaired and passing nondestructive test are obtained. In addition, passing destructive test results shall be achieved prior to placing any material over geomembrane.
3. When seaming of a geomembrane is completed (or when seaming of a large area of a geomembrane is completed) and prior to placing overlying materials, the QAC shall identify excessive geomembrane wrinkles. The Geosynthetics Installer shall cut and reseam the wrinkle areas so identified. The seams thus produced shall be tested like any other seams.
4. Repair Procedures.
   a. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Geosynthetics Installer. Several repair procedures are specified below. The final decision as to the appropriate repair procedure shall be agreed upon between the QAC and the Geosynthetics Installer. The procedures available include:
      i. patching (used to repair large holes, small tears, undispersed raw materials, and contamination by foreign matter);
      ii. abrading and reseaming (used to repair small sections of extruded seams);
      iii. spot seaming (used to repair pinholes, or other minor, localized flaws);

iv. capping (used to repair long lengths of failed seams);
v. removing failed seam and replacing with a strip of new material seamed into place (used with long lengths of fusion seams) and/or extrusion seams.

b. In addition, the following shall be satisfied:
i. surfaces of the geomembrane that are to be repaired shall be abraded no more than 20 minutes prior to the repair;
ii. all surfaces must be clean and dry at the time of repair;
iii. all seaming equipment used in repair procedures must be approved by QAC;
iv. the repair procedures, materials, and techniques shall be approved in advance, for the specific repair, by the QAC and Geosynthetics Installer;
v. patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of holes and patches shall be rounded with a radius of at least 3 inches; and
vi. the geomembrane below large caps shall be appropriately cut to avoid water or gas collection between the two sheets.

5. Each repair shall be numbered and logged and shall be nondestructively tested using the methods described in this Section. Repairs that pass the nondestructive test shall be taken as an indication of an adequate repair. Failed tests will require the repair to be redone and retested until a passing test result is achieved. At the discretion of the QAC, destructive testing may be required on large caps.

3.06 MATERIALS IN CONTACT WITH GEOMEMBRANE

A. The Geosynthetics Installer shall take all necessary precautions to ensure that the geomembrane is not damaged during its installation or during the installation of other components of the liner system or by other construction activities. Installation on rough surfaces, such as concrete, shall be performed carefully.

B. Equipment shall not be driven directly on the geomembrane. Unless otherwise specified by QAC, all equipment operating on materials overlying the geomembrane shall comply with the following:

Allowable Equipment Ground Pressure (psi)	Thickness of Overlying Compaction Soil (feet)
<5	1.0
<10	1.5
<20	2.0
>20	3.0

C. In heavily trafficked areas such as access ramps, and in areas trafficked by rubber tire vehicles, the thickness of overlying compacted soil shall be at least 3 feet.

D. Installation of the geomembrane in sump areas, and connection of the geomembrane to appurtenances shall be made according to these Specifications and as shown on the Contract Drawings. Extreme care shall be taken while seaming around sumps and appurtenances since neither nondestructive nor destructive testing may be feasible in these areas. The Geosynthetics Installer shall ensure that the geomembrane has not been visibly damaged while making connections to sumps and appurtenances. Because of the difficulty of vacuum testing seams in the sump area, fusion seams should be made at all possible locations in the sump.

E. Placement of soils above the geomembrane will not proceed at an ambient temperature below 32°F nor above 104°F unless otherwise specified or approved by QAC.

3.07 GEOMEMBRANE ACCEPTANCE

A. The Geosynthetics Installer shall retain all ownership and responsibility for the geomembrane until accepted by OWNER and QAC.

B. The geomembrane will not be accepted by OWNER and QAC until all of the following conditions are met:
   1. the installation is finished;
   2. all documentation of installation is completed including the QAC's final report;
   3. verification of the adequacy of all field seams and repairs, including associated testing, is complete; and
   4. written certification documents, including record drawings, sealed by a professional land surveyor licensed in the State of Delaware, have been received by OWNER and QAC.

3.08 PRODUCT PROTECTION

A. CONTRACTOR shall use all means necessary to protect all prior Work and all materials and completed Work of other Sections.

B. No equipment shall be placed directly on the geomembrane during installation. Rub sheets shall be used beneath equipment to protect the geomembrane from equipment damage.

C. In the event of damage, CONTRACTOR shall immediately make all repairs and replacements necessary, to the approval of the QAC and at no additional cost to OWNER.

TABLE 02596-1

REQUIRED TEXTURED HDPE GEOMEMBRANE PROPERTY VALUES (1)

Properties	Qualifiers	Units	Specified Values 40 mil	Test Method
Thickness	Nominal	Mils	40	ASTM D5994
	Minimum Average	Mils	38	ASTM D5994
Asperity Height	Minimum Average	Mils	16	ASTM D7466
Density	Minimum	g/cc	0.94	ASTM D792 or ASTM D1505
Tensile Properties (each direction)				
1. Yield Strength	Minimum	Lb/in.	84	ASTM D638
2. Break Strength	Minimum	Lb/in.	60	ASTM D638
3. Yield Elongation	Minimum	%	12	ASTM D638
4. Break Elongation	Minimum	%	100	ASTM D638
Tear Resistance	Minimum	Lb.	28	ASTM D1004
Puncture Resistance	Minimum	Lb.	60	ASTM D4833
Direct Shear (for slopes 14% to 25%) (see Note 2)	Minimum	Degrees	19(3)	ASTM D5321
Carbon Black Content	Range	%	2 - 3	ASTM D1603
Carbon Black Dispersion	N/A	None	See Note 4	ASTM D5596
Stress Crack Resistance	Minimum	hours	200	ASTM D5397

Notes: (1) All values represent minimum average roll values (i.e., any roll in a lot should meet or exceed these values).

(2) Direct shear testing shall be performed by CONTRACTOR on the entire liner system cross section using the proposed liner system materials (i.e., cover soil, geocomposite, geomembrane, and grading fill layer). The testing shall be performed at the normal stresses indicated.

(3) Testing shall be performed at normal stresses of 100 psf, 250 psf and 500 psf.

(4) Carbon black dispersion (on near spherical agglomerates) for 10 different views:

- 9 in categories 1 or 2; and
- 1 in Category 3.

TABLE 02596-2

REQUIRED TEXTURED HDPE GEOMEMBRANE SEAM PROPERTIES

Properties	Qualifiers	Units	Specified Values 40 mil	Test Method
Gauge	Nominal	Mils	40	
Shear Strength[(1)] at yield point	Minimum	Lb/in	80	ASTM D 6392
Peel Adhesion FTB[(2)] Fusion	Minimum	Lb/in	60	ASTM D 6392
Extrusion		Lb/in	52	ASTM D 6392

Notes: (1) Also called “Bonded Seam Strength”.
(2) In addition to the minimum passing values, passing seams shall exhibit film tear bond (FTB) and the seam shall not separate more than 10 percent.

*****END OF SECTION*****

SECTION 02597

LINEAR LOW DENSITY POLYETHYLENE (LLDPE) GEOMEMBRANE

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. CONTRACTOR shall furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for the installation of geomembrane as specified herein, as shown on the Contract Drawings, and in accordance with the Construction Quality Assurance (CQA) Plan.

B. Textured linear low-density polyethylene (LLDPE) geomembrane may be selected as the geomembrane for this Project. The approved geomembrane will have properties that comply with the requirements specified on Table 02597-1.

C. CONTRACTOR shall obtain the specified geomembrane from a qualified Geomembrane Manufacturer that has the demonstrated experience with geomembrane manufacturing as stated in Part 1.02.A of this Section.

D. CONTRACTOR shall retain the services of a Geosynthetics Installer to install the approved geomembrane in conjunction with the other components of the Project. The Geosynthetics Installer shall be approved by the Geomembrane Manufacturer and have the demonstrated experience with installation of the geomembrane as stated in Part 1.02.B of this Section.

1.02 QUALIFICATIONS

A. Geomembrane Manufacturer:
   1. The Geomembrane Manufacturer shall be capable of manufacturing geomembrane rolls from resin and shall have sufficient production capacity and qualified personnel to meet the requirements of this Section and the demands (e.g., quantity production and quality control) of this Project.
   2. The Geomembrane Manufacturer shall have successfully manufactured a minimum of 20,000,000 ft^2 of LLDPE geomembrane for use in at least ten landfill projects in the past five years.

B. Geomembrane Installer:
   1. The Geosynthetics Installer shall be responsible for field handling, storing, deploying, seaming, temporarily restraining (against wind), and other site aspects of the geomembrane and other components of the liner system, and shall provide qualified installation personnel, as outlined in this Section. The Geosynthetics Installer may also be responsible for anchoring systems.
   2. As a firm, the Geosynthetics Installer shall have successfully installed a minimum of 10,000,000 ft^2 of LLDPE geomembrane for at least ten landfill projects in the past five years.
   3. The superintendent assigned to this project shall have supervised the installation of a minimum of 2,000,000 ft^2 of LLDPE geomembrane on at least ten different landfill liner systems.
   4. All personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests.

a. At least one seamer shall have experience seaming a minimum of 1,000,000 lineal ft of LLDPE geomembrane seams using the same type of seaming apparatus to be used at this Site. Seamers with such experience will be designated "master seamers" and shall provide direct supervision over less experienced seamers.

b. Seaming personnel shall have seamed at least 100,000 lineal ft of LLDPE geomembrane seams using the same type of seaming apparatus to be used at this Site.

C. CONTRACTOR shall accept and retain full responsibility for all materials and installation and shall be held responsible for any defects.

1.03 WARRANTY

A. CONTRACTOR shall provide a written warranty from the Geomembrane Manufacturer to OWNER and QUALITY ASSURANCE CONSULTANT (QAC) for a 20-year period against defects in material from the date the installation of the geomembrane is accepted.

B. CONTRACTOR shall provide a written warranty from the Geosynthetics Installer to OWNER and QAC for a one-year period against defects in workmanship from the date the installation of the geomembrane is accepted.

C. Warranty conditions concerning limits of liability will be evaluated and must be acceptable to OWNER and QAC.

1.04 SUBMITTALS

A. At least 14 days prior to shipping any geomembrane to the Site, CONTRACTOR shall provide QAC with the following documentation concerning the Geomembrane Manufacturer that will supply the geomembrane.

1. Corporate background and information.
2. Manufacturing capabilities, including:
   a. information on plant size, equipment, personnel, number of shifts per day, and capacity per shift;
   b. daily production quantity available for this Contract;
   c. manufacturing quality control procedures; and
   d. list of material properties, including certified test results, to which are attached liner samples.
3. A list of at least ten landfill projects within the last five years that the Geomembrane Manufacturer has manufactured a minimum of 20,000,000 ft^2 of LLDPE geomembrane. The following information shall be provided for each facility:
   a. name, location, and purpose of facility, and date of installation;
   b. names of OWNER, QAC, and CONTRACTOR; and
   c. thickness and surface area of geomembrane manufactured.
4. Origin (resin supplier's name, resin production plant) and identification (brand name, number) of the resin.

B. At least 14 days prior to shipping any geomembrane to the Site, CONTRACTOR shall provide QAC with the following documentation on the resin used to manufacture the geomembrane.

1. Copies of quality control certificates issued by the resin supplier including the production dates, brand name, and origin of the resin used to manufacture the geomembrane for the Project.
2. Results of tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the Project.
3. Certification that no reclaimed polymer is added to the resin during the manufacturing of the geomembrane to be used for this Project, or, if recycled polymer is used, then the Geomembrane Manufacturer shall submit a certificate signed by the Production Manager documenting the quantity of recycled material, including a description of the procedure used to measure the quantity of recycled polymer.

C. Prior to the shipping the geomembrane rolls, CONTRACTOR shall provide QAC with the following documentation on geomembrane roll production.
1. Manufacturing certificates for each shift's production of geomembrane, signed by responsible parties employed by the Geomembrane Manufacturer (such as the Production Manager).
2. The quality control certificate shall include:
    a. roll numbers and identification;
    b. sampling procedures; and
    c. results of quality control tests, including descriptions of the test methods used.
3. The Geomembrane Manufacturer quality control tests to be performed are outlined in Part 2.03 of this Section.

D. At least 14 days prior to the scheduled date of geomembrane installation, the Geosynthetics Installer shall submit to QAC the following:
1. Corporate background and information.
2. Copy of Geomembrane Installer's letter of approval or license by the Geomembrane Manufacturer.
3. Installation capabilities, including:
    a. information on equipment and personnel;
    b. average daily production anticipated for this Project; and
    c. quality control procedures;
4. A list of at least ten landfill projects within the last five years that the Geomembrane Installer has installed a minimum of 10,000,000 ft^2 of LLDPE geomembrane. The following information shall be provided for each facility:
    a. the name and purpose of the facility, its location, and dates of installation;
    b. the names of OWNER, QAC, and CONTRACTOR;
    c. name and qualifications of the installer's supervisor(s);
    d. thickness and surface area of installed geomembrane;
    e. type of seaming and type of seaming apparatus used; and
    f. duration of installation.
5. Resumes of all personnel who will perform seaming operations on this Project, including dates and duration of employment.
6. A drawing showing the installation layout identifying field seams, as well as any variance or additional details that deviate from the Drawings. The layout shall be adequate for use as a construction plan and shall include dimensions, details, etc.
7. Installation schedule
8. A Certificate. of Calibration less than 12 months old for the field tensiometer referenced in Parts 3.05.I and K of this Section.

E. At least 14 days prior to transporting welding rod to the Site, the Geosynthetic Installer shall submit the following documentation on welding rod to QAC:
   1. quality control documentation, including lot number, welding rod spool number, and results of quality control tests on the welding rod; and
   2. certification that the welding rod is compatible with the geomembrane and this Section.

F. During the installation, the Geosynthetics Installer shall be responsible for the timely submission to QAC the following:
   1. quality control documentation; and
   2. subgrade acceptance certificates, signed by the Geosynthetics Installer, for each area to be covered by geomembrane.

G. Upon completion of the installation, CONTRACTOR shall submit to QAC the following:
   1. required warranties as specified in Part 1.03 of this Section; and
   2. record drawings of the installation.

1.05 CONSTRUCTION QUALITY ASSURANCE

A. The installation of geomembrane shall be monitored by the QACas outlined in the CQA Plan.

B. CONTRACTOR and the Geosynthetics Installer shall be aware of the activities in the CQA Plan and shall account for these CQA activities in the installation schedule.

C. CONTRACTOR shall provide the QAC the opportunity to obtain conformance samples at the geomembrane manufacturing facility in order to expedite the conformance testing and approval process.

PART 2 - PRODUCTS

2.01 RESIN

A. The geomembrane shall be manufactured from new, first-quality resin, and shall be designed and manufactured specifically for use in geomembrane. Reclaimed polymer shall not be added to the resin. However, the use of polymer recycled during the manufacturing process shall be permitted if performed with appropriate cleanliness and if the recycled polymer does not exceed 2 percent by weight of the total polymer weight.

2.02 GEOMEMBRANE PROPERTIES

A. The manufacturer shall furnish geomembrane with properties that comply with the required property values provided below and on Table 02597-1.

B. In addition to the property values listed on Table 02597-1, the geomembrane shall:
   1. contains a maximum of 1 percent by weight of additives, fillers, or extenders (not including carbon black);
   2. not have striations, pinholes, or bubbles on the surface or in the interior;

3. be produced so as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter; and
4. are manufactured in a single layer (thinner layers shall not be welded together to produce the final required thickness).

2.03 MANUFACTURING QUALITY CONTROL

A. Rolls.
1. The Geomembrane Manufacturer shall continuously monitor the geomembrane during the manufacturing process for inclusions, bubbles, or other defects. Geomembrane that exhibits any defects will not be accepted.
2. The Geomembrane Manufacturer shall continuously monitor the geomembrane thickness during the manufacturing process. Geomembrane that fails to meet the specified minimum thickness will not be accepted.
3. The Geomembrane Manufacturer shall sample and test the geomembrane in accordance with the test frequency stated in GRI Test Method GM13 for LLDPE geomembrane to demonstrate that its properties conform to the values specified on Table 02597-1.
4. Samples of the geomembrane shall be taken across the entire width of the roll.
5. At a minimum, the following manufacturing quality control tests shall be performed:

TEST	PROCEDURE
Thickness	ASTM D5994
Asperity Height	ASTM D7466
Density	ASTM D792 or ASTM D1505
Tensile Properties	ASTM D638
Puncture Resistance	ASTM D4833
Carbon Black Content	ASTM D1603
Carbon Black Dispersion	ASTM D5596

6. Any geomembrane sample that does not comply with the requirement of this Section shall result in rejection of the roll from which the sample was obtained. The Geomembrane Manufacturer shall replace any rejected rolls at no additional cost to OWNER.
7. In the case of the rejection of a roll of geomembrane, the Geomembrane Manufacturer shall sample and test each roll manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established.
8. Additional testing may be performed at the Geomembrane Manufacturer's discretion and expense, to more closely identify the non-complying rolls and/or to qualify individual rolls.
9. In addition to the tests listed under Paragraph 2.03.B.5 of this Section, CONTRACTOR and/or Geomembrane Manufacturer must provide laboratory test data that demonstrates that the geomembrane supplied meets the specifications for environmental stress crack (ASTM D5397) and direct shear (ASTM D5321) as listed on Table 02597-1. This testing shall be performed on geomembrane manufactured at the same time, from the same type of resin, and exhibiting the same material properties as the geomembrane to be used for this Project. The Geomembrane

Manufacturer shall provide the test results as part of his quality control documentation.

B. Manufacturing Plant Visit
   1. The Geomembrane Manufacturer shall allow OWNER and QAC to visit the manufacturing plant for project specific visits. If possible, then the visits will be prior to or during the manufacturing of the geomembrane rolls for this Project.
   2. During the visit, OWNER or QAC may:
      a. review the manufacturing process, quality control procedures, laboratory facilities, and testing procedures;
      b. verify that properties guaranteed by the manufacturer comply with these Specifications;
      c. verify that the measurements of properties by the manufacturer are properly documented and the test methods used are acceptable;
      d. check select geomembrane rolls for evidence of holes, blisters, or any sign of contamination by foreign matter;
      e. review packaging and transportation procedures to verify that these procedures are not damaging the geomembrane; and
      f. verify that roll packages are labeled in compliance with Part 2.05 of this Section.

2.04 GEOMEMBRANE SUPPLY

A. The geomembrane shall be supplied to the Site in rolls or as factory panels. A factory panel is comprised of one or more rolls that have been seamed together in a factory.

2.05 LABELING

A. Geomembrane and fabricated panels shall be labeled with the following information:
   1. thickness of the material;
   2. length and width of the roll or factory panel;
   3. names of manufacturer;
   4. directions to unroll the material;
   5. product identification;
   6. lot number; and
   7. roll or factory panel number.

2.06 TRANSPORTATION

A. Transportation of the geomembrane is the responsibility of the Geomembrane Manufacturer. The Geomembrane Manufacturer shall be liable for all damages to the geomembrane incurred prior to and during transportation to the Site.

B. Geomembrane shall be delivered to the Site at least seven days before the scheduled date of installation to allow the QAC adequate time for taking inventory and obtaining additional conformance samples, if needed.

2.07 HANDLING AND STORAGE

A. CONTRACTOR shall be responsible for handling, storage, and care of the geomembrane prior to and following installation at the Site. CONTRACTOR shall be liable for all damages to the materials incurred prior to final acceptance by OWNER and QAC.

B. CONTRACTOR shall be responsible for storage of the geomembrane at the Site. Geomembrane storage shall be in a clean, well-drained area. During storage, the geomembrane shall be protected from excessive heat or cold, puncture, cutting, or other damaging or deleterious conditions. The geomembrane shall be stored in accordance with any additional requirements of the Geomembrane Manufacturer.

2.08 CONFORMANCE TESTING

A. Samples of the geomembrane will be removed by the QAC at the factory and sent to an independent geosynthetics laboratory (i.e., different than the Geomembrane Manufacturer) for testing to ensure conformance with the requirements of this Section.

B. Conformance sampling and testing will be performed in accordance with the CQA Plan.

C. Samples will be taken at a minimum frequency of one sample per 250,000 ft^2 with a minimum of one sample per lot. If the Geomembrane Manufacturer provides material that requires sampling at a frequency (due to lot size, shipment size, etc.) higher than necessary, then CONTRACTOR shall pay the cost for all.

D. The QAC may direct CONTRACTOR to increase the frequency of sampling in the event that test results do not comply with requirements of Part 2.02 of this Section until passing conformance test results are obtained for all material that is received at the Site. This additional testing shall be performed at the expense of CONTRACTOR.

E. Any geomembrane roll or panel that is not certified in accordance with Part 1.04 of this Section, or that conformance testing indicates do not comply with Part 2.02 of this Section, will be rejected by the QAC. The Geomembrane Manufacturer shall replace the rejected material with new material, at no additional cost to OWNER.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any Work described in this Section, the Geomembrane Installer shall become thoroughly familiar with all portions of the Work required by Section.

B. The Geosynthetic Installer shall carefully inspect the installed Work of all other Sections and verify that all Work is complete to the point where the Work of this Section may properly commence without adverse impact to the project.

C. If the Geosynthetic Installer has any concerns regarding the installed Work of other Sections, then he should notify QAC in writing prior to the start of the Work of this Section. Failure to inform QAC in writing or commencing geomembrane installation will be construed as the Geosynthetic Installer's acceptance of the related Work of other Sections.

3.02 SURFACE PREPARATION

A. The Geosynthetics Installer shall provide certification in writing that the surface on which the geomembrane will be installed is acceptable. The surface shall be free of stones, litter, organic matter, irregularities, protrusion, loose soil, and any abrupt changes in grade that could damage the geomembrane. The certification of acceptance shall be given to the QAC prior to commencement of geomembrane installation in the area under consideration.

B. Special care shall be taken to maintain the prepared subgrade.

C. No geomembrane shall be placed onto an area which has been softened by precipitation or which has cracked due to desiccation. The soil surface shall be observed daily to evaluate the effects of desiccation cracking and/or softening on the integrity of the subgrade.

D. Any damage to the soil surface caused by installation activities shall be repaired at the CONTRACTOR's expense.

E. The CONTRACTOR or Geosynthetics Installer shall be responsible for dewatering areas that have been accepted for geomembrane deployment, including anchor trenches.

3.03 ANCHORAGE

A. The anchor trench shall be excavated prior to geomembrane placement to the lines, grades, and configuration shown on the Contract Drawings and as specified in the Specifications.

B. No loose soil shall be allowed in the anchor trench beneath the geomembrane.

C. The anchor trench shall be backfilled and compacted after the geomembrane has been installed in the trench. Care shall be taken when backfilling the trenches to prevent any damage to the geomembrane.

D. Slightly rounded corners shall be provided in the trench where the geomembrane adjoins the trench to avoid sharp bends in the geomembrane.

3.04 GEOMEMBRANE DEPLOYMENT

A. The Geosynthetics Installer shall prepare a geomembrane installation layout drawing(s) prior to geomembrane deployment. These drawings shall indicate the geomembrane configuration, dimensions, details, locations of seams, etc. Field seams shall be differentiated from factory seams (if any) on the drawings. Field seams shall be oriented up or down slope and not across slope. QAC must approve the layout drawings prior to the installation of any geomembrane. The layout drawings, as modified and/or approved by QAC, shall become part of the Contract Documents.

B. Field Panel Identification
   1. A geomembrane field panel is defined as follows:
      a. If the geomembrane is not fabricated into factory panels, then a field panel is a roll or a portion of roll cut in the field.

b. If the geomembrane is fabricated into factory panels, then a field panel is a factory panel or a portion of factory panel cut in the field.

2. Each field panel must be given an identification code (number or letter-number). This identification code shall be agreed upon by the QAC and Geosynthetics Installer. The field panel identification code shall be related, through a table or chart, to the original resin, and the constituent rolls and factory panels.

C. Field Panel Placement

1. Field panels shall be installed as approved or modified at the location and positions indicated in the layout drawings.
2. Field panels shall be placed one at a time, and each field panel shall be seamed to adjacent panels the same day that it is placed.
3. Geomembrane may only be deployed daylight hours between one hour after sunrise and one hour before sunset.
4. Geomembrane shall not be placed when the ambient temperature is below 32°F or above 104°F, unless otherwise authorized by QAC.
5. Geomembrane shall not be placed during any precipitation, in the presence of excessive moisture (e.g., frost, ice, fog, dew), in an area of ponded water, or in the presence of winds exceeding 20 miles per hour.
6. The Geosynthetics Installer shall employ placement methods consistent with the following:
   a. no vehicular traffic shall be allowed on the geomembrane.
   b. equipment used shall not damage the geomembrane by handling, trafficking, leakage of hydrocarbons, or other means.
   c. personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in other activities that could damage the geomembrane.
   d. the method used to unroll the panels shall not scratch or crimp the geomembrane and shall not damage the supporting soil.
   e. the prepared surface underlying the geomembrane shall not be allowed to deteriorate after acceptance of the surface and shall remain acceptable up to the time of geomembrane placement.
   f. the method used to place the panels shall minimize wrinkles (especially differential wrinkles between adjacent panels).
   g. temporary loads and/or anchors (e.g., sand bags, tires), not likely to damage the geomembrane, may be placed on the geomembrane to prevent uplift by wind (in high winds, continuous loading is recommended along panel edges to minimize the risk of wind flow under the panels).
7. Any field panel or portion thereof that becomes seriously damaged (tom, twisted, or crimped) shall be replaced with new material at no cost to OWNER. Less serious damage may be repaired at the QAC's sole discretion and at no cost to OWNER. Damaged panels or portions of damaged panels that have been rejected shall be removed from the work area.

3.05 FIELD SEAMING

A. In general, seams shall be oriented parallel to the line of maximum slope, (i.e., oriented down, not across, the slope). In corners and at odd-shaped geometric locations, the number of field seams shall be minimized. No horizontal seam shall be made within 5 ft of any toe of the slope, except where approved by QAC. No seams shall be located in an area of potential stress concentration, as defined by QAC.

B. All personnel performing seaming operations shall be qualified as indicated in the CQA Plan and in this Section. No seaming shall be performed unless a "master seamer" (as defined in the CQA Plan and in this Section) is present.

C. The geomembrane shall have field seams that equal or exceed the strength requirements presented on Table 02597-2.

D. Weather Conditions for Seaming:
   1. Seaming shall not be attempted at ambient temperatures below 32°F or above 104°F or when wind velocity exceeds 20 miles per hour. At ambient temperatures between 32°F and 50°F, seaming shall be allowed if the geomembrane is preheated either by the sun or a hot air device, and if there is no excessive cooling from wind. At ambient temperatures above 50°F, no preheating will be required. In all cases, the geomembrane shall be dry and protected from excessive wind.
   2. If the Geosynthetics Installer wishes to use methods that allow seaming at ambient temperatures below 32°F or above 104°F, then he shall demonstrate that the seam so produced is equivalent to those produced under normally approved conditions, and that the overall quality of the geomembrane is not adversely affected. In addition, an addendum to the Contract between OWNER and the Geosynthetics Installer shall be required that specifically states that the seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short- or long-term damage to the geomembrane.
   3. To minimize geomembrane contraction stresses, seaming should ideally be carried out in the morning and late evening when the geomembrane is relatively contracted and during the middle of the day if overcast conditions prevail. If the geomembrane must be seamed in the middle of a sunny day, then the Geosynthetics Installer shall ensure that the panels to be seamed are at the same temperature and that there is sufficient slack in the geomembrane to prevent the generation of excessive stresses or trampolining when the geomembrane contracts as cooler temperatures prevail. The Geosynthetics Installer shall determine the required amount of slack and it should not be so much so as to cause significant wrinkling of the geomembrane. If trampolining of the geomembrane is observed, then the Geosynthetics Installer will be required to make repairs so that the problem is eliminated.
   4. Ambient temperatures shall be measured within 6 inches above the geomembrane surface.

E. Overlapping and Temporary Bonding
   1. Geomembrane panels shall be overlapped a minimum of 3 inches for extrusion welding and 5 inches for fusion welding, but in any event, sufficient overlap shall be provided to allow peel tests to be performed on the seam.

2. The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane. The temperature of the air at the nozzle of spot welding apparatus shall be controlled such that the geomembrane is not damaged.
3. No solvent or adhesive shall be used unless OWNER has approved the product in writing. Samples of any proposed solvent or adhesive shall be submitted to CONTRACTOR for testing and evaluation at the Geosynthetics Installer's expense.

F. Seam Preparation
1. Prior to seaming, the seam area shall be cleaned and made free of moisture, dust, dirt, debris of any kind, and foreign material.
2. If seam overlap grinding is required, then the process shall be completed according to the Geomembrane Manufacturer's instructions within 20 minutes of the seaming operation and in a manner that does not damage the geomembrane. The grind depth shall not exceed ten percent of the geomembrane thickness. Grinding marks shall not appear beyond 0.25 inches of the extrudate after it is placed.
3. Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths".

G. General Seaming Requirements
1. Seaming shall extend to the outside edge of panels, including those panels placed in the anchor trench.
2. If required to provide a firm substrate, then a board, or similar hard surface, placed directly under the seam overlap may be used to achieve proper support.
3. Fishmouths or wrinkles at the seam overlaps shall be removed by cutting the geomembrane along the ridge of the wrinkle. At the end(s) of the cut, cut a circle in the geomembrane to achieve a flat overlap. The cut shall be seamed as described in the Section. Any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane that extends a minimum of 6 inches beyond the cut in all directions.

H. Seaming Process
1. Approved processes for field seaming are extrusion welding and fusion welding. Seaming equipment shall be operated in a manner that does not cause damage to the geomembrane. Only apparatus that QAC has specifically approved by make and model shall be used. Proposed alternate seaming processes shall be documented and submitted to QAC.
2. Extrusion Equipment and Procedures:
   a. The Geosynthetics Installer shall maintain at least one spare operable extrusion seaming apparatus on site at all times.
   b. Extrusion welding apparatus shall be equipped with gauges giving the temperature in the apparatus.
   c. Prior to beginning a seam, the extruder shall be purged until all heat- degraded extrudate has been removed from the barrel.

d. The electric generator used for power supply to the welding machines shall he placed outside the area to be lined or mounted on soft tires such that no damage occurs to the geomembrane. The electric generator shall be equipped with a grounding rod that is driven into the ground outside the lined area. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

3. Fusion Equipment and Procedures:

   a. The Geosynthetics Installer shall maintain at least one spare operable seaming apparatus on site at all times.

   b. Fusion-welding apparatus shall be automated vehicular-mounted devices equipped. with gauges giving the instantaneous temperatures and pressures of the machine.

   c. The edges of cross seams shall be abraded to a smooth incline (top and bottom) prior to welding.

   d. A movable protective layer may be used directly below each geomembrane overlap to be seamed to prevent the buildup of moisture between the sheets.

   e. The electric generator used for power supply to the welding machines shall be placed outside the area to be lined or mounted on soft tires such that no damage occurs to the geomembrane. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

I. Trial Seams

1. Trial seams shall be made prior to production seaming by all seamers and by all equipment to be used during production seaming. The trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period, and at least once each five hours, for each seaming apparatus used that day. In addition, each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual production field seams. The trial seam sample shall be at least 3.5-feet long by 1-foot wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as specified in Part 3.05.E of this Section.

2. Four adjoining specimens, each 1.0-inch wide, shall be cut from the trial seam sample by the Geosynthetics Installer. The specimens shall be tested in peel (both tracks for fusion welds) using an electronic readout field tensiometer and the specimen shall fail by film tear bond (FTB) (i.e., failure in the parent material) rather than in the seam. The Geosynthetics Installer shall test the specimens in the presence of the QAC. Testing using the field tensiometer shall be performed in accordance with ASTM D 6392, at a strain rate of 2 inches/minute. Ideally, the samples shall be conditioned at 73°F at a relative humidity of 50 percent for two hours prior to testing. If test conditions vary from this requirement, then a 1 inch wide specimen of the parent geomembrane (no weld) shall be tested in the same manner as the seam specimens to determine the break strength at this condition. At no time shall the specimens be soaked in water.

3. If a specimen fails to comply with the properties stated on Table 02597-2, then the entire operation shall be repeated. If the additional specimen fails to meet these requirements, then the seaming apparatus or seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved.
4. After completion of the above described tests, the remaining portion of the trial seam sample can be discarded. If a trial seam sample fails a test, then a destructive test seam sample may be taken from the seams completed by the seamer during the shift related to the considered trial seam at the discretion of QAC. These samples shall be forwarded to CQA geosynthetics laboratory and, if they fail the tests, the procedure indicated in Part 3.05.K.5 of this Section shall apply. The results of all testing shall be reported to the QAC. The conditions of this paragraph shall be considered as met for a given seam if a destructive seam test sample has already been taken from the considered seam.

J. Nondestructive Seam Continuity Testing
1. The Geosynthetics Installer shall nondestructively test all field seams over their full length using a vacuum test, air pressure test (for double fusion seams only), or other approved method. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. The installer shall complete any required repairs in accordance with Part 3.05.L of this Section. The following procedures shall apply to locations where seams cannot be nondestructively tested:
    a. If the seam is accessible to testing equipment prior to final installation, then the seam shall be nondestructively tested prior to final installation.
    b. If the seam cannot be tested prior to final installation, then the seaming operations must be observed in their entirety by the QAC for uniformity and completeness.
2. Vacuum testing of extrusion field seams and repairs shall be performed in accordance with ASTM D 5641.
3. Air pressure testing shall be performed on double fusion seams only, and shall be performed in accordance with ASTM D 5820 and the following:
    a. Energize the air pump to a pressure between 25 and 30 psi, close valve, allow two minutes for pressure to stabilize, and sustain the pressure for not less than 5 minutes.
    b. If loss of pressure exceeds 4 psi, or if the pressure does not stabilize, then locate faulty area and repair in accordance with Part 3.05.L of this Section.
    c. Cut opposite end of air channel from pressure gauge and observe release of pressure to ensure that the entire channel is not blocked.
    d. Remove needle, or other approved pressure feed device, and seal repair in accordance with Part 3.05.L of this Section.
4. QAC may allow spark testing in accordance with ASTM D 6365 if the seam cannot be tested using other nondestructive methods.

K. Destructive Testing
1. Destructive testing of field seams shall be performed on samples collected from selected locations to evaluate seam strength and integrity according to the requirements for seam strength presented on Table 02597-2. Destructive testing shall be carried out as the geomembrane installation progresses, not at the completion of all field seaming.

2. Sampling
    a. Field seam samples shall be collected for destructive testing at a minimum average frequency of one test location per 500 ft of seam length. Test locations shall be determined during seaming, and may be prompted by suspicion of excess crystallinity, contamination, offset seams, or any other potential cause of imperfect seaming. The QAC will be responsible for choosing the locations. The Geosynthetics Installer shall not be informed in advance of the locations where the seam samples will be taken. QAC reserves the right to increase the sampling frequency.
    b. Samples of the field seams shall be cut with rounded corners by the Geosynthetics Installer at the locations designated by the Geosynthetics QAC as the seaming progresses. Passing laboratory test results must be obtained before the field seams are covered by another material. All holes in the geomembrane resulting from the field seam sampling shall be immediately repaired in accordance with the repair procedures described in Part 3.05.L of this Section. The continuity of the new seams in the repaired areas shall be tested according to Part 3.05.J of this Section.
    c. Two strips, 1-inch wide and 12-inches long with the seam centered parallel to the width, shall be taken. The strips shall be spaced a clear distance of 42- inches apart. These samples shall be tested using the field tensiometer in accordance with Part 3.05.I.2 of this Section. If these samples pass the field test, then a laboratory sample shall be taken. The laboratory sample shall be at least 1-foot wide by 42-inches long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:
        i. one 1-foot long portion to the Geosynthetics Installer.
        ii. one 1-foot long portion to OWNER for archiving;
        iii. one 1.5-feet long portion to the QAC for laboratory testing.
3. If any field test sample fails to meet the required seam strength properties presented on Table 02597-2, then the procedures outlined in Part 3.05.K.5 of this Section shall be followed.
4. Samples shall be tested in the laboratory in accordance with the requirements of this Section and the CQA Plan.
5. Destructive Test Failure
    a. The following procedures shall apply whenever a sample fails a destructive test, whether the test is conducted by the CQA laboratory, the Geosynthetics Installer's laboratory, or by a field tensiometer. The Geosynthetics Installer shall have two options, as described in b and c below.
    b. The Geosynthetics Installer can reconstruct the seam (e.g., remove the old seam and reseam) between two passing destructive test locations. The welding path of the seaming apparatus shall be tracked (in each direction).

c. The Geosynthetics Installer can trace the welding path to an intermediate location, a minimum of 10 feet from the location of the failed test (in each direction) and take a small sample for an additional field test at each location. If these additional samples pass the tests, then full laboratory samples shall be taken. If these laboratory samples pass the tests, then the seam shall be reconstructed between these locations. If either sample fails, then the process shall be repeated to establish the zone in which the seam should be reconstructed. In any case, all acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. In cases where the length of reconstructed seam exceeds 150 feet, a destructive sample taken from within the reconstructed zone must pass destructive testing. Whenever a sample fails, the QAC may require additional tests for seams that were formed by the same seamer and/or seaming apparatus or seamed during the same time shift.

L. Defects and Repairs

1. All seams and non-seam areas of the geomembrane will be examined by the QAC and the Geosynthetic Installer for evidence of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be swept or washed by the Geosynthetics Installer if surface contamination inhibits examination. The Geosynthetics Installer shall ensure that this examination of the geomembrane precedes any seaming of that section.
2. Each suspect location, both in seam and non-seam areas, shall be nondestructively tested using the methods described Part 3.05.J of this Section, as appropriate. Each location that fails nondestructive testing shall be marked by the QAC and repaired by the Geosynthetics Installer. Work shall not proceed with any materials that will cover the defective area until the suspect location is repaired and passing nondestructive test are obtained. In addition, passing destructive test results shall be achieved prior to placing any material over geomembrane.
3. When seaming of a geomembrane is completed (or when seaming of a large area of a geomembrane is completed) and prior to placing overlying materials, the QAC shall identify excessive geomembrane wrinkles. The Geosynthetics Installer shall cut and reseam the wrinkle areas so identified. The seams thus produced shall be tested like any other seams.
4. Repair Procedures.
   a. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Geosynthetics Installer. Several repair procedures are specified below. The final decision as to the appropriate repair procedure shall be agreed upon between the QAC and the Geosynthetics Installer. The procedures available include:
      i. patching (used to repair large holes, small tears, undispersed raw materials, and contamination by foreign matter);
      ii. abrading and reseaming (used to repair small sections of extruded seams);
      iii. spot seaming (used to repair pinholes, or other minor, localized flaws);

iv. capping (used to repair long lengths of failed seams);

v. removing failed seam and replacing with a strip of new material seamed into place (used with long lengths of fusion seams) and/or extrusion seams.

b. In addition, the following shall be satisfied:

i. surfaces of the geomembrane that are to be repaired shall be abraded no more than 20 minutes prior to the repair;

ii. all surfaces must be clean and dry at the time of repair;

iii. all seaming equipment used in repair procedures must be approved by QAC;

iv. the repair procedures, materials, and techniques shall be approved in advance, for the specific repair, by the QAC and Geosynthetics Installer;

v. patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of holes and patches shall be rounded with a radius of at least 3 inches; and

vi. the geomembrane below large caps shall be appropriately cut to avoid water or gas collection between the two sheets.

5. Each repair shall be numbered and logged and shall be nondestructively tested using the methods described in this Section. Repairs that pass the nondestructive test shall be taken as an indication of an adequate repair. Failed tests will require the repair to be redone and retested until a passing test result is achieved. At the discretion of the QAC, destructive testing may be required on large caps.

3.06 MATERIALS IN CONTACT WITH GEOMEMBRANE

A. The Geosynthetics Installer shall take all necessary precautions to ensure that the geomembrane is not damaged during its installation or during the installation of other components of the liner system or by other construction activities. Installation on rough surfaces, such as concrete, shall be performed carefully.

B. Equipment shall not be driven directly on the geomembrane. Unless otherwise specified by QAC, all equipment operating on materials overlying the geomembrane shall comply with the following:

Allowable Equipment Ground Pressure (psi)	Thickness of Overlying Compaction Soil (feet)
<5	1.0
<10	1.5
<20	2.0
>20	3.0

C. In heavily trafficked areas such as access ramps, and in areas trafficked by rubber tire vehicles, the thickness of overlying compacted soil shall be at least 3 feet.

D. Installation of the geomembrane in sump areas, and connection of the geomembrane to appurtenances shall be made according to these Specifications and as shown on the Contract Drawings. Extreme care shall be taken while seaming around sumps and appurtenances since neither nondestructive nor destructive testing may be feasible in these areas. The Geosynthetics Installer shall ensure that the geomembrane has not been visibly damaged while making connections to sumps and appurtenances. Because of the difficulty of vacuum testing seams in the sump area, fusion seams should be made at all possible locations in the sump.

E. Placement of soils above the geomembrane will not proceed at an ambient temperature below 32°F nor above 104°F unless otherwise specified or approved by QAC.

3.07 GEOMEMBRANE ACCEPTANCE

A. The Geosynthetics Installer shall retain all ownership and responsibility for the geomembrane until accepted by OWNER and QAC.

B. The geomembrane will not be accepted by OWNER and QAC until all of the following conditions are met:
1. the installation is finished;
2. all documentation of installation is completed including the QAC's final report;
3. verification of the adequacy of all field seams and repairs, including associated testing, is complete; and
4. written certification documents, including record drawings, sealed by a professional land surveyor licensed in the State of Delaware, have been received by OWNER and QAC.

3.08 PRODUCT PROTECTION

A. CONTRACTOR shall use all means necessary to protect all prior Work and all materials and completed Work of other Sections.

B. No equipment shall be placed directly on the geomembrane during installation. Rub sheets shall be used beneath equipment to protect the geomembrane from equipment damage.

C. In the event of damage, CONTRACTOR shall immediately make all repairs and replacements necessary, to the approval of the QAC and at no additional cost to OWNER.

TABLE 02597-1

REQUIRED TEXTURED LLDPE GEOMEMBRANE PROPERTY VALUES [1]

Properties	Qualifiers	Units	Specified Values 40 mil	Test Method
Thickness	Nominal	Mils	40	ASTM D5994
	Minimum Average	Mils	38	ASTM D5994
Asperity Height	Minimum Average	Mils	16	ASTM D7466
Density	Minimum	g/cc	0.939	ASTM D792 or ASTM D1505
Tensile Properties (each direction)				
1. Break Strength	Minimum	Lb/in.	60	ASTM D638
2. Break Elongation	Minimum	%	100	ASTM D638
2% Modulus	Maximum	Lb/in.	2400	ASTM D5323
Tear Resistance	Minimum	Lb.	22	ASTM D1004
Puncture Resistance	Minimum	Lb.	44	ASTM D4833
Axi-Symmetric Break Resistance Strain	Minimum	%	30	ASTM D5617
Direct Shear (for slopes 14% to 25%) (see Note 2)	Minimum	Degrees	19[3]	ASTM D5321
Carbon Black Content	Range	%	2 - 3	ASTM D1603
Carbon Black Dispersion	N/A	None	See Note 4	ASTM D5596
Stress Crack Resistance	Minimum	hours	200	ASTM D5397

Notes: (1) All values represent minimum average roll values (i.e., any roll in a lot should meet or exceed these values).

(2) Direct shear testing shall be performed by CONTRACTOR on the entire liner system cross section using the proposed liner system materials (i.e., cover soil, geocomposite, geomembrane, and grading fill layer). The testing shall be performed at the normal stresses indicated.

(3) Testing shall be performed at normal stresses of 100 psf, 250 psf and 500 psf.

(4) Carbon black dispersion (on near spherical agglomerates) for 10 different views:

- 9 in categories 1 or 2; and
- 1 in Category 3.

TABLE 02597-2

REQUIRED TEXTURED LLDPE GEOMEMBRANE SEAM PROPERTIES

Properties	Qualifiers	Units	Specified Values 40 mil	Test Method
Gauge	Nominal	Mils	40	
Shear Strength[(1)] at yield point	Minimum	Lb/in	60	ASTM D 6392
Peel Adhesion FTB[(2)] Fusion	Minimum	Lb/in	50	ASTM D 6392
Extrusion		Lb/in	44	ASTM D 6392

Notes: (1) Also called “Bonded Seam Strength”.
(2) In addition to the minimum passing values, passing seams shall exhibit film tear bond (FTB) and the seam shall not separate more than 10 percent.

*****END OF SECTION*****

SECTION 02598

HIGH DENSITY POLYETHYLENE (HDPE) MICRODRAIN LINER®

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools, and appurtenances required to complete the work of the installation of high density polyethylene (HDPE) MicroDrain® Liner for the ash landfill closure cap and other related and incidental work within the designated area and as required for the construction of other work, as shown, specified, or required. CONTRACTOR shall provide a "Competent Person" to implement and supervise all work.

B. Comply with applicable codes, ordinances, rules, regulations, and laws of local, municipal, State, or Federal authorities having jurisdiction.

1.02 SUBMITTALS

A. Pre-installation: CONTRACTOR shall submit the following prior to MicroDrain® deployment:

1. Origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture MicroDrain®.
2. Copies of dated quality control certificates issued by resin supplier.
3. Results of tests conducted by MicroDrain® manufacturer to verify that resin used to manufacture MicroDrain® meets Specifications.
4. Statement that amount of reclaimed polymer added to resin during manufacturing did not exceed 2% by weight.
5. List of materials that comprise MicroDrain®, expressed in following categories as percent by weight:
    a. polyethylene;
    b. carbon black; and,
    c. other additives.
6. Manufacturer's specification for MicroDrain®, including properties listed and measured using appropriate test methods.
7. Written certification that minimum values given in manufacturer's specification are guaranteed by MicroDrain® manufacturer.
8. Quality control certificates, signed by MicroDrain® manufacturer. Each quality control certificate shall include applicable roll identification numbers, testing procedures, and results of quality control tests.
9. Field panel layout and identification code including dimensions and details.
10. Resumes of INSTALLER’s Superintendent and Master Seamer, including dates and duration of employment.
11. Installation schedule.
12. List of personnel performing seaming operations, including experience information.
13. Certificate that extrusion rod is comprised of same resin as MicroDrain® liner material.
14. Manufacturer Material and Installation warranties.

B. Installation: Submit as installation proceeds.

1. Quality control documentation recorded during installation.
2. Subgrade surface acceptance certificates signed by INSTALLER for each area that will be covered directly by MicroDrain®. Submit on deployment of MicroDrain®.
3. Deployment of MicroDrain® will be considered acceptance of subgrade by the INSTALLER, if certificate is not submitted.

1.03 PRE-QUALIFICATIONS

A. Manufacturer

Manufacturer shall have minimum 5 years continuous experience in manufacture of HDPE MicroDrain®, or experience totaling 10,000,000 square feet (sq. ft.) of manufactured HDPE, or MicroDrain® manufacture for minimum of ten (10) completed facilities.

B. Installer

1. Installer shall have minimum 5 years continuous experience in installation of HDPE MicroDrain® or experience totaling 2,000,000 sq. ft. of installed HDPE MicroDrain® for minimum of five (5) completed facilities.

2. Personnel performing seaming operations shall be qualified by experience or training. Minimum of one seamer shall have experience seaming minimum 2,000,000 sq. ft. of HDPE MicroDrain® using same type of seaming apparatus in use at Site. Most experienced seamer, "Master Seamer," shall provide direct supervision, as required, over less experienced seamers.

1.04 QUALITY ASSURANCE PROGRAM

Manufacturer, fabricator, and installer shall participate in and conform to items and requirements of quality assurance program as outlined in this Section and the Construction Quality Assurance (CQA) Plan.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping

1. Manufacturer shall identify each roll delivered to Site with the following:

a. Manufacturer's name.
b. Product Identification.
c. Thickness.
d. Roll number.
e. Roll dimensions.

2. Protect MicroDrain® from excessive mud, dirt, puncture, cutting, or other damaging or deleterious conditions during loading, transport, and unloading at Site.

B. Acceptance at Site

1. INSTALLER shall be responsible for unloading all geosynthetics delivered to the Site, unless otherwise agreed at the geosynthetics kick-off meeting.
2. Shipper shall notify INSTALLER, or other party responsible for off-loading materials, 48-hours in advance of material delivery.
3. INSTALLER, or other party responsible for off-loading materials, shall bear all costs (including but not limited to QUALITY ASSURANCE CONSULTANT (QAC), 3rd party contractor costs) associated with failure to supply appropriate personnel and equipment required to off-load geosynthetic materials.
4. Perform physical inventory of materials delivered to the Site for use in the work. Perform inventory on delivery, or as soon as practicable thereafter.
5. Conduct surface observations of each roll for defects and damage. This examination shall be conducted without unrolling rolls, unless defects or damages are found or suspected. Note type and extent of defects or damage observed.
6. Defective or damaged rolls, or portions of rolls, will be rejected and shall be removed from Site and replaced, at no additional expense to the OWNER.
7. Rolls or portions of rolls without proper identification or labeling will be rejected and shall be removed from Site.

C. Storage and Protection

1. The MicroDrain® will be unloaded, transported, stored, and protected in accordance with the manufacturers' recommendations so as not to damage or degrade the properties of the material.
2. QAC will provide on-Site storage area for MicroDrain® rolls from time of delivery until deployment.
3. INSTALLER shall protect MicroDrain® from dirt, water, and other sources of damage.
4. Preserve integrity and readability of MicroDrain® roll labels.

PART 2 – PRODUCTS

2.01 MATERIALS

The MicroDrain® used for the ash landfill closure cap area is a high density polyethylene (HDPE) 50-mil liner manufactured by Agru-America. The MicroDrain® shall meet the following properties:

Table 02598-1: Minimum Properties 50-mil HDPE MicroDrain® Liner

Testing Properties	Testing Method	50 mil HDPE Value
Thickness, mils (min. avg.) Thickness, mils (lowest individual)	ASTM D5994	47.5 42.5
Density (g/cc)	ASTM D1505 or ASTM D792	0.940 (min. avg.) (either method)
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	20 mils
Drainage Stud Height (min. avg.)	ASTM D7466	130 mils
Transmissivity – Machine Direction MD (min. avg.) (11)	ASTM D4716	8.0×10^{-4} m^2/s for i=0.14

Testing Properties	Testing Method	50 mil HDPE Value
Direct Shear (Friction Angle) – degrees (min)	ASTM D5321	19 degrees
Tensile Properties (min. avg.) (3) • yield strength, lb/in • break strength, lb/in • yield elongation, % • break elongation,%	ASTM D6693	 110 110 12 300
Tear Resistance – lb (min. avg.)	ASTM D1004	38
Puncture Resistance – lb (min. avg.)	ASTM D4833	80
Stress Crack Resistance (10)	ASTM D5397 (10) (Appendix)	500
Carbon Black Content - %	ASTM D1603 (4)	2.0 to 3.0
Carbon Black Dispersion	ASTM D 5596	Note (5)
Oxidative Induction Time (OIT) (min. avg.) (6) • Standard OIT	ASTM D3895	100
Melt Flow Index, g/10 minutes	ASTM D1238	1
Oven Aging at 85°C (6)(7) • High Pressure OIT (min. avg.), % retained after 90 days	ASTM D5721 ASTM D5885	80
UV Resistance (8) • High Pressure OIT (min. avg.) % retained after 1600 hrs(9)	ASTM D5885	50

Notes:

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet. Both sides are to be measured and considered separately.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed in GRI GM-13 to evaluate the antioxidant content in the MicroDrain®

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hour UV cycle at 75°C followed by 4 hour condensation at 60°C.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

(10) The SP-NCTL per ASTM D5397 test is not appropriate for testing MicroDrain®s with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacture's mean value via MQC testing.

(11) Conduct test for Transmissivity at a normal compressive load of 500 pounds per square feet (psf) and at a hydraulic gradient of 0.14 (top of final grade surface). Boundary conditions from top to bottom are: upper load plate/ soil / nonwoven geotextile / geomembrane / lower load plate. Seating period shall be at least 100 hours to meet design criteria, and one (1) hour to meet conformance criteria.

A MicroDrain® shall be manufactured from new polyethylene resin, except as noted below:

1. Use of MicroDrain® recycled during manufacturing process shall be permitted, with written approval from QAC, if recycled MicroDrain® does not exceed 2% by weight.
2. MicroDrain® manufactured from non-complying resin shall be rejected.

B. MicroDrain® Characteristics

1. Contain maximum of 1%, by weight, of additives, fillers or extenders (not including carbon black).
2. Contain between 2% and 3%, by weight, of carbon black for ultraviolet light resistance.
3. No pinholes, bubbles or other surface features that compromise MicroDrain® integrity are allowed. MicroDrain® shall be free of blisters, nondispersed raw materials, or other signs of contamination resulting from the manufacturing process. MicroDrain® rolls or portions of rolls with these defects shall be rejected.

C. Geotextile Characteristics

1. The geotextile used to cover the MicroDrain® ash landfill closure cap shall be as shown on the Construction Drawings and meet the requirements of Section 02595.
2. Geotextiles will be generally aligned with seams parallel to the prevailing slope and HEAT TREATED side of the geotextile to be face down in contact with the MicroDrain® and can be seamed by either heat seaming with an approved hand held or self motivated thermal device or by sewing with a stitching approved by the QAC. Whichever stitching method is used the thread should be compatible with the fabric and have similar chemical resistance to the liner that is being used.
3. Any holes, tears, or burn throughs from thermal seaming in geotextiles will be repaired by patching with the same geotextiles. The patch will be a minimum of twelve inches larger in all directions than the area to be repaired and will be spot bonded thermally.
4. The CONTRACTOR shall protect the work described in this Section before, during, and after installation, and shall protect the installed work covered by other Sections.

2.02 SEAMING AND TESTING EQUIPMENT

A. Welding

1. Maintain on-Site minimum of two (2) spare operable seaming machines, unless otherwise agreed upon at pre-construction meeting.
2. Seaming equipment shall not damage MicroDrain®.
3. Use extrusion welding apparatus equipped with gauges indicating temperature of extrudate at the equipment nozzle or utilize hand-held gauges to measure extrudate temperatures.
4. Use self-propelled fusion-welding machines equipped with following:
   a. Gauge indicating temperature of heating element; and,
   b. Gauge indicating the speed of travel.

5. Place electric generator on smooth base such that no damage occurs to MicroDrain®.

B. Vacuum Testing Equipment

1. Vacuum box assembly shall consist of a rigid housing open at the bottom, with a transparent viewing window and soft neoprene gasket attached to bottom rim of housing, a porthole or valve assembly, and a vacuum gauge;
2. Pump assembly equipped with pressure controller and pipe connections;
3. Pressure/vacuum rubber hose with fittings and connections;
4. Soapy solution to wet test area; and,
5. Means of applying soapy solution.

C. Air Pressure Testing Equipment

1. Air pump (manual or motor driven), equipped with pressure gauge, capable of generating, sustaining, and measuring pressure between 24 and 35 pounds per square inch (psi) (165 and 240 kilopascals (kPa)), and mounted on cushion to protect MicroDrain®;
2. Rubber hose with fittings and connections;
3. Means of safely sealing weld air channel;
4. Sharp hollow needle, or other approved pressure feed device; and,
5. Air pressure monitoring device.

D. Tensiometer

1. Tensiometer shall be capable of maintaining constant jaw separation rate of 2-inches per minute; and,
2. Tensiometer shall be calibrated annually. A certificate indicating that the equipment has been calibrated within one (1) year of use in the work shall be maintained with the tensiometer. The INSTALLER will provide the QAC with a copy of the certificate of calibration.

2.03 SOURCE QUALITY CONTROL

Tests and inspections shall be performed by MicroDrain® manufacturer as follows:

A. Test MicroDrain® to demonstrate that resin meets this Specification.

B. Continuously monitor MicroDrain® during manufacturing process for inclusions, bubbles, or other defects. MicroDrain®, which exhibit defects, shall not be acceptable for installation.

C. Monitor thickness continuously during manufacturing process.

D. The MANUFACTURER shall conduct quality control (QC) testing to verify conformance with Table 02598-1 in section 2.01, at the following frequencies:

Table 02598-2: Quality Control (QC) Manufacturers Testing

Testing Properties	Testing Method	Manufacturer QC Testing Frequency
Thickness mils (min. avg.)	ASTM D 5994	1 per Roll
Density g/cc	ASTM D1505 or ASTM D792	1 per 50,000 SF
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	1 per 50,000 SF
Drainage Stud Height (min. avg.)	ASTM D7466	1 per 50,000 SF
Transmissivity	ASTM D4716	1 per 200,000 SF
Tensile Properties (min. avg.) (3)	ASTM D6693	1 per 50,000 SF
Tear Resistance – lb (min. avg.)	ASTM D1004	1 per 50,000 SF
Puncture Resistance – lb (min. avg.)	ASTM D4833	1 per 50,000 SF
Stress Crack Resistance (11)	ASTM D5397	per GRI GM10
Melt Flow Index, g/10 minutes	ASTM D1238	1 per 200,000 lbs
Low Temperature Brittleness	ASTM 746	1 per 200,000 lbs
Carbon Black Content - %	ASTM D1603 (4)	1 per 50,000 SF
Carbon Black Dispersion(5)	ASTM D 5596	1 per 50,000 SF
Oxidative Induction Time (OIT) (min. avg.) (6) • Standard OIT, or • High Pressure OIT	ASTM D3895 ASTM D5885	(6)
Oven Aging at 85°C (7) • Std. OIT (min. avg.), % retained after 90 days or • High Pressure OIT (min. avg.), % retained after 90 days	ASTM D5721 ASTM D3895 ASTM D5885	(6)
UV Resistance (8) • Std. OIT (min. avg.)(9), or • High Pressure OIT (min. avg.) % retained after 1600 hours(10)	ASTM D3895 ASTM D5885	(6)

Notes:

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet. Both sides are to be measured and considered separately.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the MicroDrain®.

(7) *It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.*
(8) *The condition of the test should be 20 hour UV cycle at 75℃ followed by 4 hour condensation at 60℃.*
(9) *Not recommended since high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.*
(10) *UV resistance is based on percent retained value regardless of the original HP-OIT value.*
(11) *Manufacturer may provide a certification letter. The SP-NCTL test is not appropriate for testing MicroDrain® with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.*

PART 3 – EXECUTION

3.01 QUALITY ASSURANCE SAMPLING AND TESTING

A. Upon delivery of the material to the Site, the QAC shall obtain conformance test samples from selected MicroDrain®. INSTALLER shall make rolls available and assist QAC in obtaining material inventory and samples. Samples shall be tested in accordance with Table 02598-1 in section 2.01, at the following frequencies:

Table 02598-3: Quality Assurance (QA) Conformance Testing

Testing Properties	Testing Method	Conformance QA Testing Frequency
Thickness mils (min. avg.)	ASTM D 5994	1 per 200,000 SF*
Density g/cc	ASTM D1505 or ASTM D792	1 per 200,000 SF*
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	1 per 200,000 SF*
Drainage Stud Height (min. avg.)	ASTM D7466	1 per 200,000 SF*
Transmissivity	ASTM D 4716	1 per 200,000 SF*
Tensile Properties (min. avg.) (3)	ASTM D6693	1 per 200,000 SF*
Tear Resistance – lb (min. avg.)	ASTM D1004	1 per 200,000 SF*
Puncture Resistance – lb (min. avg.)	ASTM D4833	1 per 200,000 SF*
Stress Crack Resistance (7)	ASTM D5397	N/A
Carbon Black Content - %	ASTM D1603 (4)	1 per 200,000 SF*
Carbon Black Dispersion(5)	ASTM D 5596	1 per 200,000 SF*
Direct Shear (Friction Angle) – degrees (min)(6)	ASTM D5321	1 per Lot

Notes:
(1) *Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils*
(2) *Alternate the measurement side for double sided textured sheet.*
(3) *Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.*

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
**- Or minimum 1 per lot.*
(6) Direct shear testing shall be performed by the CONTRACTOR on the entire liner system cross section using the proposed liner system materials (i.e. cover soil, geocomposite, geomembrane, geotextile, and grading fill). The testing shall be performed at normal stresses of 100 psf, 250 psf, and 500 psf.
(7) Manufacturer may provide a certification letter. The SP-NCTL test is not appropriate for testing MicroDrain® with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.

B. Rolls represented by quality assurance testing shall be rejected if test failure occurs. INSTALLER may at their expense request additional testing to validate individual rolls. Rolls bracketed by passing tests may be used in the work.

3.02 SURFACE PREPARATION

A. CONTRACTOR is responsible for preparing subgrade surface for MicroDrain® placement.

B. After prepared subgrade surface has been accepted in accordance with CQA Plan, report to QAC any change in subgrade surface condition that may require repair work. Maintain prepared surface.

C. Do not place MicroDrain® onto an area that has become degraded due to weather conditions. Observe and report surface condition daily to evaluate suitability for MicroDrain® deployment.

D. Repair damage to prepared surface caused by installation activities at INSTALLER'S expense.

3.03 INSTALLATION

A. Panel Nomenclature

1. Field panel is defined as a roll or portion of roll cut and seamed in field, excluding patches and cap strips.
2. Identify each field panel with a unique identification code (number or letter-number). This identification code shall be agreed upon by INSTALLER and QAC.
3. The INSTALLER shall be responsible for marking the panel and roll number on the MicroDrain®.

B. Protection

1. Do not use equipment that damages MicroDrain®;
2. Ensure subgrade surface underlying MicroDrain® has not deteriorated since previous acceptance, and remains acceptable immediately prior to and during MicroDrain® deployment;
3. Keep geosynthetic elements immediately underlying MicroDrain® clean and free of debris;

4. Do not permit personnel to smoke or wear shoes that can damage MicroDrain® while working on MicroDrain®. Personnel shall not bring glass or metal containers on MicroDrain®, except as required to perform the work;
5. Unroll panels in manner that does not cause excessive scratches or crimps in MicroDrain® and does not damage supporting soil;
6. Place panels in manner that minimizes wrinkles (especially differential wrinkles between adjacent panels);
7. Prevent wind uplift by providing adequate temporary loading and/or anchoring (e.g., sandbags) that shall not damage MicroDrain®. In case of high winds, continuous loading is recommended along panel edges; and,
8. Protect MicroDrain® in areas where excessive traffic is expected, using geotextiles, extra MicroDrain®, or other suitable materials.
9. The CONTRACTOR must protect the work described in this section before, during, and after installation.
10. Unless otherwise specified by the QAC, all equipment for spreading fill materials overlying the geosynthetics shall comply with the following:

Maximum Equipment Ground Pressure (psi)	Minimum Separation Thickness (inches)
<5	12
5 – 10	24
>10	36

11. No equipment shall be placed directly on the geomembrane during installation. Rub sheets shall be used beneath equipment to protect the geomembrane from equipment damage.

C. Field Panel Deployment

1. Install field panels at locations indicated on INSTALLER's layout plan to the greatest extent possible.
2. Replace seriously damaged (torn, twisted or crimped) field panels, or portions thereof, at no cost to OWNER. Repair less serious damage as specified herein. QAC shall determine if material shall be repaired or replaced.
3. Remove from work area damaged panels, or portions of panels, that have been rejected by the QAC.
4. Do not proceed with deployment at ambient temperature below 32°F (0°C) or above 104°F (40°C) unless authorized, in writing, by QAC.
5. Do not deploy during precipitation, in presence of excessive moisture, (i.e., fog, dew, etc.), in areas of ponded water, or in presence of excessive winds.
6. Do not undertake deployment if weather conditions will preclude material seaming on same day as deployment.
7. Do not deploy more MicroDrain® field panels in one day than can be seamed during that day.

D. Seam Layout

1. Orient seams parallel to line of maximum slope (i.e., oriented along, not across, slope).
2. No horizontal seams will be permitted on the slope.
3. No horizontal seam shall be less than 5 feet (1.5 meters) from toe of slope, unless approved by the QAC.
4. In general, maximize lengths of field panels and minimize number of field seams.

5. Align MicroDrain® panels to have nominal overlap of 3 inches (75 millimeters) for extrusion welding and 4 to 6 inches (100 to 150 millimeters) for fusion welding. Final overlap shall be sufficient to allow destructive “peel” tests to be performed on seam.

E. Temporary Bonding

1. Hot air device (Leister) may be used to temporarily bond MicroDrain® panels to be extrusion welded.
2. Do not damage MicroDrain® when temporarily bonding adjacent panels. Apply minimal amount of heat required to lightly tack MicroDrain® panels together. Control temperature of hot air at nozzle of any temporary welding apparatus to prevent damage to MicroDrain®.
3. Do not use solvent or adhesive.

F. Seaming Methods

1. Approved processes for field seaming are extrusion fillet welding and fusion welding. Proposed alternate processes shall be documented and submitted to QAC for approval. Alternate procedures shall be used only after being approved in writing by QAC.
2. Use fusion welding as primary method of seaming adjacent field panels.

   a. Cross seam “tees”, associated with fusion or extrusion seam welding, shall be patched in accordance with the requirements of this Section.
   b. Place welder on protective pad to prevent MicroDrain® damage when not in use.
   c. When subgrade conditions dictate, use movable protective layer (e.g. rub sheet) directly below each overlap of MicroDrain® that is to be seamed to prevent buildup of moisture between sheets and prevent debris from collecting around pressure rollers. Rub sheet shall be removed from under the liner once seaming is complete.

3. Use extrusion fillet welding as secondary method for seaming between adjacent panels and as primary method of welding for detail and repair work.

   a. Purge heat-degraded extrudate from barrel of extruder
   b. Place smooth insulating plate or fabric beneath hot welding apparatus when not in use
   c. Use clean and dry welding rods or extrudate pellets.
   d. Clean dirt and debris from MicroDrain® surface prior to extrusion welding.
   e. Grind weld area to using suitable handheld equipment to prepare MicroDrain® surface for extrusion welding. Grind perpendicular to seam. Take care not to over-grind MicroDrain®
   f. Minimize exposed grinding marks adjacent to extrusion weld. Do not allow exposed grinding marks to extend more than 1/4-inch outside finished seam area.
   g. Complete extrusion welding within one (1) hour of seaming operation grinding process without damaging MicroDrain®

G. Seaming Procedures

1. General Seaming Procedures - Ambient temperature between 32°F (0°C) and 104°F (40°C).

   a. Do not field seam without Master Seamer being present.
   b. Seam only during dry conditions, i.e., no precipitation or other excessive moisture, such as fog or dew.
   c. Do not seam during excessive winds, except as needed to protect the work. Do not seam if wind creates unsafe working conditions.
   d. If required, use “rub-sheet” or similar hard surface directly under seam overlap to achieve proper support for seaming apparatus.
   e. Align panels to minimize wrinkles and/or “fishmouths” in welds.
   f. Extend seams to outside edge of panels placed in anchor trench.
   g. Prior to seaming, ensure that seam area is free of moisture, dust, dirt, debris, or foreign material.
   h. “Fishmouths” or wrinkles at seam overlaps shall be cut along ridge of wrinkle in order to achieve flat overlap. Cut “fishmouths” or wrinkles shall be seamed or patched in accordance with this Section.

2. Cold Weather Seaming Procedures (ambient temperature is below 32°F (0°C)).

   a. No seaming of MicroDrain® is permitted unless demonstrated to QAC that MicroDrain® seam quality will not be compromised.
   b. Additional destructive samples and/or field test strips shall be cut from seams welded under ambient temperature of 32°F (0°C), at QAC’s discretion.

3. Warm Weather Procedures (ambient temperature is above 104°F (40°C)).

   a. No seaming of MicroDrain® is permitted unless demonstrated to QAC that MicroDrain® seam quality will not be compromised.
   b. Additional destructive samples and/or field test strips shall be cut from seams welded over ambient temperature of 104°F (40°C), at QAC’s discretion.

H. Repair Procedures:

1. Acceptable repair procedures include following:

   a. Patching: Piece of same MicroDrain® material extrusion welded into place. Use to repair large holes, tears, nondispersed raw materials, and contamination by foreign matter. All panel intersections shall be patched.
   b. Capping: Strip of same MicroDrain® material extrusion welded into place over inadequate seam. Use to repair large lengths of failed seams.
   c. Spot welding or seaming (Grind and Weld): Bead of molten extrudate placed on flaw. Use to repair scuffing, dimpling, or other minor, localized flaws. Spot welding shall not be used to repair holes in the MicroDrain® liner.
   d. Removal and replacement: Remove bad seam and replace with strip of same MicroDrain® material welded into place. Use to repair large lengths of failed seams.

e. Extrusion welding flap: Repairs of this type shall not be used unless approved by QAC, and only if the flap is a minimum of 1.5 inches long. Repairs of this type shall not exceed 100 feet (30 meters) in length.

2. For each repair method:

a. Ensure surfaces are clean, dry, and prepared in accordance with specified seaming process.
b. Ensure seaming equipment used in repairing procedures meet requirements of this Specification.
c. Extend patches or caps at least 6 inches (150 millimeters) beyond edge of defect. Round corners of patches with radius of approximately 6 inches (150 millimeters).

I. Anchor Trench:

1. CONTRACTOR shall excavate anchor trenches to lines and grades shown on Contract Drawings prior to MicroDrain® placement, unless otherwise specified.
2. CONTRACTOR shall provide anchor trench with slightly rounded corners shall be provided, to avoid sharp bends in MicroDrain®.
3. INSTALLER shall provide and use plywood, boards, or other suitable materials, to permit welding machines to weld across, rather than through, anchor trenches.
4. CONTRACTOR shall dewater the completed anchor trench, to prevent ponding or softening of adjacent soils while trench is open.
5. CONTRACTOR and INSTALLER shall coordinate operations to minimize time anchor trench remains open and uncovered.
6. INSTALLER shall provide sufficient temporary ballast to prevent geosynthetics from being pulled or blown from the anchor trench.
7. CONTRACTOR and INSTALLER shall remove debris related to their respective construction activities, including temporary ballast material, from anchor trench, prior to installation of subsequent materials. The anchor trench shall be cleaned to the satisfaction of the QAC.
8. CONTRACTOR shall backfill and compact anchor trench as soon as practical after geosynthetic installation is completed. Anchor trench shall be backfilled prior to placing leachate drainage layer material. Refer to specification section 02223 "Backfill and Fill" for backfilling procedure.

3.04 FIELD QUALITY ASSURANCE AND QUALITY CONTROL

A. Visual Inspection:

1. QAC will examine seam and non-seam areas of MicroDrain® to identify defects, holes, blisters, nondispersed raw materials, and any sign of contamination by foreign matter.

B. Trial Seams:

1. Make trial seams on fragment pieces of MicroDrain® liner to verify that conditions are adequate for production seaming.
2. Make trial seams for each combination of materials to be welded (i.e., textured/smooth, smooth/smooth, textured/textured). Seamers may only weld those combinations for which they have produced acceptable trial welds. Seamers are not required to produce trial seams for material combinations they will not be welding.

3. Make trial seams at beginning of each seaming period, following restart of welding equipment, upon change of seamers, and at least once every five (5) hours, for each production seaming apparatus used that day.
4. Make trial seams using the same materials and under the under same conditions as production welding.
5. Trial seam sample shall be at least 4-feet (1.2 meters) long by 1-foot (0.3 meters) wide (after seaming) with seam centered lengthwise.
6. Cut six (6) test specimens from sample, using 1-inch (25 millimeters) wide die cutter. These specimen locations shall be selected randomly along trial seam sample by QAC. Test three (3) specimens in peel and three (3) specimens in shear, using field tensiometer. Samples shall fail in film tear bond FTB) mode. Trial seams shall meet the following minimum strengths:

Table 02598-4: Seam Strength Values for Trial Seams and Destructive Sample Testing

PROPERTY	METHOD	50 MIL HDPE MICRODRAIN LINER SPECIFIED VALUE
Shear Strength	ASTM D6392	100 lbs/in (min.)
Peel Adhesion: Fusion Extrusion	 ASTM D6392 ASTM D6392	76 lbs/in (min.) 65 lbs/in (min.)
For shear tests, sheet shall yield before failure of seam. For peel adhesion, seam separation shall not extend more than 25 percent of seam width into seam. For either test, testing shall be discontinued when sample has visually yielded. Four (4) out of 5 specimens shall meet the, or exceed, the values listed for shear and peel. The 5th specimen can be as low as 80%.		

7. If specimen fails, the INSTALLER will attempt to identify the cause of the failure (e.g., mechanical malfunction, dirt in weld). On correction of the deficiency, the seamer shall produce a second trial seam. If the second trial seam fails, the seamer shall not be permitted to weld production seams until deficiencies are corrected and two (2) consecutive successful trial welds are achieved. If mechanical failure is determined to be the cause of the second trial seam failure, the machine shall be removed from service until suitable repairs are made. The seamer shall be required to produce a passing trial seam with the replacement machine.

C. Non-destructive Seam Testing:

1. General:

a. Purpose of non-destructive tests is to check continuity of seams. It will not provide quantitative information on seam strength.
b. Non-destructively test field seams over their full length using vacuum test for extrusion seams, air pressure for double-fusion seams, or other QAC approved method. QAC shall document results.
c. Perform non-destructive testing as seaming work progresses.
d. The QAC shall observe all non-destructive testing on a full-time basis. The INSTALLER and QAC shall coordinate to ensure that all installation activities are monitored by the QAC in accordance with these Specifications.

2. Vacuum Testing for extrusion seam:

   a. Energize vacuum pump and reduce tank pressure to approximately 5 pounds per square inch [gauge] (psig) (10 inches of Hg) (35 kPa) gauge pressure.
   b. Wet strip of extrusion seam approximately 12 inches by 48 inches (0.3 m by 1.2 meters) with soapy solution.
   c. Ensure viewing window is clean.
   d. Place box over wetted area.
   e. Close bleed valve and open vacuum valve.
   f. Ensure that leak-tight seal is created.
   g. For minimum of 10 seconds, apply vacuum and examine MicroDrain® through viewing window for presence of soap bubbles.
   h. If no bubbles appear within 10 seconds, close vacuum valve and open bleed valve, move box over to next adjoining area with minimum 3-inch (75 -millimeter) overlap and repeat process.
   i. Mark and repair areas where soap bubbles appear.

3. Air Pressure Testing for dual track, hot wedge fusion weld:

   a. Seal both ends of seam to be tested. Take suitable precautions if sealing seam ends with open flame.
   b. Insert needle or other approved pressure feed device into air channel created by fusion weld.
   c. Insert protective cushion between air pump and MicroDrain®.
   d. Pressurize air channel to approximately 30 psig (206 kPa). Close valve and allow pressure to stabilize for approximately two (2) minutes.
   e. Observe air pressure 5 minutes after initial stabilization period ends. If pressure loss exceeds 4 psig or pressure does not stabilize, locate faulty area, repair, and retest.
   f. On completion of testing, cut opposite end of tested seam length to verify continuity of air channel. If air does not escape, locate blockage and retest unpressurized area. Repair cut end of air channel.
   g. Cap any seam length that cannot be successfully air pressure tested.
   h. Remove needle or other approved pressure feed device and repair hole in MicroDrain®.

4. Inaccessible Seams:

   a. Cap-strip seams that cannot be nondestructively tested.
   b. Cap-strip material shall be composed of same type and thickness MicroDrain® as MicroDrain® to be capped.
   c. Examine cap-stripping operations with QAC for uniformity and completeness. Document observations.

D. Destructive Seam Testing:

1. General:

   a. Purpose of destructive seam testing to evaluate seam strength.
   b. Perform destructive seam test as seaming progresses.
   c. The destructive seam sample shall fail if the overlap is insufficient for grips of testing machine to close on sample (available flap is 1/2 inch long or less).

2. Location and frequency:

   a. Test at minimum frequency of one (1) test location per 500 feet (150 meters) of welding length performed by each welding machine. This minimum frequency to be determined as an average taken from the total linear footage of seaming, per machine, at the end of the MicroDrain® installation.
   b. Test locations shall be determined by the QAC, during seaming operations.
   c. INSTALLER will not be informed in advance of locations where seam samples will be taken.
   d. QAC reserves right to increase frequency of testing in accordance with performance results of samples previously tested.

3. Sampling Procedures:

   a. Cut samples at locations selected by QAC.
   b. QAC shall number each sample and record sample number and location in panel layout drawing.
   c. QAC shall mark each section of destructive test sample with sample number, seam number, seamer and machine identification, and date.
   d. Repair holes in MicroDrain® resulting from destructive seam sampling as soon as possible, in accordance with repair procedures described in this Section.
   e. Non-destructively test repairs in accordance with this Section.

4. Sample Dimensions:

   a. Field Testing: Cut two (2) 1-inch (25 millimeters) wide sample coupons, from each end of seam section identified by QAC. Distance between these two (2) samples shall be approximately 42 inches (1.1 meters). Test both samples in peel mode, using field tensiometer. If both samples meet requirements of Table 4 located in Section 3.04 B item 6, collect sample for laboratory testing.
   b. Laboratory Testing: Collect laboratory test sample from seam length between field test sample coupon locations. Cut sample for laboratory testing, approximately 12 inches (0.3 meters) wide by a minimum 42-inches (1.1 meters) long, with seam centered lengthwise. Cut this sample into three (3) sections. QAC shall distribute sample sections as follows:

      1) Geosynthetic Quality Assurance Laboratory: minimum 18-inch (0.5 meters) long section for laboratory testing.
      2) INSTALLER: minimum 12 inches (0.3 meters) long section for archive or optional laboratory testing.
      3) QAC: minimum 12 inches (0.3 meters) long section for archive storage.

   c. Final determination of sample sizes shall be agreed upon at the geosynthetics kick-off meeting. Sample sizes shall be minimized, consistent with laboratory testing requirements.
   d. Submit laboratory sample for quantitative testing in accordance with the CQA Plan.

5. Destructive Test Failure Procedures:

When sample fails destructive testing, whether test is conducted in the field or at Geosynthetic Quality Assurance Laboratory, CONTRACTOR has following options:

a. Repair entire seam between two (2) passing destructive test locations along the path of machine producing the failed weld bracketing the failed location.
b. Trace welding path 10-feet (3 meters) minimum in each direction from failed test, and repeat field testing procedures indicated in this Section at each location. If these additional samples pass field test, then collect laboratory test samples. If these laboratory samples pass tests, repair seam between these locations. If either, or both, sample fails, repeat process until passing sample is located. If necessary, tracking will extend back to previous days of welding until a passing sample is located. Repair seam between passing destructive sample locations.
c. Acceptable repaired seams shall be bound by passing laboratory destructive tests locations. The QAC shall mark and additional destructive test sample for seam cap strip repairs of 150 feet (45 meters) or more.
d. If a destructive test sample fails, QAC may require additional testing of seams welded by same seamer and/or welding apparatus produced during same time shift as failed seam.

E. Repair Verification:

1. Repairs shall be non-destructively tested.
2. Nondestructive test results that pass shall indicate adequate repair.
3. Destructive test samples shall be collected on repairs 100-feet long, or greater. Frequency may be increased at the discretion of the QAC.
4. In the event destructive or nondestructive tests of repairs fail to meet the requirements of this Section, the work will be redone, at no expense to the OWNER, until passing test results are achieved.
5. QAC shall monitor and document MicroDrain® repairs, and non-destructive testing.

F. Large Wrinkles: Wrinkle is considered to be large when MicroDrain® can be folded over onto itself during the coolest part of the day.

1. When seaming of MicroDrain® is completed, and prior to placing overlying materials, QAC shall identify all large MicroDrain® wrinkles, to be repaired.
2. Cut and repair all wrinkles identified by QAC. Welds produced while repairing wrinkles shall be nondestructively tested.
3. Repair wrinkles identified by QAC. Repair during coldest part of installation period.

*****END OF SECTION*****

SECTION 02599

LINEAR LOW DENSITY POLYETHYLENE (LLDPE) MICRODRAIN® LINER

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools, and appurtenances required to complete the work of the installation of linear low density polyethylene (LLDPE) MicroDrain® Liner for the ash landfill closure cap and other related and incidental work within the designated area and as required for the construction of other work, as shown, specified, or required. CONTRACTOR shall provide a "Competent Person" to implement and supervise all work.

B. Comply with applicable codes, ordinances, rules, regulations, and laws of local, municipal, State, or Federal authorities having jurisdiction.

1.02 SUBMITTALS

A. Pre-installation: CONTRACTOR shall submit the following prior to MicroDrain® deployment:

1. Origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture MicroDrain®.
2. Copies of dated quality control certificates issued by resin supplier.
3. Results of tests conducted by MicroDrain® manufacturer to verify that resin used to manufacture MicroDrain® meets Specifications.
4. Statement that amount of reclaimed polymer added to resin during manufacturing did not exceed 2% by weight.
5. List of materials that comprise MicroDrain®, expressed in following categories as percent by weight:
    a. polyethylene;
    b. carbon black; and,
    c. other additives.
6. Manufacturer's specification for MicroDrain®, including properties listed and measured using appropriate test methods.
7. Written certification that minimum values given in manufacturer's specification are guaranteed by MicroDrain® manufacturer.
8. Quality control certificates, signed by MicroDrain® manufacturer. Each quality control certificate shall include applicable roll identification numbers, testing procedures, and results of quality control tests.
9. Field panel layout and identification code including dimensions and details.
10. Resumes of INSTALLER's Superintendent and Master Seamer, including dates and duration of employment.
11. Installation schedule.
12. List of personnel performing seaming operations, including experience information.
13. Certificate that extrusion rod is comprised of same resin as MicroDrain® liner material.
14. Manufacturer Material and Installation warranties.

B. Installation: Submit as installation proceeds.

1. Quality control documentation recorded during installation.
2. Subgrade surface acceptance certificates signed by INSTALLER for each area that will be covered directly by MicroDrain®. Submit on deployment of MicroDrain®.
3. Deployment of MicroDrain® will be considered acceptance of subgrade by the INSTALLER, if certificate is not submitted.

1.03 PRE-QUALIFICATIONS

A. Manufacturer

Manufacturer shall have minimum 5 years continuous experience in manufacture of LLDPE MicroDrain®, or experience totaling 10,000,000 square feet (sq. ft.) of manufactured LLDPE, or MicroDrain® manufacture for minimum of ten (10) completed facilities.

B. Installer

1. Installer shall have minimum 5 years continuous experience in installation of LLDPE MicroDrain® or experience totaling 2,000,000 sq. ft. of installed LLDPE MicroDrain® for minimum of five (5) completed facilities.

2. Personnel performing seaming operations shall be qualified by experience or training. Minimum of one seamer shall have experience seaming minimum 2,000,000 sq. ft. of LLDPE MicroDrain® using same type of seaming apparatus in use at Site. Most experienced seamer, "Master Seamer," shall provide direct supervision, as required, over less experienced seamers.

1.04 QUALITY ASSURANCE PROGRAM

Manufacturer, fabricator, and installer shall participate in and conform to items and requirements of quality assurance program as outlined in this Section and the Construction Quality Assurance (CQA) Plan.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping

1. Manufacturer shall identify each roll delivered to Site with the following:

a. Manufacturer's name.
b. Product Identification.
c. Thickness.
d. Roll number.
e. Roll dimensions.

2. Protect MicroDrain® from excessive mud, dirt, puncture, cutting, or other damaging or deleterious conditions during loading, transport, and unloading at Site.

B. Acceptance at Site

1. INSTALLER shall be responsible for unloading all geosynthetics delivered to the Site, unless otherwise agreed at the geosynthetics kick-off meeting.
2. Shipper shall notify INSTALLER, or other party responsible for off-loading materials, 48-hours in advance of material delivery.
3. INSTALLER, or other party responsible for off-loading materials, shall bear all costs (including but not limited to QUALITY ASSURANCE CONSULTANT (QAC), 3rd party contractor costs) associated with failure to supply appropriate personnel and equipment required to off-load geosynthetic materials.
4. Perform physical inventory of materials delivered to the Site for use in the work. Perform inventory on delivery, or as soon as practicable thereafter.
5. Conduct surface observations of each roll for defects and damage. This examination shall be conducted without unrolling rolls, unless defects or damages are found or suspected. Note type and extent of defects or damage observed.
6. Defective or damaged rolls, or portions of rolls, will be rejected and shall be removed from Site and replaced, at no additional expense to the OWNER.
7. Rolls or portions of rolls without proper identification or labeling will be rejected and shall be removed from Site.

C. Storage and Protection

1. The MicroDrain® will be unloaded, transported, stored, and protected in accordance with the manufacturers' recommendations so as not to damage or degrade the properties of the material.
2. QAC will provide on-Site storage area for MicroDrain® rolls from time of delivery until deployment.
3. INSTALLER shall protect MicroDrain® from dirt, water, and other sources of damage.
4. Preserve integrity and readability of MicroDrain® roll labels.

PART 2 – PRODUCTS

2.01 MATERIALS

The MicroDrain® used for the ash landfill closure cap area is a linear low density polyethylene (LLDPE) 50-mil liner manufactured by Agru-America. The MicroDrain® shall meet the following properties:

Table 02599-1: Minimum Properties 50-mil LLDPE MicroDrain® Liner

Testing Properties	Testing Method	50 mil LLDPE Value
Thickness, mils (min. avg.) Thickness, mils (lowest individual)	ASTM D5994	47.5 42.5
Density g/cc	ASTM D1505 or ASTM D792	0.940 (min. avg.) (either method)
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	20 mils
Drainage Stud Height (min. avg.)	ASTM D7466	130 mils
Transmissivity – Machine Direction MD (min. avg.) (11)	ASTM D4716	8.0 x 10^{-4} m^2/s for i=0.14
Direct Shear (Friction Angle) – degrees (min)	ASTM D5321	19 degrees

Testing Properties	Testing Method	50 mil LLDPE Value
Tensile Properties (min. avg.) [3] • break strength, lb/in • break elongation,%	ASTM D6693	105 300
Tear Resistance – lb (min. avg.)	ASTM D1004	30
Puncture Resistance – lb (min. avg.)	ASTM D4833	55
Stress Crack Resistance [10]	ASTM D5397 [10] (Appendix)	500
Carbon Black Content - %	ASTM D1603 [4]	2.0 to 3.0
Carbon Black Dispersion	ASTM D 5596	Note [5]
Oxidative Induction Time (OIT) (min. avg.) [6] • Standard OIT	ASTM D3895	≥100
Melt Flow Index, g/10 minutes	ASTM D1238	≤1
Oven Aging at 85°C [7] • High Pressure OIT (min. avg.), % retained after 90 days	ASTM D5721 ASTM D5885	80
UV Resistance [8] • High Pressure OIT (min. avg.) % retained after 1600 hrs[9]	ASTM D5885	50
2% Secant Modulus (max), lb/in	ASTM D5323	3000
Axi-Symmetric Break Resistance Strain, % (min.)	ASTM D5617	30

Notes:

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet. Both sides are to be measured and considered separately.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed in GRI GM-13 to evaluate the antioxidant content in the MicroDrain®

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hour UV cycle at 75°C followed by 4 hour condensation at 60°C.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

(10) The SP-NCTL test is not appropriate for testing MicroDrain®s with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.

(11) Conduct test for Transmissivity at a normal compressive load of 500 pounds per square feet (psf) and at a hydraulic gradient of 0.14 (top of final grade surface). Boundary conditions from top to bottom are: upper load plate/ soil / nonwoven geotextile / geomembrane / lower load plate. Seating period shall be at least 100 hours to meet design criteria, and one (1) hour to meet conformance criteria.

A MicroDrain® shall be manufactured from new polyethylene resin, except as noted below:

1. Use of MicroDrain® recycled during manufacturing process shall be permitted, with written approval from QAC, if recycled MicroDrain® does not exceed 2% by weight.
2. MicroDrain® manufactured from non-complying resin shall be rejected.

B. MicroDrain® Characteristics

1. Contain maximum of 1%, by weight, of additives, fillers or extenders (not including carbon black).
2. Contain between 2% and 3%, by weight, of carbon black for ultraviolet light resistance.
3. No pinholes, bubbles or other surface features that compromise MicroDrain® integrity are allowed. MicroDrain® shall be free of blisters, nondispersed raw materials, or other signs of contamination resulting from the manufacturing process. MicroDrain® rolls or portions of rolls with these defects shall be rejected.

C. Geotextile Characteristics

1. The geotextile used to cover the MicroDrain® ash landfill closure cap shall be as shown on the Construction Drawings and meet the requirements of Section 02595.
2. Geotextiles will be generally aligned with seams parallel to the prevailing slope and HEAT TREATED side of the geotextile to be face down in contact with the MicroDrain® and can be seamed by either heat seaming with an approved hand held or self motivated thermal device or by sewing with a stitching approved by the QAC. Whichever stitching method is used the thread should be compatible with the fabric and have similar chemical resistance to the liner that is being used.
3. Any holes, tears, or burn throughs from thermal seaming in geotextiles will be repaired by patching with the same geotextiles. The patch will be a minimum of twelve inches larger in all directions than the area to be repaired and will be spot bonded thermally.
4. The CONTRACTOR shall protect the work described in this Section before, during, and after installation, and shall protect the installed work covered by other Sections.

2.02 SEAMING AND TESTING EQUIPMENT

A. Welding

1. Maintain on-Site minimum of two (2) spare operable seaming machines, unless otherwise agreed upon at pre-construction meeting.
2. Seaming equipment shall not damage MicroDrain®.
3. Use extrusion welding apparatus equipped with gauges indicating temperature of extrudate at the equipment nozzle, or utilize hand-held gauges to measure extrudate temperatures.
4. Use self-propelled fusion-welding machines equipped with following:

    a. Gauge indicating temperature of heating element; and,
    b. Gauge indicating the speed of travel.

5. Place electric generator on smooth base such that no damage occurs to MicroDrain®.

B. Vacuum Testing Equipment

1. Vacuum box assembly shall consist of a rigid housing open at the bottom, with a transparent viewing window and soft neoprene gasket attached to bottom rim of housing, a porthole or valve assembly, and a vacuum gauge;
2. Pump assembly equipped with pressure controller and pipe connections;
3. Pressure/vacuum rubber hose with fittings and connections;
4. Soapy solution to wet test area; and,
5. Means of applying soapy solution.

C. Air Pressure Testing Equipment

1. Air pump (manual or motor driven), equipped with pressure gauge, capable of generating, sustaining, and measuring pressure between 24 and 35 pounds per square inch (psi) (165 and 240 kilopascals (kPa)), and mounted on cushion to protect MicroDrain®;
2. Rubber hose with fittings and connections;
3. Means of safely sealing weld air channel;
4. Sharp hollow needle, or other approved pressure feed device; and,
5. Air pressure monitoring device.

D. Tensiometer

1. Tensiometer shall be capable of maintaining constant jaw separation rate of 2-inches per minute; and,
2. Tensiometer shall be calibrated annually. A certificate indicating that the equipment has been calibrated within one (1) year of use in the work shall be maintained with the tensiometer. The INSTALLER will provide the QAC with a copy of the certificate of calibration.

2.03 SOURCE QUALITY CONTROL

Tests and inspections shall be performed by MicroDrain® manufacturer as follows:

A. Test MicroDrain® to demonstrate that resin meets this Specification.

B. Continuously monitor MicroDrain® during manufacturing process for inclusions, bubbles, or other defects. MicroDrain®, which exhibit defects, shall not be acceptable for installation.

C. Monitor thickness continuously during manufacturing process.

D. The MANUFACTURER shall conduct quality control (QC) testing to verify conformance with Table 02599-1 in section 2.01, at the following frequencies:

Table 02599-2: Quality Control (QC) Manufacturers Testing

Testing Properties	Testing Method	Manufacturer QC Testing Frequency
Thickness mils (min. avg.)	ASTM D 5994	1 per Roll
Density g/cc	ASTM D1505 or ASTM D792	1 per 50,000 SF
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	1 per 50,000 SF
Drainage Stud Height (min. avg.)	ASTM D7466	1 per 50,000 SF
Transmissivity	ASTM D4716	1 per 200,000 SF
Tensile Properties (min. avg.) (3)	ASTM D6693	1 per 50,000 SF
Tear Resistance – lb (min. avg.)	ASTM D1004	1 per 50,000 SF
Puncture Resistance – lb (min. avg.)	ASTM D4833	1 per 50,000 SF
Stress Crack Resistance (12)	ASTM D5397	per GRI GM10
Melt Flow Index, g/10 minutes	ASTM D1238	1 per 200,000 lbs
Low Temperature Brittleness	ASTM 746	1 per 200,000 lbs
Carbon Black Content - %	ASTM D1603 (4)	1 per 50,000 SF
Carbon Black Dispersion(5)	ASTM D 5596	1 per 50,000 SF
Oxidative Induction Time (OIT) (min. avg.) (6) • Standard OIT, or • High Pressure OIT	ASTM D3895 ASTM D5885	(11)
Oven Aging at 85°C (7) • Std. OIT (min. avg.), % retained after 90 days or • High Pressure OIT (min. avg.), % retained after 90 days	ASTM D5721 ASTM D3895 ASTM D5885	(11)
UV Resistance (8) • Std. OIT (min. avg.)(9), or • High Pressure OIT (min. avg.) % retained after 1600 hours(10)	ASTM D3895 ASTM D5885	(11)
2% Secant Modulus, lb/in (max.)	ASTM D5323	Per resin formulation
Axi-Symmetric Break Resistance Strain, % (min.)	ASTM D5617	Per resin formulation

Notes:

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet. Both sides are to be measured and considered separately.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3
(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the MicroDrain®.
(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(8) The condition of the test should be 20 hour UV cycle at 75℃ followed by 4 hour condensation at 60℃.
(9) Not recommended since high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.
(11) Manufacturer may provide a certification letter.
(12) The SP-NCTL test is not appropriate for testing MicroDrain®s with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.

PART 3 – EXECUTION

3.01 QUALITY ASSURANCE SAMPLING AND TESTING

A. Upon delivery of the material to the Site, the QAC shall obtain conformance test samples from selected MicroDrain®. INSTALLER shall make rolls available and assist QAC in obtaining material inventory and samples. Samples shall be tested in accordance with Table 02599-1 in section 2.01,at the following frequencies:

Table 02599-3: Quality Assurance (QA) Conformance Testing

Testing Properties	Testing Method	Conformance QA Testing Frequency
Thickness mils (min. avg.)	ASTM D5994	1 per 200,000 SF*
Density g/cc	ASTM D1505 or ASTM D792	1 per 200,000 SF*
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	1 per 200,000 SF*
Drainage Stud Height (min. avg.)	ASTM D7466	1 per 200,000 SF*
Transmissivity	ASTM D4716	1 per 200,000 SF*
Tensile Properties (min. avg.) (3)	ASTM D6693	1 per 200,000 SF*
Tear Resistance – lb (min. avg.)	ASTM D1004	1 per 200,000 SF*
Puncture Resistance – lb (min. avg.)	ASTM D4833	1 per 200,000 SF*
Stress Crack Resistance (7)	ASTM D5397	N/A
Carbon Black Content - %	ASTM D1603 (4)	1 per 200,000 SF*
Carbon Black Dispersion(5)	ASTM D5596	1 per 200,000 SF*
Direct Shear (Friction Angle) – degrees (min)(6)	ASTM D5321	1 per Lot

Notes:
(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils
(2) Alternate the measurement side for double sided textured sheet.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.
(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
**- Or minimum 1 per lot.*
(6) Direct shear testing shall be performed by the CONTRACTOR on the entire liner system cross section using the proposed liner system materials (i.e. cover soil, geocomposite, geomembrane, geotextile, and grading fill). The testing shall be performed at normal stresses of 100 psf, 250 psf, and 500 psf.
(7) The SP-NCTL test is not appropriate for testing MicroDrain®s with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.

B. Rolls represented by quality assurance testing shall be rejected if test failure occurs. INSTALLER may at their expense request additional testing to validate individual rolls. Rolls bracketed by passing tests may be used in the work.

3.02 SURFACE PREPARATION

A. CONTRACTOR is responsible for preparing subgrade surface for MicroDrain® placement.

B. After prepared subgrade surface has been accepted in accordance with CQA Plan, report to QAC any change in subgrade surface condition that may require repair work. Maintain prepared surface.

C. Do not place MicroDrain® onto an area that has become degraded due to weather conditions. Observe and report surface condition daily to evaluate suitability for MicroDrain® deployment.

D. Repair damage to prepared surface caused by installation activities at INSTALLER'S expense.

3.03 INSTALLATION

A. Panel Nomenclature

1. Field panel is defined as a roll or portion of roll cut and seamed in field, excluding patches and cap strips.
2. Identify each field panel with a unique identification code (number or letter-number). This identification code shall be agreed upon by INSTALLER and QAC.
3. The INSTALLER shall be responsible for marking the panel and roll number on the MicroDrain®.

B. Protection

1. Do not use equipment that damages MicroDrain®;
2. Ensure subgrade surface underlying MicroDrain® has not deteriorated since previous acceptance, and remains acceptable immediately prior to and during MicroDrain® deployment;
3. Keep geosynthetic elements immediately underlying MicroDrain® clean and free of debris;

4. Do not permit personnel to smoke or wear shoes that can damage MicroDrain® while working on MicroDrain®. Personnel shall not bring glass or metal containers on MicroDrain®, except as required to perform the work;
5. Unroll panels in manner that does not cause excessive scratches or crimps in MicroDrain® and does not damage supporting soil;
6. Place panels in manner that minimizes wrinkles (especially differential wrinkles between adjacent panels);
7. Prevent wind uplift by providing adequate temporary loading and/or anchoring (e.g., sandbags) that shall not damage MicroDrain®. In case of high winds, continuous loading is recommended along panel edges; and,
8. Protect MicroDrain® in areas where excessive traffic is expected, using geotextiles, extra MicroDrain®, or other suitable materials.
9. The CONTRACTOR must protect the work described in this section before, during, and after installation.
10. Unless otherwise specified by the QAC, all equipment for spreading fill materials overlying the geosynthetics shall comply with the following:

Maximum Equipment Ground Pressure (psi)	Minimum Separation Thickness (inches)
<5	12
5 – 10	24
>10	36

11. No equipment shall be placed directly on the geomembrane during installation. Rub sheets shall be used beneath equipment to protect the geomembrane from equipment damage.

C. Field Panel Deployment

1. Install field panels at locations indicated on INSTALLER's layout plan to the greatest extent possible.
2. Replace seriously damaged (torn, twisted or crimped) field panels, or portions thereof, at no cost to OWNER. Repair less serious damage as specified herein. QAC shall determine if material shall be repaired or replaced.
3. Remove from work area damaged panels, or portions of panels, that have been rejected by the QAC.
4. Do not proceed with deployment at ambient temperature below 32°F (0°C) or above 104°F (40°C) unless authorized, in writing, by QAC.
5. Do not deploy during precipitation, in presence of excessive moisture, (i.e., fog, dew, etc.), in areas of ponded water, or in presence of excessive winds.
6. Do not undertake deployment if weather conditions will preclude material seaming on same day as deployment.
7. Do not deploy more MicroDrain® field panels in one day than can be seamed during that day.

D. Seam Layout

1. Orient seams parallel to line of maximum slope (i.e., oriented along, not across, slope).
2. No horizontal seams will be permitted on the slope.
3. No horizontal seam shall be less than 5 feet (1.5 meters) from toe of slope, unless approved by the QAC.
4. In general, maximize lengths of field panels and minimize number of field seams.

5. Align MicroDrain® panels to have nominal overlap of 3 inches (75 millimeters) for extrusion welding and 4 to 6 inches (100 to 150 millimeters) for fusion welding. Final overlap shall be sufficient to allow destructive "peel" tests to be performed on seam.

E. Temporary Bonding

1. Hot air device (Leister) may be used to temporarily bond MicroDrain® panels to be extrusion welded.
2. Do not damage MicroDrain® when temporarily bonding adjacent panels. Apply minimal amount of heat required to lightly tack MicroDrain® panels together. Control temperature of hot air at nozzle of any temporary welding apparatus to prevent damage to MicroDrain®.
3. Do not use solvent or adhesive.

F. Seaming Methods

1. Approved processes for field seaming are extrusion fillet welding and fusion welding. Proposed alternate processes shall be documented and submitted to QAC for approval. Alternate procedures shall be used only after being approved in writing by QAC.
2. Use fusion welding as primary method of seaming adjacent field panels.

    a. Cross seam "tees", associated with fusion or extrusion seam welding, shall be patched in accordance with the requirements of this Section.
    b. Place welder on protective pad to prevent MicroDrain® damage when not in use.
    c. When subgrade conditions dictate, use movable protective layer (e.g. MicroDrain® rub sheet) directly below each overlap of MicroDrain® that is to be seamed to prevent buildup of moisture between sheets and prevent debris from collecting around pressure rollers. Rub sheet shall be removed from under the liner once seaming is complete.

3. Use extrusion fillet welding as secondary method for seaming between adjacent panels and as primary method of welding for detail and repair work.

    a. Purge heat-degraded extrudate from barrel of extruder
    b. Place smooth insulating plate or fabric beneath hot welding apparatus when not in use
    c. Use clean and dry welding rods or extrudate pellets.
    d. Clean dirt and debris from MicroDrain® surface prior to extrusion welding.
    e. Grind weld area to using suitable hand held equipment to prepare MicroDrain® surface for extrusion welding. Grind perpendicular to seam. Take care not to over-grind MicroDrain®
    f. Minimize exposed grinding marks adjacent to extrusion weld. Do not allow exposed grinding marks to extend more than 1/4-inch outside finished seam area.
    g. Complete extrusion welding within one (1) hour of seaming operation grinding process without damaging MicroDrain®

G. Seaming Procedures

1. General Seaming Procedures - Ambient temperature between 32°F (0°C) and 104°F (40°C).

   a. Do not field seam without Master Seamer being present.
   b. Seam only during dry conditions, i.e., no precipitation or other excessive moisture, such as fog or dew.
   c. Do not seam during excessive winds, except as needed to protect the work. Do not seam if wind creates unsafe working conditions.
   d. If required, use “rub-sheet” or similar hard surface directly under seam overlap to achieve proper support for seaming apparatus.
   e. Align panels to minimize wrinkles and/or “fishmouths” in welds.
   f. Extend seams to outside edge of panels placed in anchor trench.
   g. Prior to seaming, ensure that seam area is free of moisture, dust, dirt, debris, or foreign material.
   h. “Fishmouths” or wrinkles at seam overlaps shall be cut along ridge of wrinkle in order to achieve flat overlap. Cut “fishmouths” or wrinkles shall be seamed or patched in accordance with this Section.

2. Cold Weather Seaming Procedures (ambient temperature is below 32°F (0°C)).

   a. No seaming of MicroDrain® is permitted unless demonstrated to QAC that MicroDrain® seam quality will not be compromised.
   b. Additional destructive samples and/or field test strips shall be cut from seams welded under ambient temperature of 32°F (0°C), at QAC’s discretion.

3. Warm Weather Procedures (ambient temperature is above 104°F (40°C)).

   a. No seaming of MicroDrain® is permitted unless demonstrated to QAC that MicroDrain® seam quality will not be compromised.
   b. Additional destructive samples and/or field test strips shall be cut from seams welded over ambient temperature of 104°F (40°C), at QAC’s discretion.

H. Repair Procedures:

1. Acceptable repair procedures include following:

   a. Patching: Piece of same MicroDrain® material extrusion welded into place. Use to repair large holes, tears, nondispersed raw materials, and contamination by foreign matter. All panel intersections shall be patched.
   b. Capping: Strip of same MicroDrain® material extrusion welded into place over inadequate seam. Use to repair large lengths of failed seams.
   c. Spot welding or seaming (Grind and Weld): Bead of molten extrudate placed on flaw. Use to repair scuffing, dimpling, or other minor, localized flaws. Spot welding shall not be used to repair holes in the MicroDrain® liner.
   d. Removal and replacement: Remove bad seam and replace with strip of same MicroDrain® material welded into place. Use to repair large lengths of failed seams.

e. Extrusion welding flap: Repairs of this type shall not be used unless approved by QAC, and only if the flap is a minimum of 1.5 inches long. Repairs of this type shall not exceed 100 feet (30 meters) in length.

2. For each repair method:

a. Ensure surfaces are clean, dry, and prepared in accordance with specified seaming process.
b. Ensure seaming equipment used in repairing procedures meet requirements of this Specification.
c. Extend patches or caps at least 6 inches (150 millimeters) beyond edge of defect. Round corners of patches with radius of approximately 6 inches (150 millimeters).

I. Anchor Trench:

1. CONTRACTOR shall excavate anchor trenches to lines and grades shown on Contract Drawings prior to MicroDrain® placement, unless otherwise specified.
2. CONTRACTOR shall provide anchor trench with slightly rounded corners shall be provided, to avoid sharp bends in MicroDrain®.
3. INSTALLER shall provide and use plywood, boards, or other suitable materials, to permit welding machines to weld across, rather than through, anchor trenches.
4. CONTRACTOR shall dewater the completed anchor trench, to prevent ponding or softening of adjacent soils while trench is open.
5. CONTRACTOR and INSTALLER shall coordinate operations to minimize time anchor trench remains open and uncovered.
6. INSTALLER shall provide sufficient temporary ballast to prevent geosynthetics from being pulled or blown from the anchor trench.
7. CONTRACTOR and INSTALLER shall remove debris related to their respective construction activities, including temporary ballast material, from anchor trench, prior to installation of subsequent materials. The anchor trench shall be cleaned to the satisfaction of the QAC.
8. CONTRACTOR shall backfill and compact anchor trench as soon as practical after geosynthetic installation is completed. Anchor trench shall be backfilled prior to placing leachate drainage layer material. Refer to specification section 02223 “Backfill and Fill” for backfilling procedure.

3.04 FIELD QUALITY ASSURANCE AND QUALITY CONTROL

A. Visual Inspection:

1. QAC will examine seam and non-seam areas of MicroDrain® to identify defects, holes, blisters, nondispersed raw materials, and any sign of contamination by foreign matter.

B. Trial Seams:

1. Make trial seams on fragment pieces of MicroDrain® liner to verify that conditions are adequate for production seaming.
2. Make trial seams for each combination of materials to be welded (i.e., textured/smooth, smooth/smooth, textured/textured). Seamers may only weld those combinations for which they have produced acceptable trial welds. Seamers are not required to produce trial seams for material combinations they will not be welding.

3. Make trial seams at beginning of each seaming period, following restart of welding equipment, upon change of seamers, and at least once every five (5) hours, for each production seaming apparatus used that day.
4. Make trial seams using the same materials and under the under same conditions as production welding.
5. Trial seam sample shall be at least 4-feet (1.2 meters) long by 1-foot (0.3 meters) wide (after seaming) with seam centered lengthwise.
6. Cut six (6) test specimens from sample, using 1-inch (25 millimeters) wide die cutter. These specimen locations shall be selected randomly along trial seam sample by QAC. Test three (3) specimens in peel and three (3) specimens in shear, using field tensiometer. Samples shall fail in film tear bond (FTB) mode. Trial seams shall meet the following minimum strengths:

Table 02599-4: Seam Strength Values for Trial Seams and Destructive Sample Testing

PROPERTY	METHOD	50 MIL LLDPE MICRODRAIN LINER SPECIFIED VALUE
Shear Strength	ASTM D6392	75 lbs/in (min.)
Peel Adhesion: Fusion Extrusion	ASTM D6392 ASTM D6392	63 lbs/in (min.) 57 lbs/in (min.)
For shear tests, sheet shall yield before failure of seam. For peel adhesion, seam separation shall not extend more than 25 percent of seam width into seam. For either test, testing shall be discontinued when sample has visually yielded. Four (4) out of 5 specimens shall meet the, or exceed, the values listed for shear and peel. The 5th specimen can be as low as 80%.		

7. If specimen fails, the INSTALLER will attempt to identify the cause of the failure (e.g., mechanical malfunction, dirt in weld). On correction of the deficiency, the seamer shall produce a second trial seam. If the second trial seam fails, the seamer shall not be permitted to weld production seams until deficiencies are corrected and two (2) consecutive successful trial welds are achieved. If mechanical failure is determined to be the cause of the second trial seam failure, the machine shall be removed from service until suitable repairs are made. The seamer shall be required to produce a passing trial seam with the replacement machine.

C. Non-destructive Seam Testing:

1. General:

a. Purpose of non-destructive tests is to check continuity of seams. It will not provide quantitative information on seam strength.
b. Non-destructively test field seams over their full length using vacuum test for extrusion seams, air pressure for double-fusion seams, or other QAC approved method. QAC shall document results.
c. Perform non-destructive testing as seaming work progresses.
d. The QAC shall observe all non-destructive testing on a full-time basis. The INSTALLER and QAC shall coordinate to ensure that all installation activities are monitored by the QAC in accordance with these Specifications.

2. Vacuum Testing for extrusion seam:

   a. Energize vacuum pump and reduce tank pressure to approximately 5 pounds per square inch [gauge] (psig) (10 inches of Hg) (35 kPa) gauge pressure.
   b. Wet strip of extrusion seam approximately 12 inches by 48 inches (0.3 m by 1.2 meters) with soapy solution.
   c. Ensure viewing window is clean.
   d. Place box over wetted area.
   e. Close bleed valve and open vacuum valve.
   f. Ensure that leak-tight seal is created.
   g. For minimum of 10 seconds, apply vacuum and examine MicroDrain® through viewing window for presence of soap bubbles.
   h. If no bubbles appear within 10 seconds, close vacuum valve and open bleed valve, move box over to next adjoining area with minimum 3-inch (75 -millimeter) overlap and repeat process.
   i. Mark and repair areas where soap bubbles appear.

3. Air Pressure Testing for dual track, hot wedge fusion weld:

   a. Seal both ends of seam to be tested. Take suitable precautions if sealing seam ends with open flame.
   b. Insert needle or other approved pressure feed device into air channel created by fusion weld.
   c. Insert protective cushion between air pump and MicroDrain®.
   d. Pressurize air channel to approximately 30 psig (206 kPa). Close valve and allow pressure to stabilize for approximately two (2) minutes.
   e. Observe air pressure 5 minutes after initial stabilization period ends. If pressure loss exceeds 4 psig or pressure does not stabilize, locate faulty area, repair, and retest.
   f. On completion of testing, cut opposite end of tested seam length to verify continuity of air channel. If air does not escape, locate blockage and retest unpressurized area. Repair cut end of air channel.
   g. Cap any seam length that cannot be successfully air pressure tested.
   h. Remove needle or other approved pressure feed device and repair hole in MicroDrain®.

4. Inaccessible Seams:

   a. Cap-strip seams that cannot be nondestructively tested.
   b. Cap-strip material shall be composed of same type and thickness MicroDrain® as MicroDrain® to be capped.
   c. Examine cap-stripping operations with QAC for uniformity and completeness. Document observations.

D. Destructive Seam Testing:

1. General:

   a. Purpose of destructive seam testing to evaluate seam strength.
   b. Perform destructive seam test as seaming progresses.
   c. The destructive seam sample shall fail if the overlap is insufficient for grips of testing machine to close on sample (available flap is 1/2 inch long or less).

2. Location and frequency:

   a. Test at minimum frequency of one (1) test location per 500 feet (150 meters) of welding length performed by each welding machine. This minimum frequency to be determined as an average taken from the total linear footage of seaming, per machine, at the end of the MicroDrain® installation.
   b. Test locations shall be determined by the QAC, during seaming operations.
   c. INSTALLER will not be informed in advance of locations where seam samples will be taken.
   d. QAC reserves right to increase frequency of testing in accordance with performance results of samples previously tested.

3. Sampling Procedures:

   a. Cut samples at locations selected by QAC.
   b. QAC shall number each sample and record sample number and location in panel layout drawing.
   c. QAC shall mark each section of destructive test sample with sample number, seam number, seamer and machine identification, and date.
   d. Repair holes in MicroDrain® resulting from destructive seam sampling as soon as possible, in accordance with repair procedures described in this Section.
   e. Non-destructively test repairs in accordance with this Section.

4. Sample Dimensions:

   a. Field Testing: Cut two (2) 1-inch (25 millimeters) wide sample coupons, from each end of seam section identified by QAC. Distance between these two (2) samples shall be approximately 42 inches (1.1 meters). Test both samples in peel mode, using field tensiometer. If both samples meet requirements of Table 4 located in Section 3.04 B item 6, collect sample for laboratory testing.
   b. Laboratory Testing: Collect laboratory test sample from seam length between field test sample coupon locations. Cut sample for laboratory testing, approximately 12 inches (0.3 meters) wide by a minimum 42-inches (1.1 meters) long, with seam centered lengthwise. Cut this sample into three (3) sections. QAC shall distribute sample sections as follows:

      1) Geosynthetic Quality Assurance Laboratory: minimum 18-inch (0.5 meters) long section for laboratory testing.
      2) INSTALLER: minimum 12 inches (0.3 meters) long section for archive or optional laboratory testing.
      3) QAC: minimum 12 inches (0.3 meters) long section for archive storage.

   c. Final determination of sample sizes shall be agreed upon at the geosynthetics kick-off meeting. Sample sizes shall be minimized, consistent with laboratory testing requirements.
   d. Submit laboratory sample for quantitative testing in accordance with the CQA Plan.

5. Destructive Test Failure Procedures:

   When sample fails destructive testing, whether test is conducted in the field or at Geosynthetic Quality Assurance Laboratory, CONTRACTOR has following options:

   a. Repair entire seam between two (2) passing destructive test locations along the path of machine producing the failed weld bracketing the failed location.
   b. Trace welding path 10-feet (3 meters) minimum in each direction from failed test, and repeat field testing procedures indicated in this Section at each location. If these additional samples pass field test, then collect laboratory test samples. If these laboratory samples pass tests, repair seam between these locations. If either, or both, sample fails, repeat process until passing sample is located. If necessary, tracking will extend back to previous days of welding until a passing sample is located. Repair seam between passing destructive sample locations.
   c. Acceptable repaired seams shall be bound by passing laboratory destructive tests locations. The QAC shall mark and additional destructive test sample for seam cap strip repairs of 150 feet (45 meters) or more.
   d. If a destructive test sample fails, QAC may require additional testing of seams welded by same seamer and/or welding apparatus produced during same time shift as failed seam.

E. Repair Verification:

   1. Repairs shall be non-destructively tested.
   2. Nondestructive test results that pass shall indicate adequate repair.
   3. Destructive test samples shall be collected on repairs 100-feet long, or greater. Frequency may be increased at the discretion of the QAC.
   4. In the event destructive or nondestructive tests of repairs fail to meet the requirements of this Section, the work will be redone, at no expense to the OWNER, until passing test results are achieved.
   5. QAC shall monitor and document MicroDrain® repairs, and non-destructive testing.

F. Large Wrinkles: Wrinkle is considered to be large when MicroDrain® can be folded over onto itself during the coolest part of the day.

   1. When seaming of MicroDrain® is completed, and prior to placing overlying materials, QAC shall identify all large MicroDrain® wrinkles, to be repaired.
   2. Cut and repair all wrinkles identified by QAC. Welds produced while repairing wrinkles shall be nondestructively tested.
   3. Repair wrinkles identified by QAC. Repair during coldest part of installation period.

*****END OF SECTION*****

SECTION 02600

HIGH DENSITY POLYETHYLENE (HDPE) SUPER GRIPNET®

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools, and appurtenances required to complete the work of the installation of high density polyethylene (HDPE) Super GripNet® for the ash landfill closure cap areas and other related and incidental work within the designated area and as required for the construction of other work, as shown, specified, or required. CONTRACTOR shall provide a "Competent Person" to implement and supervise all work.

B. Comply with applicable codes, ordinances, rules, regulations, and laws of local, municipal, State, or Federal authorities having jurisdiction.

1.02 SUBMITTALS

A. Pre-installation: CONTRACTOR shall submit the following prior to Super GripNet® deployment:

1. Origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture Super GripNet®.
2. Copies of dated quality control certificates issued by resin supplier.
3. Results of tests conducted by Super GripNet® manufacturer to verify that resin used to manufacture Super GripNet® meets Specifications.
4. Statement that amount of reclaimed polymer added to resin during manufacturing did not exceed 2% by weight.
5. List of materials that comprise Super GripNet®, expressed in following categories as percent by weight:
   a. polyethylene;
   b. carbon black; and,
   c. other additives.
6. Manufacturer's specification for Super GripNet®, including properties listed and measured using appropriate test methods.
7. Written certification that minimum values given in manufacturer's specification are guaranteed by Super GripNet® manufacturer.
8. Quality control certificates, signed by Super GripNet® manufacturer. Each quality control certificate shall include applicable roll identification numbers, testing procedures, and results of quality control tests.
9. Field panel layout and identification code including dimensions and details.
10. Resumes of INSTALLER's Superintendent and Master Seamer, including dates and duration of employment.
11. Installation schedule.
12. List of personnel performing seaming operations, including experience information.
13. Certificate that extrusion rod is comprised of same resin as Super GripNet® liner material.
14. Manufacturer Material and Installation warranties.

B. Installation: Submit as installation proceeds.

1. Quality control documentation recorded during installation.
2. Subgrade surface acceptance certificates signed by INSTALLER for each area that will be covered directly by Super GripNet®. Submit on deployment of Super GripNet®.
3. Deployment of Super GripNet® will be considered acceptance of subgrade by the INSTALLER, if certificate is not submitted.

1.03 PRE-QUALIFICATIONS

A. Manufacturer

Manufacturer shall have minimum 5 years continuous experience in manufacture of HDPE Super GripNet®, or experience totaling 10,000,000 square feet (sq. ft.) of manufactured HDPE, or Super GripNet® manufacture for minimum of ten (10) completed facilities.

B. Installer

1. Installer shall have minimum 5 years continuous experience in installation of HDPE Super GripNet® or experience totaling 2,000,000 sq. ft. of installed HDPE Super GripNet® for minimum of five (5) completed facilities.

2. Personnel performing seaming operations shall be qualified by experience or training. Minimum of one seamer shall have experience seaming minimum 2,000,000 sq. ft. of HDPE Super GripNet® using same type of seaming apparatus in use at Site. Most experienced seamer, "Master Seamer," shall provide direct supervision, as required, over less experienced seamers.

1.04 QUALITY ASSURANCE PROGRAM

Manufacturer, fabricator, and installer shall participate in and conform to items and requirements of quality assurance program as outlined in this Section and the Construction Quality Assurance (CQA) Plan.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping

1. Manufacturer shall identify each roll delivered to Site with the following:

   a. Manufacturer's name.
   b. Product Identification.
   c. Thickness.
   d. Roll number.
   e. Roll dimensions.

2. Protect Super GripNet® from excessive mud, dirt, puncture, cutting, or other damaging or deleterious conditions during loading, transport, and unloading at Site.

B. Acceptance at Site

1. INSTALLER shall be responsible for unloading all geosynthetics delivered to the Site, unless otherwise agreed at the geosynthetics kick-off meeting.
2. Shipper shall notify INSTALLER, or other party responsible for off-loading materials, 48-hours in advance of material delivery.
3. INSTALLER, or other party responsible for off-loading materials, shall bear all costs (including but not limited to QUALITY ASSURANCE CONSULTANT (QAC), 3rd party contractor costs) associated with failure to supply appropriate personnel and equipment required to off-load geosynthetic materials.
4. Perform physical inventory of materials delivered to the Site for use in the work. Perform inventory on delivery, or as soon as practicable thereafter.
5. Conduct surface observations of each roll for defects and damage. This examination shall be conducted without unrolling rolls, unless defects or damages are found or suspected. Note type and extent of defects or damage observed.
6. Defective or damaged rolls, or portions of rolls, will be rejected and shall be removed from Site and replaced, at no additional expense to the OWNER.
7. Rolls or portions of rolls without proper identification or labeling will be rejected and shall be removed from Site.

C. Storage and Protection

1. The Super GripNet® will be unloaded, transported, stored, and protected in accordance with the manufacturers' recommendations so as not to damage or degrade the properties of the material.
2. OWNER will provide on-Site storage area for Super GripNet® rolls from time of delivery until deployment.
3. INSTALLER shall protect Super GripNet® from dirt, water, and other sources of damage.
4. Preserve integrity and readability of Super GripNet® roll labels.

PART 2 – PRODUCTS

2.01 MATERIALS

The Super GripNet® used for the ash landfill closure cap area is a high density polyethylene (HDPE) 50-mil liner manufactured by Agru-America. The Super GripNet® shall meet the following properties:

Table 02600-1: Minimum Properties 50-mil HDPE Super GripNet® Liner

Testing Properties	Testing Method	50 mil HDPE Value
Thickness, mils (min. avg.) Thickness, mils (lowest individual)	ASTM D5994	47.5 42.5
Density g/cc	ASTM D1505 or ASTM D792	0.940 (min. avg.) (either method)
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	175 mils
Drainage Stud Height (min. avg.)	ASTM D7466	130 mils
Transmissivity – Machine Direction MD (min. avg.) (12)	ASTM D4716	8.0×10^{-4} m^2/s for i=0.14

Testing Properties	Testing Method	50 mil HDPE Value
Direct Shear (Friction Angle) – degrees (min)	ASTM D5321	19 degrees
Tensile Properties (min. avg.) (3) • yield strength, lb/in • break strength, lb/in • yield elongation, % • break elongation,%	ASTM D6693	 110 110 13 200
Tear Resistance – lb (min. avg.)	ASTM D1004	38
Puncture Resistance – lb (min. avg.)	ASTM D4833	80
Stress Crack Resistance (10)	ASTM D5397 (10) (Appendix)	300
Carbon Black Content - %	ASTM D1603 (4)	2.0 to 3.0
Carbon Black Dispersion	ASTM D 5596	Note (5)
Oxidative Induction Time (OIT) (min. avg.) (6) • Standard OIT	ASTM D3895	100
Melt Flow Index, g/10 minutes	ASTM D1238	1
Oven Aging at 85°C (7) • High Pressure OIT (min. avg.), % retained after 90 days	ASTM D5721 ASTM D5885	80
UV Resistance (8) • High Pressure OIT (min. avg.) % retained after 1600 hrs (9)	ASTM D5885	50

Notes:

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet. Both sides are to be measured and considered separately.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the Super GripNet®

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hour UV cycle at 75°C followed by 4 hour condensation at 60°C.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

(10) The SP-NCTL test is not appropriate for testing Super GripNet® with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.

(11) Conduct test for Transmissivity at a normal compressive load of 500 pounds per square feet (psf) and at a hydraulic gradient of 0.14 (top of final grade surface). Boundary conditions from top to bottom are: upper load plate/ soil / nonwoven geotextile / geomembrane / lower load plate. Seating period shall be at least 100 hours to meet design criteria, and one (1) hour to meet conformance criteria.

A Super GripNet® shall be manufactured from new polyethylene resin, except as noted below:

1. Use of Super GripNet® recycled during manufacturing process shall be permitted, with written approval from QAC, if recycled Super GripNet® does not exceed 2% by weight.
2. Super GripNet® manufactured from non-complying resin shall be rejected.

B. Super GripNet® Characteristics

1. Contain maximum of 1%, by weight, of additives, fillers or extenders (not including carbon black).
2. Contain between 2% and 3%, by weight, of carbon black for ultraviolet light resistance.
3. No pinholes, bubbles or other surface features that compromise Super GripNet® integrity are allowed. Super GripNet® shall be free of blisters, nondispersed raw materials, or other signs of contamination resulting from the manufacturing process. Super GripNet® rolls or portions of rolls with these defects shall be rejected.

C. Geotextile Characteristics

1. The geotextile used to cover the Super GripNet® ash landfill closure cap shall be as shown on the Contract Drawings and meet the requirements of Section 02595.
2. Geotextiles will be generally aligned with seams parallel to the prevailing slope and HEAT TREATED side of the geotextile to be face down in contact with the SuperGripNet™ and can be seamed by either heat seaming with an approved hand held or self motivated thermal device or by sewing with a stitching approved by the QAC. Whichever stitching method is used the thread should be compatible with the fabric and have similar chemical resistance to the liner that is being used.
3. Any holes, tears, or burn throughs from thermal seaming in geotextiles will be repaired by patching with the same geotextiles. The patch will be a minimum of twelve inches larger in all directions than the area to be repaired and will be spot bonded thermally.
4. The CONTRACTOR shall protect the work described in this Section before, during, and after installation, and shall protect the installed work covered by other Sections.

2.02 SEAMING AND TESTING EQUIPMENT

A. Welding

1. Maintain on-Site minimum of two (2) spare operable seaming machines, unless otherwise agreed upon at pre-construction meeting.
2. Seaming equipment shall not damage Super GripNet®.
3. Use extrusion welding apparatus equipped with gauges indicating temperature of extrudate at the equipment nozzle or utilize hand-held gauges to measure extrudate temperatures.
4. Use self-propelled fusion-welding machines equipped with following:

   a. Gauge indicating temperature of heating element; and,
   b. Gauge indicating the speed of travel.

5. Place electric generator on smooth base such that no damage occurs to Super GripNet®.

B. Vacuum Testing Equipment

1. Vacuum box assembly shall consist of a rigid housing open at the bottom, with a transparent viewing window and soft neoprene gasket attached to bottom rim of housing, a porthole or valve assembly, and a vacuum gauge;
2. Pump assembly equipped with pressure controller and pipe connections;
3. Pressure/vacuum rubber hose with fittings and connections;
4. Soapy solution to wet test area; and,
5. Means of applying soapy solution.

C. Air Pressure Testing Equipment

1. Air pump (manual or motor driven), equipped with pressure gauge, capable of generating, sustaining, and measuring pressure between 24 and 35 pounds per square inch (psi) (165 and 240 kilopascals (kPa)), and mounted on cushion to protect Super GripNet®;
2. Rubber hose with fittings and connections;
3. Means of safely sealing weld air channel;
4. Sharp hollow needle, or other approved pressure feed device; and,
5. Air pressure monitoring device.

D. Tensiometer

1. Tensiometer shall be capable of maintaining constant jaw separation rate of 2-inches per minute; and,
2. Tensiometer shall be calibrated annually. A certificate indicating that the equipment has been calibrated within one (1) year of use in the work shall be maintained with the tensiometer. The INSTALLER will provide the QAC with a copy of the certificate of calibration.

2.03 SOURCE QUALITY CONTROL

Tests and inspections shall be performed by Super GripNet® manufacturer as follows:

A. Test Super GripNet® to demonstrate that resin meets this Specification.

B. Continuously monitor Super GripNet® during manufacturing process for inclusions, bubbles, or other defects. Super GripNet®, which exhibit defects, shall not be acceptable for installation.

C. Monitor thickness continuously during manufacturing process.

D. The MANUFACTURER shall conduct quality control (QC) testing to verify conformance with Table 02600-1 in section 2.01, at the following frequencies:

Table 02600-2: Quality Control (QC) Manufacturers Testing

Testing Properties	Testing Method	Manufacturer QC Testing Frequency
Thickness mils (min. avg.)	ASTM D 5994	1 per Roll
Density g/cc	ASTM D1505 or ASTM D792	1 per 50,000 SF
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	1 per 50,000 SF
Drainage Stud Height (min. avg.)	ASTM D7466	1 per 50,000 SF
Transmissivity	ASTM D4716	1 per 200,000 SF
Tensile Properties (min. avg.) (3)	ASTM D6693	1 per 50,000 SF
Tear Resistance – lb (min. avg.)	ASTM D1004	1 per 50,000 SF
Puncture Resistance – lb (min. avg.)	ASTM D4833	1 per 50,000 SF
Stress Crack Resistance (12)	ASTM D5397	per GRI GM10
Melt Flow Index, g/10 minutes	ASTM D1238	1 per 200,000 lbs
Low Temperature Brittleness	ASTM 746	1 per 200,000 lbs
Carbon Black Content - %	ASTM D1603 (4)	1 per 50,000 SF
Carbon Black Dispersion	ASTM D 5596	1 per 50,000 SF
Oxidative Induction Time (OIT) (min. avg.) (6) • Standard OIT, or • High Pressure OIT	ASTM D3895 ASTM D5885	(11)
Oven Aging at 85°C (7) • Std. OIT (min. avg.), % retained after 90 days or • High Pressure OIT (min. avg.), % retained after 90 days	ASTM D5721 ASTM D3895 ASTM D5885	(11)
UV Resistance (8) • Std. OIT (min. avg.) (9), or • High Pressure OIT (min. avg.) % retained after 1600 hours (10)	ASTM D3895 ASTM D5885	(11)

Notes:

(1) *Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils*

(2) *Alternate the measurement side for double sided textured sheet. Both sides are to be measured and considered separately.*

(3) *Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.*

(4) *Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.*

(5) *Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3*

(6) *The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the Super GripNet®.*

(7) *It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.*
(8) *The condition of the test should be 20 hour UV cycle at 75℃ followed by 4 hour condensation at 60℃.*
(9) *Not recommended since high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.*
(10) *UV resistance is based on percent retained value regardless of the original HP-OIT value.*
(11) *Manufacturer may provide a certification letter.*
(12) *The SP-NCTL test is not appropriate for testing Super GripNet® with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.*

PART 3 – EXECUTION

3.01 QUALITY ASSURANCE SAMPLING AND TESTING

A. Upon delivery of the material to the Site, the QAC shall obtain conformance test samples from selected Super GripNet®. INSTALLER shall make rolls available and assist QAC in obtaining material inventory and samples. Samples shall be tested in accordance with Table 02600-1 in section 2.01,at the following frequencies:

Table 02600-3: Quality Assurance (QA) Conformance Testing

Testing Properties	Testing Method	Conformance QA Testing Frequency
Thickness mils (min. avg.)	ASTM D 5994	1 per 200,000 SF*
Density g/cc	ASTM D1505 or ASTM D792	1 per 200,000 SF*
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	1 per 200,000 SF*
Drainage Stud Height (min. avg.)	ASTM D7466	1 per 200,000 SF*
Transmissivity	ASTM D 4716	1 per 200,000 SF*
Tensile Properties (min. avg.) (3)	ASTM D6693	1 per 200,000 SF*
Tear Resistance – lb (min. avg.)	ASTM D1004	1 per 200,000 SF*
Puncture Resistance – lb (min. avg.)	ASTM D4833	1 per 200,000 SF*
Stress Crack Resistance (7)	ASTM D5397	N/A
Carbon Black Content - %	ASTM D1603 (4)	1 per 200,000 SF*
Carbon Black Dispersion (5)	ASTM D 5596	1 per 200,000 SF*
Direct Shear (Friction Angle) – degrees (min) (6)	ASTM D5321	1 per Lot

Notes:
(1) *Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils*
(2) *Alternate the measurement side for double sided textured sheet.*
(3) *Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.*

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
**- Or minimum 1 per lot.*
(6) Direct shear testing shall be performed by the CONTRACTOR on the entire liner system cross section using the proposed liner system materials (i.e. cover soil, geocomposite, geomembrane, geotextile, and grading fill). The testing shall be performed at normal stresses of 100 psf, 250 psf, and 500 psf.
(7) The SP-NCTL test is not appropriate for testing Super GripNet® with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.

B. Rolls represented by quality assurance testing shall be rejected if test failure occurs. INSTALLER may at their expense request additional testing to validate individual rolls. Rolls bracketed by passing tests may be used in the work.

3.02 SURFACE PREPARATION

A. CONTRACTOR is responsible for preparing subgrade surface for Super GripNet® placement.

B. After prepared subgrade surface has been accepted in accordance with CQA Plan, report to QAC any change in subgrade surface condition that may require repair work. Maintain prepared surface.

C. Do not place Super GripNet® onto an area that has become degraded due to weather conditions. Observe and report surface condition daily to evaluate suitability for Super GripNet® deployment.

D. Repair damage to prepared surface caused by installation activities at INSTALLER'S expense.

3.03 INSTALLATION

A. Panel Nomenclature

1. Field panel is defined as a roll or portion of roll cut and seamed in field, excluding patches and cap strips.
2. Identify each field panel with a unique identification code (number or letter-number). This identification code shall be agreed upon by INSTALLER and QAC.
3. The INSTALLER shall be responsible for marking the panel and roll number on the Super GripNet®.

B. Protection

1. Do not use equipment that damages Super GripNet®;
2. Ensure subgrade surface underlying Super GripNet® has not deteriorated since previous acceptance, and remains acceptable immediately prior to and during Super GripNet® deployment;
3. Keep geosynthetic elements immediately underlying Super GripNet® clean and free of debris;
4. Do not permit personnel to smoke or wear shoes that can damage Super GripNet® while working on Super GripNet®. Personnel shall not bring glass or metal containers on Super GripNet®, except as required to perform the work;

5. Unroll panels in manner that does not cause excessive scratches or crimps in Super GripNet® and does not damage supporting soil;
6. Place panels in manner that minimizes wrinkles (especially differential wrinkles between adjacent panels);
7. Prevent wind uplift by providing adequate temporary loading and/or anchoring (e.g., sandbags) that shall not damage Super GripNet®. In case of high winds, continuous loading is recommended along panel edges; and,
8. Protect Super GripNet® in areas where excessive traffic is expected, using geotextiles, extra Super GripNet®, or other suitable materials.
9. The CONTRACTOR must protect the work described in this section before, during, and after installation.
10. Unless otherwise specified by the QAC, all equipment for spreading fill materials overlying the geosynthetics shall comply with the following:

Maximum Equipment Ground Pressure (psi)	Minimum Separation Thickness (inches)
<5	12
5 – 10	24
>10	36

11. No equipment shall be placed directly on the geomembrane during installation. Rub sheets shall be used beneath equipment to protect the geomembrane from equipment damage.

C. Field Panel Deployment

1. Install field panels at locations indicated on INSTALLER's layout plan to the greatest extent possible.
2. Replace seriously damaged (torn, twisted or crimped) field panels, or portions thereof, at no cost to OWNER. Repair less serious damage as specified herein. QAC shall determine if material shall be repaired or replaced.
3. Remove from work area damaged panels, or portions of panels, that have been rejected by the QAC.
4. Do not proceed with deployment at ambient temperature below 32°F (0°C) or above 104°F (40°C) unless authorized, in writing, by QAC.
5. Do not deploy during precipitation, in presence of excessive moisture, (i.e., fog, dew, etc.), in areas of ponded water, or in presence of excessive winds.
6. Do not undertake deployment if weather conditions will preclude material seaming on same day as deployment.
7. Do not deploy more Super GripNet® field panels in one day than can be seamed during that day.

D. Seam Layout

1. Orient seams parallel to line of maximum slope (i.e., oriented along, not across, slope).
2. No horizontal seams will be permitted on the slope.
3. No horizontal seam shall be less than 5 feet (1.5 meters) from toe of slope, unless approved by the QAC.
4. In general, maximize lengths of field panels and minimize number of field seams.
5. Align Super GripNet® panels to have nominal overlap of 3 inches (75 millimeters) for extrusion welding and 4 to 6 inches (100 to 150 millimeters) for fusion welding. Final overlap shall be sufficient to allow destructive “peel” tests to be performed on seam.

E. Temporary Bonding

1. Hot air device (Leister) may be used to temporarily bond Super GripNet® panels to be extrusion welded.
2. Do not damage Super GripNet® when temporarily bonding adjacent panels. Apply minimal amount of heat required to lightly tack Super GripNet® panels together. Control temperature of hot air at nozzle of any temporary welding apparatus to prevent damage to Super GripNet®.
3. Do not use solvent or adhesive.

F. Seaming Methods

1. Approved processes for field seaming are extrusion fillet welding and fusion welding. Proposed alternate processes shall be documented and submitted to QAC for approval. Alternate procedures shall be used only after being approved in writing by QAC.
2. Use fusion welding as primary method of seaming adjacent field panels.

    a. Cross seam "tees", associated with fusion or extrusion seam welding, shall be patched in accordance with the requirements of this Section.
    b. Place welder on protective pad to prevent Super GripNet® damage when not in use.
    c. When subgrade conditions dictate, use movable protective layer (e.g. Super GripNet® rub sheet) directly below each overlap of Super GripNet® that is to be seamed to prevent buildup of moisture between sheets and prevent debris from collecting around pressure rollers. Rub sheet shall be removed from under the liner once seaming is complete.

3. Use extrusion fillet welding as secondary method for seaming between adjacent panels and as primary method of welding for detail and repair work.

    a. Purge heat-degraded extrudate from barrel of extruder
    b. Place smooth insulating plate or fabric beneath hot welding apparatus when not in use
    c. Use clean and dry welding rods or extrudate pellets.
    d. Clean dirt and debris from Super GripNet® surface prior to extrusion welding.
    e. Grind weld area to using suitable hand held equipment to prepare Super GripNet® surface for extrusion welding. Grind perpendicular to seam. Take care not to over-grind Super GripNet®.
    f. Minimize exposed grinding marks adjacent to extrusion weld. Do not allow exposed grinding marks to extend more than 1/4-inch outside finished seam area.
    g. Complete extrusion welding within one (1) hour of seaming operation grinding process without damaging Super GripNet®.

G. Seaming Procedures

1. General Seaming Procedures - Ambient temperature between 32°F (0°C) and 104°F (40°C).

    a. Do not field seam without Master Seamer being present.
    b. Seam only during dry conditions, i.e., no precipitation or other excessive moisture, such as fog or dew.

c. Do not seam during excessive winds, except as needed to protect the work. Do not seam if wind creates unsafe working conditions.
d. If required, use “rub-sheet” or similar hard surface directly under seam overlap to achieve proper support for seaming apparatus.
e. Align panels to minimize wrinkles and/or “fishmouths” in welds.
f. Extend seams to outside edge of panels placed in anchor trench.
g. Prior to seaming, ensure that seam area is free of moisture, dust, dirt, debris, or foreign material.
h. “Fishmouths” or wrinkles at seam overlaps shall be cut along ridge of wrinkle in order to achieve flat overlap. Cut “fishmouths” or wrinkles shall be seamed or patched in accordance with this Section.

2. Cold Weather Seaming Procedures (ambient temperature is below 32°F (0°C)).

a. No seaming of Super GripNet® is permitted unless demonstrated to QAC that Super GripNet® seam quality will not be compromised.
b. Additional destructive samples and/or field test strips shall be cut from seams welded under ambient temperature of 32°F (0°C), at QAC’s discretion.

3. Warm Weather Procedures (ambient temperature is above 104°F (40°C)).

a. No seaming of Super GripNet® is permitted unless demonstrated to QAC that Super GripNet® seam quality will not be compromised.
b. Additional destructive samples and/or field test strips shall be cut from seams welded over ambient temperature of 104°F (40°C), at QAC’s discretion.

H. Repair Procedures:

1. Acceptable repair procedures include following:

a. Patching: Piece of same Super GripNet® material extrusion welded into place. Use to repair large holes, tears, nondispersed raw materials, and contamination by foreign matter. All panel intersections shall be patched.
b. Capping: Strip of same Super GripNet® material extrusion welded into place over inadequate seam. Use to repair large lengths of failed seams.
c. Spot welding or seaming (Grind and Weld): Bead of molten extrudate placed on flaw. Use to repair scuffing, dimpling, or other minor, localized flaws. Spot welding shall not be used to repair holes in the Super GripNet® liner.
d. Removal and replacement: Remove bad seam and replace with strip of same Super GripNet® material welded into place. Use to repair large lengths of failed seams.
e. Extrusion welding flap: Repairs of this type shall not be used unless approved by QAC, and only if the flap is a minimum of 1.5 inches long. Repairs of this type shall not exceed 100 feet (30 meters) in length.

2. For each repair method:

a. Ensure surfaces are clean, dry, and prepared in accordance with specified seaming process.

b. Ensure seaming equipment used in repairing procedures meet requirements of this Specification.
c. Extend patches or caps at least 6 inches (150 millimeters) beyond edge of defect. Round corners of patches with radius of approximately 6 inches (150 millimeters).

I. Anchor Trench:

1. CONTRACTOR shall excavate anchor trenches to lines and grades shown on Contract Drawings prior to Super GripNet® placement, unless otherwise specified.
2. CONTRACTOR shall provide anchor trench with slightly rounded corners shall be provided, to avoid sharp bends in Super GripNet®.
3. INSTALLER shall provide and use plywood, boards, or other suitable materials, to permit welding machines to weld across, rather than through, anchor trenches.
4. CONTRACTOR shall dewater the completed anchor trench, to prevent ponding or softening of adjacent soils while trench is open.
5. CONTRACTOR and INSTALLER shall coordinate operations to minimize time anchor trench remains open and uncovered.
6. INSTALLER shall provide sufficient temporary ballast to prevent geosynthetics from being pulled or blown from the anchor trench.
7. CONTRACTOR and INSTALLER shall remove debris related to their respective construction activities, including temporary ballast material, from anchor trench, prior to installation of subsequent materials. The anchor trench shall be cleaned to the satisfaction of the QAC.
8. CONTRACTOR shall backfill and compact anchor trench as soon as practical after geosynthetic installation is completed. Anchor trench shall be backfilled prior to placing leachate drainage layer material. Refer to specification section 02223 “Backfill and Fill” for backfilling procedure.

3.04 FIELD QUALITY ASSURANCE AND QUALITY CONTROL

A. Visual Inspection:

1. QAC will examine seam and non-seam areas of SuperGripNet™ to identify defects, holes, blisters, nondispersed raw materials, and any sign of contamination by foreign matter.

B. Trial Seams:

1. Make trial seams on fragment pieces of Super GripNet® liner to verify that conditions are adequate for production seaming.
2. Make trial seams for each combination of materials to be welded (i.e., textured/smooth, smooth/smooth, textured/textured). Seamers may only weld those combinations for which they have produced acceptable trial welds. Seamers are not required to produce trial seams for material combinations they will not be welding.
3. Make trial seams at beginning of each seaming period, following restart of welding equipment, upon change of seamers, and at least once every five (5) hours, for each production seaming apparatus used that day.
4. Make trial seams using the same materials and under the under same conditions as production welding.
5. Trial seam sample shall be at least 4-feet (1.2 meters) long by 1-foot (0.3 meters) wide (after seaming) with seam centered lengthwise.

6. Cut six (6) test specimens from sample, using 1-inch (25 millimeters) wide die cutter. These specimen locations shall be selected randomly along trial seam sample by QAC. Test three (3) specimens in peel and three (3) specimens in shear, using field tensiometer. Samples shall fail in film tear bond (FTB) mode. Trial seams shall meet the following minimum strengths:

Table 02600-4: Seam Strength Values for Trial Seams and Destructive Sample Testing

PROPERTY	METHOD	50 MIL HDPE SUPER GRIPNET® LINER SPECIFIED VALUE
Shear Strength	ASTM D6392	100 lbs/in (min.)
Peel Adhesion: Fusion Extrusion	ASTM D6392 ASTM D6392	76 lbs/in (min.) 65 lbs/in (min.)
For shear tests, sheet shall yield before failure of seam. For peel adhesion, seam separation shall not extend more than 25 percent of seam width into seam. For either test, testing shall be discontinued when sample has visually yielded. Four (4) out of 5 specimens shall meet the, or exceed, the values listed for shear and peel. The 5th specimen can be as low as 80%.		

7. If specimen fails, the INSTALLER will attempt to identify the cause of the failure (e.g., mechanical malfunction, dirt in weld). On correction of the deficiency, the seamer shall produce a second trial seam. If the second trial seam fails, the seamer shall not be permitted to weld production seams until deficiencies are corrected and two (2) consecutive successful trial welds are achieved. If mechanical failure is determined to be the cause of the second trial seam failure, the machine shall be removed from service until suitable repairs are made. The seamer shall be required to produce a passing trial seam with the replacement machine.

C. Non-destructive Seam Testing:

1. General:

a. Purpose of non-destructive tests is to check continuity of seams. It will not provide quantitative information on seam strength.
b. Non-destructively test field seams over their full length using vacuum test for extrusion seams, air pressure for double-fusion seams, or other QAC approved method. QAC shall document results.
c. Perform non-destructive testing as seaming work progresses.
d. The QAC shall observe all non-destructive testing on a full-time basis. The INSTALLER and QAC shall coordinate to ensure that all installation activities are monitored by the QAC in accordance with these Specifications.

2. Vacuum Testing for extrusion seam:

a. Energize vacuum pump and reduce tank pressure to approximately 5 pounds per square inch [gauge] (psig) (10 inches of Hg) (35 kPa) gauge pressure.
b. Wet strip of extrusion seam approximately 12 inches by 48 inches (0.3 m by 1.2 meters) with soapy solution.
c. Ensure viewing window is clean.
d. Place box over wetted area.
e. Close bleed valve and open vacuum valve.

f. Ensure that leak-tight seal is created.
g. For minimum of 10 seconds, apply vacuum and examine Super GripNet® through viewing window for presence of soap bubbles.
h. If no bubbles appear within 10 seconds, close vacuum valve and open bleed valve, move box over to next adjoining area with minimum 3-inch (75 -millimeter) overlap and repeat process.
i. Mark and repair areas where soap bubbles appear.

3. Air Pressure Testing for dual track, hot wedge fusion weld:

a. Seal both ends of seam to be tested. Take suitable precautions if sealing seam ends with open flame.
b. Insert needle or other approved pressure feed device into air channel created by fusion weld.
c. Insert protective cushion between air pump and Super GripNet®.
d. Pressurize air channel to approximately 30 psig (206 kPa). Close valve and allow pressure to stabilize for approximately two (2) minutes.
e. Observe air pressure 5 minutes after initial stabilization period ends. If pressure loss exceeds 4 psig or pressure does not stabilize, locate faulty area, repair, and retest.
f. On completion of testing, cut opposite end of tested seam length to verify continuity of air channel. If air does not escape, locate blockage and retest unpressurized area. Repair cut end of air channel.
g. Cap any seam length that cannot be successfully air pressure tested.
h. Remove needle or other approved pressure feed device and repair hole in Super GripNet®.

4. Inaccessible Seams:

a. Cap-strip seams that cannot be nondestructively tested.
b. Cap-strip material shall be composed of same type and thickness as Super GripNet® to be capped.
c. Examine cap-stripping operations with QAC for uniformity and completeness. Document observations.

D. Destructive Seam Testing:

1. General:

a. Purpose of destructive seam testing to evaluate seam strength.
b. Perform destructive seam test as seaming progresses.
c. The destructive seam sample shall fail if the overlap is insufficient for grips of testing machine to close on sample (available flap is 1/2 inch long or less).

2. Location and frequency:

a. Test at minimum frequency of one (1) test location per 500 feet (150 meters) of welding length performed by each welding machine. This minimum frequency to be determined as an average taken from the total linear footage of seaming, per machine, at the end of the Super GripNet® installation.
b. Test locations shall be determined by the QAC, during seaming operations.

c. INSTALLER will not be informed in advance of locations where seam samples will be taken.
d. QAC reserves right to increase frequency of testing in accordance with performance results of samples previously tested.

3. Sampling Procedures:

a. Cut samples at locations selected by QAC.
b. QAC shall number each sample and record sample number and location in panel layout drawing.
c. QAC shall mark each section of destructive test sample with sample number, seam number, seamer and machine identification, and date.
d. Repair holes in Super GripNet® resulting from destructive seam sampling as soon as possible, in accordance with repair procedures described in this Section.
e. Non-destructively test repairs in accordance with this Section.

4. Sample Dimensions:

a. Field Testing: Cut two (2) 1-inch (25 millimeters) wide sample coupons, from each end of seam section identified by QAC. Distance between these two (2) samples shall be approximately 42 inches (1.1 meters). Test both samples in peel mode, using field tensiometer. If both samples meet requirements of Table 4 located in Section 3.04 B item 6, collect sample for laboratory testing.
b. Laboratory Testing: Collect laboratory test sample from seam length between field test sample coupon locations. Cut sample for laboratory testing, approximately 12 inches (0.3 meters) wide by a minimum 42-inches (1.1 meters) long, with seam centered lengthwise. Cut this sample into three (3) sections. QAC shall distribute sample sections as follows:

1) Geosynthetic Quality Assurance Laboratory: minimum 18-inch (0.5 meters) long section for laboratory testing.
2) INSTALLER: minimum 12 inches (0.3 meters) long section for archive or optional laboratory testing.
3) QAC: minimum 12 inches (0.3 meters) long section for archive storage.

c. Final determination of sample sizes shall be agreed upon at the geosynthetics kick-off meeting. Sample sizes shall be minimized, consistent with laboratory testing requirements.
d. Submit laboratory sample for quantitative testing in accordance with the CQA Plan.

5. Destructive Test Failure Procedures:

When sample fails destructive testing, whether test is conducted in the field or at Geosynthetic Quality Assurance Laboratory, CONTRACTOR has following options:

a. Repair entire seam between two (2) passing destructive test locations along the path of machine producing the failed weld bracketing the failed location.

b. Trace welding path 10-feet (3 meters) minimum in each direction from failed test, and repeat field testing procedures indicated in this Section at each location. If these additional samples pass field test, then collect laboratory test samples. If these laboratory samples pass tests, repair seam between these locations. If either, or both, sample fails, repeat process until passing sample is located. If necessary, tracking will extend back to previous days of welding until a passing sample is located. Repair seam between passing destructive sample locations.

c. Acceptable repaired seams shall be bound by passing laboratory destructive tests locations. The QAC shall mark and additional destructive test sample for seam cap strip repairs of 150 feet (45 meters) or more.

d. If a destructive test sample fails, QAC may require additional testing of seams welded by same seamer and/or welding apparatus produced during same time shift as failed seam.

E. Repair Verification:

1. Repairs shall be non-destructively tested.
2. Nondestructive test results that pass shall indicate adequate repair.
3. Destructive test samples shall be collected on repairs 100-feet long, or greater. Frequency may be increased at the discretion of the QAC.
4. In the event destructive or nondestructive tests of repairs fail to meet the requirements of this Section, the work will be redone, at no expense to the OWNER, until passing test results are achieved.
5. QAC shall monitor and document Super GripNet® repairs, and non-destructive testing.

F. Large Wrinkles: Wrinkle is considered to be large when Super GripNet® can be folded over onto itself during the coolest part of the day.

1. When seaming of Super GripNet® is completed, and prior to placing overlying materials, QAC shall identify all large Super GripNet® wrinkles, to be repaired.
2. Cut and repair all wrinkles identified by QAC. Welds produced while repairing wrinkles shall be nondestructively tested.
3. Repair wrinkles identified by QAC. Repair during coldest part of installation period.

*****END OF SECTION*****

SECTION 02601

LINEAR LOW DENSITY POLYETHYLENE (LLDPE) SUPER GRIPNET®

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools, and appurtenances required to complete the work of the installation of linear low density polyethylene (LLDPE) Super GripNet® for the landfill cap areas and other related and incidental work within the designated area and as required for the construction of other work, as shown, specified, or required. CONTRACTOR shall provide a "Competent Person" to implement and supervise all work.

B. Comply with applicable codes, ordinances, rules, regulations, and laws of local, municipal, State, or Federal authorities having jurisdiction.

1.02 SUBMITTALS

A. Pre-installation: CONTRACTOR shall submit the following prior to Super GripNet® deployment:

1. Origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture Super GripNet®.
2. Copies of dated quality control certificates issued by resin supplier.
3. Results of tests conducted by Super GripNet® manufacturer to verify that resin used to manufacture Super GripNet® meets Specifications.
4. Statement that amount of reclaimed polymer added to resin during manufacturing did not exceed 2% by weight.
5. List of materials that comprise Super GripNet®, expressed in following categories as percent by weight:
   a. polyethylene;
   b. carbon black; and,
   c. other additives.
6. Manufacturer's specification for Super GripNet®, including properties listed and measured using appropriate test methods.
7. Written certification that minimum values given in manufacturer's specification are guaranteed by Super GripNet® manufacturer.
8. Quality control certificates, signed by Super GripNet® manufacturer. Each quality control certificate shall include applicable roll identification numbers, testing procedures, and results of quality control tests.
9. Field panel layout and identification code including dimensions and details.
10. Resumes of INSTALLER’s Superintendent and Master Seamer, including dates and duration of employment.
11. Installation schedule.
12. List of personnel performing seaming operations, including experience information.
13. Certificate that extrusion rod is comprised of same resin as Super GripNet® liner material.
14. Manufacturer Material and Installation warranties.

B. Installation: Submit as installation proceeds.

1. Quality control documentation recorded during installation.
2. Subgrade surface acceptance certificates signed by INSTALLER for each area that will be covered directly by Super GripNet®. Submit on deployment of Super GripNet®.
3. Deployment of Super GripNet® will be considered acceptance of subgrade by the INSTALLER, if certificate is not submitted.

1.03 PRE-QUALIFICATIONS

A. Manufacturer

Manufacturer shall have minimum 5 years continuous experience in manufacture of LLDPE Super GripNet®, or experience totaling 10,000,000 square feet (sq. ft.) of manufactured LLDPE, or Super GripNet® manufacture for minimum of ten (10) completed facilities.

B. Installer

1. Installer shall have minimum 5 years continuous experience in installation of LLDPE Super GripNet® or experience totaling 2,000,000 sq. ft. of installed LLDPE Super GripNet® for minimum of five (5) completed facilities.

2. Personnel performing seaming operations shall be qualified by experience or training. Minimum of one seamer shall have experience seaming minimum 2,000,000 sq. ft. of LLDPE Super GripNet® using same type of seaming apparatus in use at Site. Most experienced seamer, "Master Seamer," shall provide direct supervision, as required, over less experienced seamers.

1.04 QUALITY ASSURANCE PROGRAM

Manufacturer, fabricator, and installer shall participate in and conform to items and requirements of quality assurance program as outlined in this Section and the Construction Quality Assurance (CQA) Plan.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping

1. Manufacturer shall identify each roll delivered to Site with the following:

a. Manufacturer's name.
b. Product Identification.
c. Thickness.
d. Roll number.
e. Roll dimensions.

2. Protect Super GripNet® from excessive mud, dirt, puncture, cutting, or other damaging or deleterious conditions during loading, transport, and unloading at Site.

B. Acceptance at Site

1. INSTALLER shall be responsible for unloading all geosynthetics delivered to the Site, unless otherwise agreed at the geosynthetics kick-off meeting.
2. Shipper shall notify INSTALLER, or other party responsible for off-loading materials, 48-hours in advance of material delivery.
3. INSTALLER, or other party responsible for off-loading materials, shall bear all costs (including but not limited to QUALITY ASSURANCE CONSULTANT's (QAC), 3rd party contractor costs) associated with failure to supply appropriate personnel and equipment required to off-load geosynthetic materials.
4. Perform physical inventory of materials delivered to the Site for use in the work. Perform inventory on delivery, or as soon as practicable thereafter.
5. Conduct surface observations of each roll for defects and damage. This examination shall be conducted without unrolling rolls, unless defects or damages are found or suspected. Note type and extent of defects or damage observed.
6. Defective or damaged rolls, or portions of rolls, will be rejected and shall be removed from Site and replaced, at no additional expense to the OWNER.
7. Rolls or portions of rolls without proper identification or labeling will be rejected and shall be removed from Site.

C. Storage and Protection

1. The Super GripNet® will be unloaded, transported, stored, and protected in accordance with the manufacturers' recommendations so as not to damage or degrade the properties of the material.
2. OWNER will provide on-Site storage area for Super GripNet® rolls from time of delivery until deployment.
3. INSTALLER shall protect Super GripNet® from dirt, water, and other sources of damage.
4. Preserve integrity and readability of Super GripNet® roll labels.

PART 2 – PRODUCTS

2.01 MATERIALS

The Super GripNet® used for the landfill cap area is a linear low density polyethylene (LLDPE) 50-mil liner manufactured by Agru-America. The Super GripNet® shall meet the following properties:

Table 02601-1: Minimum Properties 50-mil LLDPE Super GripNet® Liner

Testing Properties	Testing Method	50 mil LLDPE Value
Thickness, mils (min. avg.) Thickness, mils (lowest individual)	ASTM D5994	47.5 42.5
Density g/cc	ASTM D1505 or ASTM D792	0.939 (min. avg.) (either method)
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	175 mils
Drainage Stud Height (min. avg.)	ASTM D7466	130 mils
Transmissivity – Machine Direction MD (min. avg.) (11)	ASTM D4716	8.0×10^{-4} m^2/s for i=0.14
Direct Shear (Friction Angle) – degrees (min	ASTM D5321	19 degrees

Testing Properties	Testing Method	50 mil LLDPE Value
Tensile Properties (min. avg.) (3) • break strength, lb/in • break elongation,%	ASTM D6693	105 300
Tear Resistance – lb (min. avg.)	ASTM D1004	30
Puncture Resistance – lb (min. avg.)	ASTM D4833	55
Stress Crack Resistance (10)	ASTM D5397 (11) (Appendix)	NA
Carbon Black Content - %	ASTM D1603 (4)	2.0 to 3.0
Carbon Black Dispersion	ASTM D 5596	Note (5)
Oxidative Induction Time (OIT) (min. avg.) (6) • Standard OIT	ASTM D3895	≥100
Melt Flow Index, g/10 minutes	ASTM D1238	≤1
Oven Aging at 85°C (7) • High Pressure OIT (min. avg.), % retained after 90 days	ASTM D5721 ASTM D5885	60
UV Resistance (8) • High Pressure OIT (min. avg.) % retained after 1600 hrs (9)	ASTM D5885	35
2% Secant Modulus (max), lb/in	ASTM D5323	3000
Axi-Symmetric Break Resistance Strain, % (min.)	ASTM D5617	30

Notes:

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet. Both sides are to be measured and considered separately.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the Super GripNet®

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hour UV cycle at 75°C followed by 4 hour condensation at 60°C.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

(10) The SP-NCTL test is not appropriate for testing Super GripNet® with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.

(11) Conduct test for Transmissivity at a normal compressive load of 500 pounds per square feet (psf) and at a hydraulic gradient of 0.14 (top of final grade surface). Boundary conditions from top to bottom are: upper load plate/ soil / nonwoven geotextile / geomembrane / lower load plate. Seating period shall be at least 100 hours to meet design criteria, and one (1) hour to meet conformance criteria.

A Super GripNet® shall be manufactured from new polyethylene resin, except as noted below:

1. Use of Super GripNet® recycled during manufacturing process shall be permitted, with written approval from QAC, if recycled Super GripNet® does not exceed 2% by weight.
2. Super GripNet® manufactured from non-complying resin shall be rejected.

B. Super GripNet® Characteristics

1. Contain maximum of 1%, by weight, of additives, fillers or extenders (not including carbon black).
2. Contain between 2% and 3%, by weight, of carbon black for ultraviolet light resistance.
3. No pinholes, bubbles or other surface features that compromise Super GripNet® integrity are allowed. Super GripNet® shall be free of blisters, nondispersed raw materials, or other signs of contamination resulting from the manufacturing process. Super GripNet® rolls or portions of rolls with these defects shall be rejected.

C. Geotextile Characteristics

1. The geotextile used to cover the Super GripNet® landfill cap shall be as shown on the Contract Drawings and meet the requirements of Section 02595.
2. Geotextiles will be generally aligned with seams parallel to the prevailing slope and HEAT TREATED side of the geotextile to be face down in contact with the Super GripNet® and can be seamed by either heat seaming with an approved hand held or self motivated thermal device or by sewing with a stitching approved by the QAC. Whichever stitching method is used the thread should be compatible with the fabric and have similar chemical resistance to the liner that is being used.
3. Any holes, tears, or burn throughs from thermal seaming in geotextiles will be repaired by patching with the same geotextiles. The patch will be a minimum of twelve inches larger in all directions than the area to be repaired and will be spot bonded thermally.
4. The CONTRACTOR shall protect the work described in this Section before, during, and after installation, and shall protect the installed work covered by other Sections.

2.02 SEAMING AND TESTING EQUIPMENT

A. Welding

1. Maintain on-Site minimum of two (2) spare operable seaming machines, unless otherwise agreed upon at pre-construction meeting.
2. Seaming equipment shall not damage Super GripNet®.
3. Use extrusion welding apparatus equipped with gauges indicating temperature of extrudate at the equipment nozzle, or utilize hand-held gauges to measure extrudate temperatures.
4. Use self-propelled fusion-welding machines equipped with following:

    a. Gauge indicating temperature of heating element; and,
    b. Gauge indicating the speed of travel.

5. Place electric generator on smooth base such that no damage occurs to Super GripNet®.

B. Vacuum Testing Equipment

1. Vacuum box assembly shall consist of a rigid housing open at the bottom, with a transparent viewing window and soft neoprene gasket attached to bottom rim of housing, a porthole or valve assembly, and a vacuum gauge;
2. Pump assembly equipped with pressure controller and pipe connections;
3. Pressure/vacuum rubber hose with fittings and connections;
4. Soapy solution to wet test area; and,
5. Means of applying soapy solution.

C. Air Pressure Testing Equipment

1. Air pump (manual or motor driven), equipped with pressure gauge, capable of generating, sustaining, and measuring pressure between 24 and 35 pounds per square inch (psi) (165 and 240 kilopascals (kPa)), and mounted on cushion to protect Super GripNet®;
2. Rubber hose with fittings and connections;
3. Means of safely sealing weld air channel;
4. Sharp hollow needle, or other approved pressure feed device; and,
5. Air pressure monitoring device.

D. Tensiometer

1. Tensiometer shall be capable of maintaining constant jaw separation rate of 2-inches per minute; and,
2. Tensiometer shall be calibrated annually. A certificate indicating that the equipment has been calibrated within one (1) year of use in the work shall be maintained with the tensiometer. The INSTALLER will provide the QAC with a copy of the certificate of calibration.

2.03 SOURCE QUALITY CONTROL

Tests and inspections shall be performed by Super GripNet® manufacturer as follows:

A. Test Super GripNet® to demonstrate that resin meets this Specification.

B. Continuously monitor Super GripNet® during manufacturing process for inclusions, bubbles, or other defects. Super GripNet®, which exhibit defects, shall not be acceptable for installation.

C. Monitor thickness continuously during manufacturing process.

D. The MANUFACTURER shall conduct quality control (QC) testing to verify conformance with Table 02601-1 in section 2.01, at the following frequencies:

Table 02601-2: Quality Control (QC) Manufacturers Testing

Testing Properties	Testing Method	Manufacturer QC Testing Frequency
Thickness mils (min. avg.)	ASTM D 5994	1 per Roll
Density g/cc	ASTM D1505 or ASTM D792	1 per 50,000 SF
Friction Spike Height (min. avg.) (1) (2)	ASTM D7466	1 per 50,000 SF
Drainage Stud Height (min. avg.)	ASTM D7466	1 per 50,000 SF
Transmissivity	ASTM D4716	1 per 200,000 SF
Tensile Properties (min. avg.) (3)	ASTM D6693	1 per 50,000 SF
Tear Resistance – lb (min. avg.)	ASTM D1004	1 per 50,000 SF
Puncture Resistance – lb (min. avg.)	ASTM D4833	1 per 50,000 SF
Stress Crack Resistance (12)	ASTM D5397	per GRI GM10
Melt Flow Index, g/10 minutes	ASTM D1238	1 per 200,000 lbs
Low Temperature Brittleness	ASTM 746	1 per 200,000 lbs
Carbon Black Content - %	ASTM D1603 (4)	1 per 50,000 SF
Carbon Black Dispersion (5)	ASTM D 5596	1 per 50,000 SF
Oxidative Induction Time (OIT) (min. avg.) (6) • Standard OIT, or • High Pressure OIT	ASTM D3895 ASTM D5885	(11)
Oven Aging at 85°C (7) • Std. OIT (min. avg.), % retained after 90 days or • High Pressure OIT (min. avg.), % retained after 90 days	ASTM D5721 ASTM D3895 ASTM D5885	(11)
UV Resistance (8) • Std. OIT (min. avg.) (9), or • High Pressure OIT (min. avg.) % retained after 1600 hours (10)	ASTM D3895 ASTM D5885	(11)
2% Secant Modulus, lb/in (max.)	ASTM D5323	Per resin formulation
Axi-Symmetric Break Resistance Strain, % (min.)	ASTM D5617	Per resin formulation

Notes:

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet. Both sides are to be measured and considered separately.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) *Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3*
(6) *The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the Super GripNet®.*
(7) *It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.*
(8) *The condition of the test should be 20 hour UV cycle at 75°C followed by 4 hour condensation at 60°C.*
(9) *Not recommended since high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.*
(10) *UV resistance is based on percent retained value regardless of the original HP-OIT value.*
(11) *Manufacturer may provide a certification letter.*
(12) *The SP-NCTL test is not appropriate for testing Super GripNet®. with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.*

PART 3 – EXECUTION

3.01 QUALITY ASSURANCE SAMPLING AND TESTING

A. Upon delivery of the material to the Site, the QAC shall obtain conformance test samples from selected Super GripNet®. INSTALLER shall make rolls available and assist QAC in obtaining material inventory and samples. Samples shall be tested in accordance with Table 02601-1 in section 2.01,at the following frequencies:

Table 02601-3: Quality Assurance (QA) Conformance Testing

Testing Properties	Testing Method	Conformance QA Testing Frequency
Thickness mils (min. avg.)	ASTM D 5994	1 per 200,000 SF*
Density g/cc	ASTM D1505 or ASTM D792	1 per 200,000 SF*
Friction Spike Height (min. avg.) (1) (2)	GM-12	1 per 200,000 SF*
Drainage Stud Height (min. avg.)	GM-12	1 per 200,000 SF*
Transmissivity	ASTM D 4716	1 per 200,000 SF*
Tensile Properties (min. avg.) (3)	ASTM D6693	1 per 200,000 SF*
Tear Resistance – lb (min. avg.)	ASTM D1004	1 per 200,000 SF*
Puncture Resistance – lb (min. avg.)	ASTM D4833	1 per 200,000 SF*
Stress Crack Resistance (7)	ASTM D5397	N/A
Carbon Black Content - %	ASTM D1603 (4)	1 per 200,000 SF*
Carbon Black Dispersion (5)	ASTM D 5596	1 per 200,000 SF*
Direct Shear (Friction Angle) – degrees (min)(6)	ASTM D5321	1 per Lot

Notes:

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches at 2.0 inches/minute.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
**- Or minimum 1 per lot.*

(6) Direct shear testing shall be performed by the CONTRACTOR on the entire liner system cross section using the proposed liner system materials (i.e. cover soil, geocomposite, geomembrane, geotextile, and grading fill). The testing shall be performed at normal stresses of 100 psf, 250 psf, and 500 psf.

(7) The SP-NCTL test is not appropriate for testing Super GripNet®. with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheet made from the same formulation as being used for the textured sheet materials, or the texturing act as the notch. Follow procedure listed in ASTM D5397 appendix.

B. Rolls represented by quality assurance testing shall be rejected if test failure occurs. INSTALLER may at their expense request additional testing to validate individual rolls. Rolls bracketed by passing tests may be used in the work.

3.02 SURFACE PREPARATION

A. CONTRACTOR is responsible for preparing subgrade surface for Super GripNet® placement.

B. After prepared subgrade surface has been accepted in accordance with Quality Assurance Plan, report to QAC any change in subgrade surface condition that may require repair work. Maintain prepared surface.

C. Do not place Super GripNet® onto an area that has become degraded due to weather conditions. Observe and report surface condition daily to evaluate suitability for Super GripNet® deployment.

D. Repair damage to prepared surface caused by installation activities at INSTALLER'S expense.

3.03 INSTALLATION

A. Panel Nomenclature

1. Field panel is defined as a roll or portion of roll cut and seamed in field, excluding patches and cap strips.
2. Identify each field panel with a unique identification code (number or letter-number). This identification code shall be agreed upon by INSTALLER and QAC.
3. The INSTALLER shall be responsible for marking the panel and roll number on the Super GripNet®.

B. Protection

1. Do not use equipment that damages Super GripNet®;
2. Ensure subgrade surface underlying Super GripNet® has not deteriorated since previous acceptance, and remains acceptable immediately prior to and during Super GripNet® deployment;

3. Keep geosynthetic elements immediately underlying Super GripNet® clean and free of debris;
4. Do not permit personnel to smoke or wear shoes that can damage Super GripNet® while working on Super GripNet®. Personnel shall not bring glass or metal containers on Super GripNet®, except as required to perform the work;
5. Unroll panels in manner that does not cause excessive scratches or crimps in Super GripNet® and does not damage supporting soil;
6. Place panels in manner that minimizes wrinkles (especially differential wrinkles between adjacent panels);
7. Prevent wind uplift by providing adequate temporary loading and/or anchoring (e.g., sandbags) that shall not damage Super GripNet®. In case of high winds, continuous loading is recommended along panel edges; and,
8. Protect Super GripNet® in areas where excessive traffic is expected, using geotextiles, extra Super GripNet®, or other suitable materials.
9. The CONTRACTOR must protect the work described in this section before, during, and after installation.
10. Unless otherwise specified by the QAC, all equipment for spreading fill materials overlying the geosynthetics shall comply with the following:

Maximum Equipment Ground Pressure (psi)	Minimum Separation Thickness (inches)
<5	12
5 – 10	24
>10	36

11. No equipment shall be placed directly on the geomembrane during installation. Rub sheets shall be used beneath equipment to protect the geomembrane from equipment damage.

C. Field Panel Deployment

1. Install field panels at locations indicated on INSTALLER's layout plan to the greatest extent possible.
2. Replace seriously damaged (torn, twisted or crimped) field panels, or portions thereof, at no cost to OWNER. Repair less serious damage as specified herein. QAC shall determine if material shall be repaired or replaced.
3. Remove from work area damaged panels, or portions of panels, that have been rejected by the QAC.
4. Do not proceed with deployment at ambient temperature below 32°F (0°C) or above 104°F (40°C) unless authorized, in writing, by QAC.
5. Do not deploy during precipitation, in presence of excessive moisture, (i.e., fog, dew, etc.), in areas of ponded water, or in presence of excessive winds.
6. Do not undertake deployment if weather conditions will preclude material seaming on same day as deployment.
7. Do not deploy more Super GripNet® field panels in one day than can be seamed during that day.

D. Seam Layout

1. Orient seams parallel to line of maximum slope (i.e., oriented along, not across, slope).
2. No horizontal seams will be permitted on the slope.
3. No horizontal seam shall be less than 5 feet (1.5 meters) from toe of slope, unless approved by the QAC.

4. In general, maximize lengths of field panels and minimize number of field seams.
5. Align Super GripNet® panels to have nominal overlap of 3 inches (75 millimeters) for extrusion welding and 4 to 6 inches (100 to 150 millimeters) for fusion welding. Final overlap shall be sufficient to allow destructive "peel" tests to be performed on seam.

E. Temporary Bonding

1. Hot air device (Leister) may be used to temporarily bond Super GripNet® panels to be extrusion welded.
2. Do not damage Super GripNet® when temporarily bonding adjacent panels. Apply minimal amount of heat required to lightly tack Super GripNet® panels together. Control temperature of hot air at nozzle of any temporary welding apparatus to prevent damage to Super GripNet®.
3. Do not use solvent or adhesive.

F. Seaming Methods

1. Approved processes for field seaming are extrusion fillet welding and fusion welding. Proposed alternate processes shall be documented and submitted to QAC for approval. Alternate procedures shall be used only after being approved in writing by QAC.
2. Use fusion welding as primary method of seaming adjacent field panels.

   a. Cross seam "tees", associated with fusion or extrusion seam welding, shall be patched in accordance with the requirements of this Section.
   b. Place welder on protective pad to prevent Super GripNet® damage when not in use.
   c. When subgrade conditions dictate, use movable protective layer (e.g. Super GripNet® rub sheet) directly below each overlap of Super GripNet® that is to be seamed to prevent buildup of moisture between sheets and prevent debris from collecting around pressure rollers. Rub sheet shall be removed from under the liner once seaming is complete.

3. Use extrusion fillet welding as secondary method for seaming between adjacent panels and as primary method of welding for detail and repair work.

   a. Purge heat-degraded extrudate from barrel of extruder
   b. Place smooth insulating plate or fabric beneath hot welding apparatus when not in use
   c. Use clean and dry welding rods or extrudate pellets.
   d. Clean dirt and debris from Super GripNet® surface prior to extrusion welding.
   e. Grind weld area to using suitable handheld equipment to prepare Super GripNet® surface for extrusion welding. Grind perpendicular to seam. Take care not to over-grind Super GripNet®
   f. Minimize exposed grinding marks adjacent to extrusion weld. Do not allow exposed grinding marks to extend more than 1/4-inch outside finished seam area.
   g. Complete extrusion welding within one (1) hour of seaming operation grinding process without damaging Super GripNet®

G. Seaming Procedures

1. General Seaming Procedures - Ambient temperature between 32°F (0°C) and 104°F (40°C).

   a. Do not field seam without Master Seamer being present.
   b. Seam only during dry conditions, i.e., no precipitation or other excessive moisture, such as fog or dew.
   c. Do not seam during excessive winds, except as needed to protect the work. Do not seam if wind creates unsafe working conditions.
   d. If required, use "rub-sheet" or similar hard surface directly under seam overlap to achieve proper support for seaming apparatus.
   e. Align panels to minimize wrinkles and/or "fishmouths" in welds.
   f. Extend seams to outside edge of panels placed in anchor trench.
   g. Prior to seaming, ensure that seam area is free of moisture, dust, dirt, debris, or foreign material.
   h. "Fishmouths" or wrinkles at seam overlaps shall be cut along ridge of wrinkle in order to achieve flat overlap. Cut "fishmouths" or wrinkles shall be seamed or patched in accordance with this Section.

2. Cold Weather Seaming Procedures (ambient temperature is below 32°F (0°C)).

   a. No seaming of Super GripNet® is permitted unless demonstrated to QAC that Super GripNet® seam quality will not be compromised.
   b. Additional destructive samples and/or field test strips shall be cut from seams welded under ambient temperature of 32°F (0°C), at QAC's discretion.

3. Warm Weather Procedures (ambient temperature is above 104°F (40°C)).

   a. No seaming of Super GripNet® is permitted unless demonstrated to QAC that Super GripNet® seam quality will not be compromised.
   b. Additional destructive samples and/or field test strips shall be cut from seams welded over ambient temperature of 104°F (40°C), at QAC's discretion.

H. Repair Procedures:

1. Acceptable repair procedures include following:

   a. Patching: Piece of same Super GripNet® material extrusion welded into place. Use to repair large holes, tears, nondispersed raw materials, and contamination by foreign matter. All panel intersections shall be patched.
   b. Capping: Strip of same Super GripNet® material extrusion welded into place over inadequate seam. Use to repair large lengths of failed seams.
   c. Spot welding or seaming (Grind and Weld): Bead of molten extrudate placed on flaw. Use to repair scuffing, dimpling, or other minor, localized flaws. Spot welding shall not be used to repair holes in the Super GripNet® liner.
   d. Removal and replacement: Remove bad seam and replace with strip of same Super GripNet® material welded into place. Use to repair large lengths of failed seams.

e. Extrusion welding flap: Repairs of this type shall not be used unless approved by QAC, and only if the flap is a minimum of 1.5 inches long. Repairs of this type shall not exceed 100 feet (30 meters) in length.

2. For each repair method:

   a. Ensure surfaces are clean, dry, and prepared in accordance with specified seaming process.
   b. Ensure seaming equipment used in repairing procedures meet requirements of this Specification.
   c. Extend patches or caps at least 6 inches (150 millimeters) beyond edge of defect. Round corners of patches with radius of approximately 6 inches (150 millimeters).

I. Anchor Trench:

1. CONTRACTOR shall excavate anchor trenches to lines and grades shown on Construction Drawings prior to Super GripNet® placement, unless otherwise specified.
2. CONTRACTOR shall provide anchor trench with slightly rounded corners shall be provided, to avoid sharp bends in Super GripNet®.
3. INSTALLER shall provide and use plywood, boards, or other suitable materials, to permit welding machines to weld across, rather than through, anchor trenches.
4. CONTRACTOR shall dewater the completed anchor trench, to prevent ponding or softening of adjacent soils while trench is open.
5. CONTRACTOR and INSTALLER shall coordinate operations to minimize time anchor trench remains open and uncovered.
6. INSTALLER shall provide sufficient temporary ballast to prevent geosynthetics from being pulled or blown from the anchor trench.
7. CONTRACTOR and INSTALLER shall remove debris related to their respective construction activities, including temporary ballast material, from anchor trench, prior to installation of subsequent materials. The anchor trench shall be cleaned to the satisfaction of the QAC.
8. CONTRACTOR shall backfill and compact anchor trench as soon as practical after geosynthetic installation is completed. Anchor trench shall be backfilled prior to placing leachate drainage layer material. Refer to specification section 02223 “Backfill and Fill” for backfilling procedure.

3.04 FIELD QUALITY ASSURANCE AND QUALITY CONTROL

A. Visual Inspection:

1. QAC will examine seam and non-seam areas of Super GripNet® to identify defects, holes, blisters, nondispersed raw materials, and any sign of contamination by foreign matter.

B. Trial Seams:

1. Make trial seams on fragment pieces of Super GripNet® liner to verify that conditions are adequate for production seaming.
2. Make trial seams for each combination of materials to be welded (i.e., textured/smooth, smooth/smooth, textured/textured). Seamers may only weld those combinations for which they have produced acceptable trial welds. Seamers are not required to produce trial seams for material combinations they will not be welding.

3. Make trial seams at beginning of each seaming period, following restart of welding equipment, upon change of seamers, and at least once every five (5) hours, for each production seaming apparatus used that day.
4. Make trial seams using the same materials and under the under same conditions as production welding.
5. Trial seam sample shall be at least 4-feet (1.2 meters) long by 1-foot (0.3 meters) wide (after seaming) with seam centered lengthwise.
6. Cut six (6) test specimens from sample, using 1-inch (25 millimeters) wide die cutter. These specimen locations shall be selected randomly along trial seam sample by QAC. Test three (3) specimens in peel and three (3) specimens in shear, using field tensiometer. Samples shall fail in film tear bond (FTB) mode. Trial seams shall meet the following minimum strengths:

Table 02601-4: Seam Strength Values for Trial Seams and Destructive Sample Testing

PROPERTY	METHOD	50 MIL LLDPE SUPER GRIPNET® LINER SPECIFIED VALUE
Shear Strength	ASTM D6392	75 lbs/in (min.)
Peel Adhesion: Fusion Extrusion	ASTM D6392 ASTM D6392	63 lbs/in (min.) 57 lbs/in (min.)
For shear tests, sheet shall yield before failure of seam. For peel adhesion, seam separation shall not extend more than 25 percent of seam width into seam. For either test, testing shall be discontinued when sample has visually yielded. Four (4) out of 5 specimens shall meet the, or exceed, the values listed for shear and peel. The 5th specimen can be as low as 80%.		

7. If specimen fails, the INSTALLER will attempt to identify the cause of the failure (e.g., mechanical malfunction, dirt in weld). On correction of the deficiency, the seamer shall produce a second trial seam. If the second trial seam fails, the seamer shall not be permitted to weld production seams until deficiencies are corrected and two (2) consecutive successful trial welds are achieved. If mechanical failure is determined to be the cause of the second trial seam failure, the machine shall be removed from service until suitable repairs are made. The seamer shall be required to produce a passing trial seam with the replacement machine.

C. Non-destructive Seam Testing:

1. General:

a. Purpose of non-destructive tests is to check continuity of seams. It will not provide quantitative information on seam strength.
b. Non-destructively test field seams over their full length using vacuum test for extrusion seams, air pressure for double-fusion seams, or other QAC approved method. QAC shall document results.
c. Perform non-destructive testing as seaming work progresses.
d. The QAC shall observe all non-destructive testing on a full-time basis. The INSTALLER and QAC shall coordinate to ensure that all installation activities are monitored by the QAC in accordance with these Specifications.

2. Vacuum Testing for extrusion seam:

   a. Energize vacuum pump and reduce tank pressure to approximately 5 pounds per square inch [gauge] (psig) (10 inches of Hg) (35 kPa) gauge pressure.
   b. Wet strip of extrusion seam approximately 12 inches by 48 inches (0.3 m by 1.2 meters) with soapy solution.
   c. Ensure viewing window is clean.
   d. Place box over wetted area.
   e. Close bleed valve and open vacuum valve.
   f. Ensure that leak-tight seal is created.
   g. For minimum of 10 seconds, apply vacuum and examine Super GripNet® through viewing window for presence of soap bubbles.
   h. If no bubbles appear within 10 seconds, close vacuum valve and open bleed valve, move box over to next adjoining area with minimum 3-inch (75 -millimeter) overlap and repeat process.
   i. Mark and repair areas where soap bubbles appear.

3. Air Pressure Testing for dual track, hot wedge fusion weld:

   a. Seal both ends of seam to be tested. Take suitable precautions if sealing seam ends with open flame.
   b. Insert needle or other approved pressure feed device into air channel created by fusion weld.
   c. Insert protective cushion between air pump and Super GripNet®.
   d. Pressurize air channel to approximately 30 psig (206 kPa). Close valve and allow pressure to stabilize for approximately two (2) minutes.
   e. Observe air pressure 5 minutes after initial stabilization period ends. If pressure loss exceeds 4 psig or pressure does not stabilize, locate faulty area, repair, and retest.
   f. On completion of testing, cut opposite end of tested seam length to verify continuity of air channel. If air does not escape, locate blockage and retest unpressurized area. Repair cut end of air channel.
   g. Cap any seam length that cannot be successfully air pressure tested.
   h. Remove needle or other approved pressure feed device and repair hole in Super GripNet®.

4. Inaccessible Seams:

   a. Cap-strip seams that cannot be nondestructively tested.
   b. Cap-strip material shall be composed of same type and thickness as Super GripNet® to be capped.
   c. Examine cap-stripping operations with QAC for uniformity and completeness. Document observations.

D. Destructive Seam Testing:

1. General:

   a. Purpose of destructive seam testing to evaluate seam strength.
   b. Perform destructive seam test as seaming progresses.
   c. The destructive seam sample shall fail if the overlap is insufficient for grips of testing machine to close on sample (available flap is 1/2 inch long or less).

2. Location and frequency:

   a. Test at minimum frequency of one (1) test location per 500 feet (150 meters) of welding length performed by each welding machine. This minimum frequency to be determined as an average taken from the total linear footage of seaming, per machine, at the end of the Super GripNet® installation.
   b. Test locations shall be determined by the QAC, during seaming operations.
   c. INSTALLER will not be informed in advance of locations where seam samples will be taken.
   d. QAC reserves right to increase frequency of testing in accordance with performance results of samples previously tested.

3. Sampling Procedures:

   a. Cut samples at locations selected by QAC.
   b. QAC shall number each sample and record sample number and location in panel layout drawing.
   c. QAC shall mark each section of destructive test sample with sample number, seam number, seamer and machine identification, and date.
   d. Repair holes in Super GripNet® resulting from destructive seam sampling as soon as possible, in accordance with repair procedures described in this Section.
   e. Non-destructively test repairs in accordance with this Section.

4. Sample Dimensions:

   a. Field Testing: Cut two (2) 1-inch (25 millimeters) wide sample coupons, from each end of seam section identified by QAC. Distance between these two (2) samples shall be approximately 42 inches (1.1 meters). Test both samples in peel mode, using field tensiometer. If both samples meet requirements of Table 4 located in Section 3.04 B item 6, collect sample for laboratory testing.
   b. Laboratory Testing: Collect laboratory test sample from seam length between field test sample coupon locations. Cut sample for laboratory testing, approximately 12 inches (0.3 meters) wide by a minimum 42-inches (1.1 meters) long, with seam centered lengthwise. Cut this sample into three (3) sections. QAC shall distribute sample sections as follows:

      1) Geosynthetic Quality Assurance Laboratory: minimum 18-inch (0.5 meters) long section for laboratory testing.
      2) INSTALLER: minimum 12 inches (0.3 meters) long section for archive or optional laboratory testing.
      3) QAC: minimum 12 inches (0.3 meters) long section for archive storage.

   c. Final determination of sample sizes shall be agreed upon at the geosynthetics kick-off meeting. Sample sizes shall be minimized, consistent with laboratory testing requirements.
   d. Submit laboratory sample for quantitative testing in accordance with the CQA Plan.

5. Destructive Test Failure Procedures:

When sample fails destructive testing, whether test is conducted in the field or at Geosynthetic Quality Assurance Laboratory, CONTRACTOR has following options:

a. Repair entire seam between two (2) passing destructive test locations along the path of machine producing the failed weld bracketing the failed location.
b. Trace welding path 10-feet (3 meters) minimum in each direction from failed test, and repeat field-testing procedures indicated in this Section at each location. If these additional samples pass field test, then collect laboratory test samples. If these laboratory samples pass tests, repair seam between these locations. If either, or both, sample fails, repeat process until passing sample is located. If necessary, tracking will extend back to previous days of welding until a passing sample is located. Repair seam between passing destructive sample locations.
c. Acceptable repaired seams shall be bound by passing laboratory destructive tests locations. The QAC shall mark and additional destructive test sample for seam cap strip repairs of 150 feet (45 meters) or more.
d. If a destructive test sample fails, QAC may require additional testing of seams welded by same seamer and/or welding apparatus produced during same time shift as failed seam.

E. Repair Verification:

1. Repairs shall be non-destructively tested.
2. Nondestructive test results that pass shall indicate adequate repair.
3. Destructive test samples shall be collected on repairs 100-feet long, or greater. Frequency may be increased at the discretion of the QAC.
4. In the event destructive or nondestructive tests of repairs fail to meet the requirements of this Section, the work will be redone, at no expense to the OWNER, until passing test results are achieved.
5. QAC shall monitor and document Super GripNet® repairs, and non-destructive testing.

F. Large Wrinkles: Wrinkle is considered to be large when Super GripNet® can be folded over onto itself during the coolest part of the day.

1. When seaming of Super GripNet® is completed, and prior to placing overlying materials, QAC shall identify all large Super GripNet® wrinkles, to be repaired.
2. Cut and repair all wrinkles identified by QAC. Welds produced while repairing wrinkles shall be nondestructively tested.
3. Repair wrinkles identified by QAC. Repair during coldest part of installation period.

*****END OF SECTION*****

SECTION 02715

GEOCOMPOSITE

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, tools, supervision, transportation, and equipment necessary for the installation of the geocomposite as specified herein, as shown on the Contract Drawings, and in accordance with the Construction Quality Assurance (CQA) Plan.

B. The CONTRACTOR shall be prepared to install the geocomposite in conjunction with the other components of the ash landfill closure system.

1.02 SUBMITTALS

A. Prior to the shipment of any geocomposite rolls to be furnished by the CONTRACTOR, the CONTRACTOR shall submit to the OWNER's QUALITY ASSURANCE CONSULTANT (QAC) the following documentation on geocomposite production.

1. Resin quality control certificates for each batch of resin. The resin certificates shall identify the manufacturer and origin of the resin and the polymer composition of the resin.
2. A statement listing:
    a. certified minimum roll property values of the proposed geocomposite and the tests used to determine those properties; and
    b. production capacity available and projected delivery dates for this project.
3. Manufacturing quality control certificates for each shift's production. The certificates shall be signed by responsible parties employed by the manufacturer (such as the production manager). The quality control certificates shall include:
    a. roll numbers and identification; and
    b. results of quality control tests, including a description of the test methods used.
4. A description of the sampling procedures used for the manufacturing quality control testing.

Geocomposite Manufacturer quality control tests to be performed are outlined in Part 2.02 of this Section.

B. The Geocomposite Manufacturer shall submit documentation that the geocomposite meets the property values listed on Table 02715-1 and that the geocomposite will:

1. retain structure during handling, placement, and long-term service; and
2. be capable of withstanding direct exposure to sunlight for a minimum of 30 days with no measurable deterioration

1.03 CONSTRUCTION QUALITY ASSURANCE

A. The installation of the geocomposite shall be monitored and tested by the QAC as outlined in the CQA Plan.

B. Installed material that does not conform to these specifications, whether tested by the CONTRACTOR or the QAC, shall be rejected and shall be repaired by the CONTRACTOR at no cost to the OWNER.

C. The CONTRACTOR shall be aware of the activities outlined in the CQA Plan and shall account for these CQA activities in the installation schedule.

1.04 RESPONSIBILITY

A. The CONTRACTOR shall furnish all geocomposite. The CONTRACTOR shall retain a Geocomposite Manufacturer who shall be responsible for production and delivery of the geocomposite and shall be a well-established firm with experience in the manufacture of geocomposite.

B. The CONTRACTOR shall install the geocomposite. The Geosynthetic Installer shall be responsible for field handling, storing, deploying, seaming or joining, temporary restraining (against wind), anchoring systems, and other site aspects of the geocomposite.

C. The CONTRACTOR shall accept and retain full responsibility for installation of the geocomposite and shall be held responsible for any defects in the completed system.

PART 2 - PRODUCTS

2.01 GEOCOMPOSITE MATERIAL

A. The geocomposite shall exhibit "Minimum Roll Values", as defined by the Federal Highway Administration (FHWA), meet or exceed the criteria specified on Table 02715-1. The Geocomposite Manufacturer shall provide test results for these procedures, as well as a certification that the material meet or exceed the specified values. The geocomposite provided by the Geocomposite Manufacturer shall be stock products. The Geocomposite Manufacturer shall not furnish products specifically manufactured to meet the Specifications of the Project unless authorized by the OWNER and the OWNER's QAC.

B. The geocomposite shall be composed of a high-density polyethylene drainage net with a nonwoven, needle-punched geotextile bonded to both sides of the drainage net. The geotextile shall not be glued or bonded to the geonet in any manner other than heat bonding. Along edges, six inches of the geotextile shall not be heat bonded to the geonet to allow connection in the field.

2.02 MANUFACTURING QUALITY CONTROL

A. The geocomposite shall be manufactured with quality control procedures that meet generally accepted industry standards.

B. The Geocomposite Manufacturer shall sample and test the geocomposite, at a minimum, once every 100,000 ft^2 to demonstrate that the material conforms to all requirements on Table 02715-1.

C. Sampling shall, in general, be performed on sacrificial portions of the material such that repair of the material is not required.

D. If a geocomposite sample fails to meet the quality control requirements of this section, then the Geocomposite Manufacturer shall sample and test each roll manufactured in the same lot, or at the same time, as the failing roll. Geocomposite rolls not meeting the required specifications will be rejected.

E. Additional sample testing may be performed at the Geocomposite Manufacturer's discretion and expense to more closely identify the noncomplying rolls and/or to qualify individual rolls.

2.03 PACKING AND LABELING

A. Geocomposite material shall be supplied in rolls wrapped in waterproof and opaque protective covers.

B. Geocomposite rolls shall be labeled with the following information:
   1. Manufacturer's name;
   2. Product identification;
   3. Lot number;
   4. Roll number; and
   5. Roll dimension.

2.04 TRANSPORTATION

A. The CONTRACTOR shall be responsible for transportation of all geotextiles. Geocomposite Manufacturer shall be liable for all damages to the materials incurred prior to and during transportation to the Site. The CONTRACTOR shall be responsible and held liable for all damages to the material once the material is on site.

B. Geocomposite material shall be delivered to the Site at least 14 days before scheduled date of deployment to allow the QAC adequate time to inventory and sample the geocomposite rolls and perform conformance testing on the samples.

2.05 HANDLING AND STORAGE

A. The CONTRACTOR shall be responsible for handling, storing, and caring for the geocomposite material prior to and following installation at the Site. The CONTRACTOR shall be liable for all damages to the materials incurred prior to final acceptance of the cover system by the OWNER

B. The CONTRACTOR shall be responsible for storage of the geocomposite material at the Site. The geocomposite shall be protected from moisture, long-term direct exposure to sunlight, puncture, or other damaging or deleterious conditions. The geocomposite material shall be stored off the ground and out of direct sunlight, and shall be protected from mud, dirt, and dust. Any additional storage procedures required by the Manufacturer or QAC shall be the CONTRACTOR's responsibility

PART 3 – EXECUTION

3.01 HANDLING AND PLACEMENT

A. The CONTRACTOR shall handle all geocomposite material in such a manner as to ensure the geocomposite material is not damaged in any way.

B. The CONTRACTOR shall take all necessary precautions to prevent damage to underlying layers during placement of the geocomposite layers.

C. The CONTRACTOR shall ballast the geocomposite layers with sandbags to prevent displacement of the geocomposite by wind. Such sandbags shall be installed during placement and shall remain on the geocomposite until it is covered with soil. Care shall be exercised when handling sandbags, to prevent rupture or damage of the sandbags.

D. The geocomposite shall be-rolled down the slope in such a manner as to continually keep the geocomposite in tension.

E. The geocomposite shall be positioned by hand after being unrolled to minimize wrinkles.

F. Care shall be taken during placement of geocomposite material not to trap dirt or excessive dust in the geonet that could cause clogging of the drainage system, and/or stones that could damage the adjacent cover. If dirt or excessive dust is entrapped in the geocomposite layer, then it should be cleaned prior to placement of the next material on top of it.

G. Geocomposite materials shall only be cut using scissors or a hook blade utility knife.

H. Geocomposite materials shall not be welded to covers.

I. Tools shall not be left on or in the geocomposite.

J. After unwrapping the geocomposite material from its opaque cover, the geocomposite material shall not be left exposed for a period in excess of 30 days unless a longer exposure period is approved by the QAC. Such approval shall be based on a formal demonstration from the Manufacturer that the geotextile component of the composite is stabilized against ultraviolet degradation for a period in excess of 30 days.

3.02 SEAMS AND OVERLAPS

A. The components of the geocomposite (i.e., geotextile-geonet-geotextile) are not to be bonded together at the ends and edges of the rolls. Each component will be secured or seamed to the like component at overlaps.

B. Geonet Components

1. The geonet components shall be overlapped by at least 4-in. These overlaps shall be secured by tying.
2. Tying shall be achieved by plastic fasteners, or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic devices shall not be used.
3. Tying shall be every 5 ft along the slope, every 2 ft across the slope, every 6-in. in the anchor trenches and on end-to-end seams, and every 10 ft on horizontal surfaces

C. Geotextile Components

a. The bottom and top layers of geotextile shall be overlapped a minimum of 6-in. prior to seaming.

3.03 REPAIR

A. Any holes or tears in the geocomposite material shall be repaired by placing a patch extending 2-ft beyond the edges of the hole or tear. The patch shall be secured by tying fasteners through the bottom geotextile and the geonet of the patch, and through the top geotextile and geonet components of the geocomposite needing repair. The patch shall be secured every 6-in. with approved tying devices. The top geotextile component of the patch shall be heat sealed to the top geotextile of the geocomposite needing repair. If the hole or tear width across the roll is more than 50 percent of the width of the roll, then the entire damaged geocomposite panel shall be removed and replaced:

3.04 PLACEMENT OF SOIL MATERIALS

A. The CONTRACTOR shall place all soil materials on top of geocomposite such that:

1. The geocomposite and underlying materials are not damaged;
2. Minimum slippage occurs between the geocomposite and underlying layers; and
3. Excess stresses are not induced in the geocomposite.

B. Equipment shall not be driven directly on the geocomposite. Unless otherwise specified by the OWNER's QAC, all equipment operating on earthen materials overlying the geocomposite shall comply with the following.

Allowable Equipment Ground Pressure (psi)	**Thickness of Overlying Compaction Soil (feet)**
<5	1.0
<10	1.5
<20	2.0
>20	3.0

3.05 PRODUCT PROTECTION

A. The CONTRACTOR shall use all means necessary to protect all prior work and all materials and completed work of other sections:

B. In the event of damage, the CONTRACTOR shall immediately make all repairs and replacements necessary, to the approval of the QAC and at no additional cost to the OWNER:

TABLE 02715-1

GEOCOMPOSITE PROPERTY VALUES (1)

Properties	Qualifiers	Units	Values	Test Method
Geonet Component				
Density(2)	Minimum	g/cc	0.94	ASTM D792
Carbon Black Content	Minimum	%	2.0 – 3.0	ASTM D1603
Thickness	Minimum	Mils	250	ASTM D5199
Tensile Strength		Lb/in	55	ASTM D638
Geotextile Component				
Construction			Nonwoven	
Apparent Opening Size	maximum	Mm	O95≤0.18 mm	ASTM D4751
Flow Rate	Minimum	Gpm/ft^2	110	ASTM D4491
Puncture Strength	Minimum	Lb.	110	ASTM D4833
Grab Strength	Minimum	Lb	200	ASTM D4632
Geocomposite				
Transmissivity(3)				
Gradient of 0.14	Minimum	m^2/s	8×10^{-4}	ASTM D4716
Direct Shear(5)	Minimum	Degrees	19	ASTM D5321

Notes: (1) All values represent minimum roll values (i.e., test results tor samples collected from any roll in a lot should meet or exceed these values).

(2) The density of the net resin shall not exceed that of the geomembrane (see Sections 02596 through 02601).

(3) Transmissivity to be measured using water at 68°F (20°C), under a confining pressure of at least 500 psf for the final closure system. The geocomposite shall be placed in the testing device between the selected and approved textured geomembrane and cover system soil. Measurements are taken 100 hours after application of confining pressure.

(4) Minimum of values measured in machine and cross machine directions with 1 in. clamp on Constant Rate of Extension (CRE) machine.

(5) Direct shear testing shall be performed by the CONTRACTOR on the entire liner system cross section using the proposed liner system materials (i.e. cover soil, geocomposite, geomembrane, geotextile, and grading fill). Testing shall be performed at 100, 250, and 500 psf normal stresses.

*****END OF SECTION*****

SECTION 02716

DRAINTUBE GEOCOMPOSITE

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, tools, supervision, transportation, and equipment necessary for the installation of DrainTube drainage geocomposite for the ash landfill closure system as specified herein, and as shown on the Contract Drawings.

B. The CONTRACTOR shall furnish all labor, materials, tools, supervision, transportation, and equipment necessary for the installation of the DrainTube geocomposite as specified herein, as shown on the Contract Drawings, and in accordance with the Construction Quality Assurance (CQA) Plan.

C. The CONTRACTOR shall be prepared to install the DrainTube geocomposite in conjunction with the other components of the ash landfill closure system.

1.02 SUBMITTALS

A. Prior to the shipment of any DrainTube geocomposite rolls to be furnished by the CONTRACTOR, the CONTRACTOR shall submit to the OWNER's QUALITY ASSURANCE CONSULTANT (QAC) the following documentation on geocomposite production.

1. Resin quality control certificates for each batch of resin. The resin certificates shall identify the manufacturer and origin of the resin and the polymer composition of the resin.
2. A statement listing:
    a. certified minimum roll property values of the proposed DrainTube geocomposite and the tests used to determine those properties; and
    b. production capacity available and projected delivery dates for this project.
3. Manufacturing quality control certificates for each shift's production. The certificates shall be signed by responsible parties employed by the manufacturer (such as the production manager). The quality control certificates shall include:
    a. roll numbers and identification; and
    b. results of quality control tests, including a description of the test methods used.
4. A description of the sampling procedures used for the manufacturing quality control testing.

DrainTube Manufacturer quality control tests to be performed are outlined in Part 2.02 of this Section.

B. The DrainTube Manufacturer shall submit documentation that the DrainTube geocomposite meets the property values listed on Table 02716-1 and that the DrainTube geocomposite will:
   1. retain structure during handling, placement, and long-term service; and
   2. be capable of withstanding direct exposure to sunlight for a minimum of 30 days with no measurable deterioration

1.03 CONSTRUCTION QUALITY ASSURANCE

A. The installation of the DrainTube geocomposite shall be monitored and tested by the QAC as outlined in the CQA Plan.

B. Installed material that does not conform to these specifications, whether tested by the CONTRACTOR or the QAC, shall be rejected and shall be repaired by the CONTRACTOR at no cost to the OWNER.

C. The CONTRACTOR shall be aware of the activities outlined in the CQA Plan and shall account for these CQA activities in the installation schedule.

1.04 RESPONSIBILITY

A. The CONTRACTOR shall furnish all DrainTube geocomposite. The CONTRACTOR shall retain a DrainTube Manufacturer who shall be responsible for production and delivery of the DrainTube geocomposite and shall be a well-established firm with experience in the manufacture of geocomposite.

B. The CONTRACTOR shall install the DrainTube geocomposite. The Geosynthetic Installer shall be responsible for field handling, storing, deploying, seaming or joining, temporary restraining (against wind), anchoring systems, and other site aspects of the DrainTube geocomposite.

C. The CONTRACTOR shall accept and retain full responsibility for installation of the DrainTube geocomposite and shall be held responsible for any defects in the completed system.

PART 2 - PRODUCTS

2.01 DrainTube GEOCOMPOSITE MATERIAL

A. DrainTube Gecomposite shall be DrainTube 808 ST4 D25 manufactured by Afitex-Texel or alternate approved by the QAC.

B. The DrainTube geocomposite shall exhibit "Minimum Roll Values", as defined by the Federal Highway Administration (FHWA), meet or exceed the criteria specified on Table 02716-1. The DrainTube Manufacturer shall provide test results for these procedures, as well as a certification that the material meet or exceed the specified values. The geocomposite provided by the DrainTube Manufacturer shall be stock products. The DrainTube Manufacturer shall not furnish products specifically manufactured to meet the Specifications of the Project unless authorized by the OWNER and the OWNER's QAC.

C. DrainTube geocomposite shall consist of two or three geotextile layers comprised of short synthetic staple fibers of 100% polypropylene or polyester needle-punched together with perforated corrugated polypropylene pipes regularly spaced inside.

D. The perforated polypropylene pipes shall function as the primary fluid conveyance. The pipes shall be corrugated with two perforations per corrugation at 180° and alternating at 90°.

2.02 MANUFACTURING QUALITY CONTROL

A. The DrainTube geocomposite shall be manufactured with quality control procedures that meet generally accepted industry standards.

B. The DrainTube Manufacturer shall sample and test the DrainTube geocomposite, at a minimum, once every 100,000 ft^2 to demonstrate that the material conforms to all requirements on Table 02716-1.

C. Sampling shall, in general, be performed on sacrificial portions of the material such that repair of the material is not required.

D. If a DrainTube geocomposite sample fails to meet the quality control requirements of this section, then the DrainTube Manufacturer shall sample and test each roll manufactured in the same lot, or at the same time, as the failing roll. DrainTube geocomposite rolls not meeting the required specifications will be rejected.

E. Additional sample testing may be performed at the DrainTube Manufacturer's discretion and expense to more closely identify the noncomplying rolls and/or to qualify individual rolls.

2.03 PACKING AND LABELING

A. DrainTube geocomposite material shall be supplied in rolls wrapped in waterproof and opaque protective covers.

B. DrainTube geocomposite rolls shall be labeled with the following information:
1. Manufacturer’s name;
2. Product identification;
3. Lot number;
4. Roll number; and
5. Roll dimension.

2.04 TRANSPORTATION

A. The CONTRACTOR shall be responsible for transportation of all geosynthetics. DrainTube Manufacturer shall be liable for all damages to the materials incurred prior to and during transportation to the Site. The CONTRACTOR shall be responsible and held liable for all damages to the material once the material is on site.

B. DrainTube geocomposite material shall be delivered to the Site at least 14 days before scheduled date of deployment to allow the QAC adequate time to inventory and sample the DrainTube geocomposite rolls and perform conformance testing on the samples.

2.05 HANDLING AND STORAGE

A. The CONTRACTOR shall be responsible for handling, storing, and caring for the DrainTube geocomposite material prior to and following installation at the Site.

The CONTRACTOR shall be liable for all damages to the materials incurred prior to final acceptance of the cover system by the OWNER

B. The CONTRACTOR shall be responsible for storage of the DrainTube geocomposite material at the Site. The geocomposite shall be protected from moisture, long-term direct exposure to sunlight, puncture, or other damaging or deleterious conditions. The DrainTube geocomposite material shall be stored off the ground and out of direct sunlight, and shall be protected from mud, dirt, and dust. Any additional storage procedures required by the Manufacturer or QAC shall be the CONTRACTOR's responsibility.

PART 3 – EXECUTION

3.01 HANDLING AND PLACEMENT

A. The CONTRACTOR shall handle all DrainTube geocomposite material in such a manner as to ensure the DrainTube geocomposite material is not damaged in any way.

B. The CONTRACTOR shall take all necessary precautions to prevent damage to underlying layers during placement of the DrainTube geocomposite layers.

C. The CONTRACTOR shall ballast the DrainTube geocomposite layers with sandbags to prevent displacement of the DrainTube geocomposite by wind. Such sandbags shall be installed during placement and shall remain on the DrainTube geocomposite until it is covered with soil. Care shall be exercised when handling sandbags, to prevent rupture or damage of the sandbags.

D. The DrainTube geocomposite shall be-rolled down the slope in such a manner as to continually keep the geocomposite in tension.

E. The DrainTube geocomposite shall be positioned by hand after being unrolled to minimize wrinkles.

F. DrainTube Drainage Geocomposite shall not be placed, seamed/joined, or repaired during periods of precipitation, excessively high winds, or in areas of ponded water or excessive moisture.

G. Care shall be taken during placement of DrainTube geocomposite material not to trap dirt or excessive dust in the perforated pipes that could cause clogging of the drainage system, and/or stones that could damage the adjacent cover. If dirt or excessive dust is entrapped in the DrainTube pipes, then it should be cleaned prior to placement of the next material on top of it.

H. DrainTube geocomposite materials shall only be cut using scissors or a hook blade utility knife.

I. Geocomposite materials shall not be welded to covers.

J. Tools shall not be left on or in the geocomposite.

K. After unwrapping the geocomposite material from its opaque cover, the geocomposite material shall not be left exposed for a period in excess of 30 days unless a longer exposure period is approved by the QAC. Such approval shall be based on a formal demonstration from the Manufacturer that the geotextile component of the composite is stabilized against ultraviolet degradation for a period in excess of 30 days.

L. If the roll length cannot cover entire slope, the locations of connections of adjacent panels should be staggered at least 3 meters (10 feet) apart.

M. DrainTube Geocomposite shall be installed in accordance with manufacturer's recommendations, and as shown on the Drawings and specified herein.

3.02 SEAMS AND OVERLAPS

A. The components of the DrainTube geocomposite (i.e., geotextile-perforated pipes) are not to be bonded together at the ends and edges of the rolls. Each component will be secured or seamed to the like component at overlaps.

B. Adjacent sheets of DrainTube Geocomposite shall be overlapped as described below.

1. Connections at along the side of the DrainTube Geocomposite roll shall be overlapped 250 mm (10 inches) and shall be secured using sewn seams, additional overlap, or welds (hot air or flame).

2. Connection at the leading or terminating edge of the DrainTube Geocomposite shall be overlapped such that the upper geotextile layer can be rolled back 250 mm (10 inches) and the end of the next roll inserted into the opening. Pipes shall be connected either using a snap coupler fitting supplied by the geocomposite manufacturer or by overlapping the pipes by 250 mm (10 inches) minimum.

C. Connections to an interceptor drain pipe shall conform to the Contract Drawings and be at the direction of QAC.

3.03 REPAIR

A. Prior to covering the deployed DrainTube Drainage Geocomposite, each roll shall be inspected for damage.

B. Any rips, tears or damaged areas on the geocomposite shall be removed and patched.

1. If a section of pipe is damaged during installation, add a piece of undamaged pipe of the same diameter next to the damaged pipe, extending a minimum of 200 mm (8 inches) beyond each end of the damaged section of pipe.
2. If the geotextile is ripped or torn, install an undamaged piece of the same material under the hole that extends a minimum of 150 mm (6 inches) beyond the hole in all directions to ensure that protection of the geomembrane is maintained.
3. If the area to be repaired is more than 50 percent of the width of the panel, then the damaged area shall be cut out and replaced with undamaged material. Damaged geotextile shall be replaced by the same type of geotextile.

3.04 PLACEMENT OF SOIL MATERIALS

A. The CONTRACTOR shall place all soil materials on top of geocomposite such that:
   1. The geocomposite and underlying materials are not damaged;
   2. Minimum slippage occurs between the geocomposite and underlying layers; and
   3. Excess stresses are not induced in the geocomposite.

B. The cover soil shall be placed on the DrainTube Geocomposite in a manner that prevents damage to the DrainTube Geocomposite. Placement of the cover soil shall proceed immediately following the placement and inspection of the DrainTube Geocomposite.

C. Cover soil shall be free of matter that could damage the DrainTube Geocomposite.

D. Cover soil shall be placed from the bottom of the slope and shall not be dropped directly onto the DrainTube Geocomposite from a height greater than 1 meter (3 feet). Cover shall be pushed over the DrainTube Geocomposite in an upward tumbling motion that prevents wrinkles in the DrainTube Geocomposite.

E. The initial loose lift thickness of soil shall be 300 mm (12 inches) or less using adapted construction methods. Compaction shall consist of a minimum of 2 passes over all areas. The loose lift thickness of each subsequent list shall be no greater than 300 mm (12 inches). Normal soil placement shall be allowed on areas after the second loose lift of fill has been placed and compacted

F. Equipment shall not be driven directly on the geocomposite. Unless otherwise specified by the QAC, all equipment operating on earthen materials overlying the geocomposite shall comply with the following.

Allowable Equipment Ground Pressure (psi)	Thickness of Overlying Compaction Soil (feet)
<5	1.0
<10	1.5
<20	2.0
>20	3.0

3.05 PRODUCT PROTECTION

A. The CONTRACTOR shall use all means necessary to protect all prior work and all materials and completed work of other sections:

B. In the event of damage, the CONTRACTOR shall immediately make all repairs and replacements necessary, to the approval of the QAC and at no additional cost to the OWNER.

C. DrainTube Geocomposite shall be covered by soil or another geosynthetic so that the material is not exposed to ultraviolet rays for more than 14 days before being covered.

TABLE 02716-1

DRAINTUBE GEOCOMPOSITE PROPERTY VALUES [(1)]

Properties	Qualifiers	Units	Values	Test Method
Mini Pipe Component				
Outside Diameter	Minimum	in	1.0	ASTM D2122
Stiffness at 5% Deflection	Minimum	psi	435	ASTM D2412
Geotextile Component				
Mass per Unit Area	Minimum	oz/sy	8	ASTM D5261
Apparent Opening Size[(1)]	Maximum	mm	O95≤0.18 mm	ASTM D4751
Water Flow Rate	Minimum	Gpm/ft^2	100	ASTM D4491
CBR Puncture Strength	Minimum	lb.	600	ASTM D6241
Trapezoidal Tear Strength	Minimum	lb.	90	ASTM D4533
Grab Strength	Minimum	lb.	220	ASTM D4632
Geocomposite				
Transmissivity[(2)]				
Gradient of 0.14	Minimum	m^2/s	8×10^{-4}	ASTM D 4716
Direct Shear[(3)]	Minimum	Degrees	19	ASTM D5321

Notes: -

(1) Maximum Average Value.

(2) Value at a gradient of 0.14 when tested with boundary conditions consisting of sealed sand / geocomposite / geomembrane / sealed sand. The seating time, with a uniformly applied load of 500 psf shall be a minimum of 100 hours.

(3) Direct shear testing shall be performed by the CONTRACTOR on the entire liner system cross section using the proposed liner system materials (i.e. cover soil, geocomposite, geomembrane, geotextile, and grading fill). Testing shall be performed at 100, 250, and 500 psf normal stresses.

*****END OF SECTION*****

SECTION 02936

SEEDING

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools, and incidentals required to complete the temporary and permanent seeding of all areas disturbed or regarded during the performance of the Work, including seed, mulch, temporary protection and watering, as required, during the course of construction as shown on the Contract Drawings.

B. Apply lime, fertilizer, seed, and mulch to all topsoiled areas disturbed by the work not receiving a specific surfacing.

C. The CONTRACTOR shall comply with all applicable codes, ordinances, rules, regulations and laws of local, municipal, State or Federal authorities having jurisdiction. The CONTRACTOR shall provide a "Competent Person" to implement, supervise, and inspect the work.

1.02 SUBMITTALS

A. The CONTRACTOR shall submit a manufacturer's Certificate of Compliance for each seed mixture it proposes to use. These certificates shall include the guaranteed percentages of purity, weed content and germination of the seed, net weight, and the date of shipment. No seed may be sown until the CONTRACTOR has submitted these certificates and they have been favorably reviewed by the QUALITY ASSURANCE CONSULTANT (QAC).

B. The CONTRACTOR shall provide analysis of soil suitability to sustain vegetation. Analyze to ascertain percentage of nitrogen, phosphorus, potash, soluble salt content, organic matter content, and pH value by performing Baker or LaMotte Test, or other test approved by the QAC.

C. QAC shall review submitted information as specified for compliance with the specifications and vegetative stabilization recommendations of the Delaware Erosion and Sediment Control Handbook.

1.03 QUALITY ASSURANCE

A. A satisfactory stand of grass, as determined by the QAC, shall be required after seeding. For grass to be acceptable, bare spots shall be scattered, there shall be no bare spots larger than one square yard, and the stand of grass shall consist of a uniform stand of at least 75% established permanent grass species within 60 days of initial seeding and maintaining that stand of grass for one year after initial seeding.

B. Maintain erosion and sediment controls in accordance with Section 02125 of these Specifications.

PART 2 – PRODUCTS

2.01 SEED

A. Furnish seed from a seed dealer or grower whose brands are grades registered or licensed by the State of Delaware, Department of Agriculture or from the approved list of seed dealers or growers on file with the Department. Furnish the kind and type of seed required that meets current specifications on file with the Department as to percentage purity, percentage weed seed, and percentage germination. The CONTRACTOR shall submit seed mixtures and application rates for approval by QAC. The seed mixtures shall be appropriate mixes taken from Section 3.4 of Delaware Erosion and Sediment Control Handbook.

B. Seed on the final cap system shall be a shallow-rooted grass as recommended by the DNREC. Seed Mix No. 3 is the preferred mix for this application and shall be as follows:

TABLE 1 – FINAL CAP SEED MIX

Species	**Seeding Rate**	
	lb/Ac.	lb/ 1000 sq. ft.
Tall Fescue (Turf Type) **OR**	50	1.15
Strong Creeping Red Fescue **OR**	50	1.15
Perennial Ryegrass	50	1.15
PLUS Flatpea	15	0.34

C. Seed in the perimeter stormwater management channels shall be for poorly drained soils. Seed Mix No. 10 is the preferred mix for this application and shall be as follows:

TABLE 2 – PERIMETER STORMWATER CHANNEL SEED MIX

Species	**Seeding Rate**	
	lb/Ac.	lb/ 1000 sq. ft.
Reed Canarygrass	10	0.23

D. Quantities refer to Percent Live Seed. The CONTRACTOR may submit alternative seed mixtures and application rates, consistent with the most recent version of the State of Delaware Erosion and Sediment Control Handbook or similar Delaware State guidance, for approval by QAC.

E. Mark the test date on seed bags. Furnish seeds as separate species and cultivars, packaged together or bagged separately, and labeled, tagged, or marked according to Delaware Code Title 3 Chapter 15. Sow seeds within 9 months of the testing date. The QAC reserves the right to test, reject, or approve seed after delivery.

2.02 FERTILIZER

A. The CONTRACTOR shall obtain commercial fertilizer from a dealer or manufacturer whose brands and grades are registered or licensed by the State of Delaware, Department of Agriculture.

B. Commercial fertilizer may be dry or liquid. Apply standard commercial fertilizer 10-10-10 evenly over the surface at a standard dry application rate of 600 pounds per acre. Furnish liquid application rates for approval by the QAC.

C. The CONTRACTOR may provide other commercial fertilizer mixture ratios, however, ensure that the ratio meets or exceeds the standard commercial fertilizer ratio of 10-10-10 by providing an application rate specific for that ratio.

D. For areas of inter-seeding apply commercial fertilizer 12-12-12 over the affected area at the above rate.

E. For commercial fertilizer second application, the method, mixture, and rate is broadcast 12-12-12 evenly over the surface without incorporation into the soil at a rate of 10 pounds per 1000 square feet (0.05 kg/m^2).

2.03 MULCH

A. Mulch materials shall consist of straw, compost, or wood fiber for 3:1 or flatter slopes. The CONTRACTOR may specify which mulch to use, if it is not shown on the Construction Drawings or identified in these Specifications. Use mulch that is reasonably free of weed seed, foreign materials, or other materials that would prohibit seed germination.

B. The CONTRACTOR shall follow the Delaware Erosion and Sediment Control Manual for specifications regarding straw, compost, or wood fiber mulch.

2.04 LIME

A. The CONTRACTOR shall provide lime application in accordance with the Delaware Erosion and Sediment Control Manual.

PART 3 – EXECUTION

3.01 INSPECTION

A. The CONTRACTOR shall verify that prepared soil base is ready to receive the work of this Section.

B. The CONTRACTOR shall inspect seedbed just prior to seeding. If traffic has left the soil compacted, the area must be re-tilled.

3.02 DELIVERY, STORAGE AND HANDLING

A. The CONTRACTOR shall deliver grass seed mixture in sealed containers showing weight, seed mix, year of production, date of packaging, and location of packaging. Seed in damaged packaging shall not be acceptable.

B. The CONTRACTOR shall deliver fertilizer in waterproof bags showing weight, chemical analysis, and name of manufacturer. Fertilizer in damaged packaging is not acceptable.

3.03 LIMING

A. When required, ground limestone that has been protected from moisture, and is dry and free flowing, shall be evenly spread over the area to be seeded at a rate that will produce a pH value of 6.5 of the soil.

B. The CONTRACTOR shall work lime into vegetative layer to a depth of 4 to 6 inches with a disc, spring-tooth harrow, or other suitable equipment unless otherwise approved by the QAC.

3.04 FERTILIZING

A. The CONTRACTOR shall apply fertilizer in accordance with manufacturer's instructions.

B. The CONTRACTOR shall apply fertilizer after grading the vegetative support layer.

C. The CONTRACTOR shall not apply fertilizer at the same time or with the same machine as that will be used to apply seed unless hydroseeding.

D. The CONTRACTOR shall mix fertilizer thoroughly into the upper 4 to 6 inches of the vegetative layer with a disc, spring-tooth harrow, or other suitable equipment.

E. The CONTRACTOR shall lightly water ground surface with potable water to aid the dissipation of fertilizer.

3.05 SEEDING

A. Areas to be seeded shall be made friable and receptive to seeding prior to seeding. Under no circumstances will seeding be permitted in muddy, hard, or crusted soils.

B. The CONTRACTOR shall apply seed at the rates shown in Article 2.01 of this Section. Seed evenly in two intersecting directions. Rake in lightly. Do not seed area in excess of that which can be mulched on same day.

C. Any temporary or permanent seed shall be applied in conformance with the requirements of the Delaware Erosion and Sediment Control Manual.

D. Planting season shall be as recommended by the Delaware Erosion and Sediment Control Manual.

E. The CONTRACTOR shall not sow immediately following rain, when ground is too dry, frozen, or during windy periods.

3.06 MULCHING

A. Mulch shall be applied at a maximum rate of 1-1.5 tons per acre in accordance with the Delaware Erosion and Sediment Control Manual.

B. Do not mulch during high winds. For slopes subject to windy conditions mulch using hydraulic methods only. Within 24 hours after seeding an area, evenly place mulch. Immediately replace mulch that becomes displaced

3.07 WATERING

A. The seed/plants shall be watered as necessary to maintain an adequate supply of moisture within the root zone. An adequate supply of moisture is estimated to be the equivalent of one inch of absorbed water per week delivered in the form of natural rain or augmented as required by periodic watering. Run-off, puddling and wilting shall be prevented.

B. Water: Seed/plants shall be watered as necessary for up to one-year after initial seeding to maintain an adequate supply of moisture within the root zone. Run-off, puddling and wilting shall be prevented.

C. Water shall not contain elements toxic to plant life.

3.08 RESEEDING

A. Where vegetative coverage with native species from the applicable seed mixture is less than 75 percent after 60 days and or 90% after one-year of initial seeding, the CONTRACTOR shall place additional seed in accordance with Articles 3.05 and 3.06 herein, at no additional cost to the OWNER.

3.09 MONITORING

A. In disturbed areas, monitoring for a period of one-year shall be performed to ensure that adequate vegetation is established. The CONTRACTOR shall perform watering and reseeding activities in accordance with Article 3.07 and 3.08 herein, at no additional cost to the OWNER. Periodic maintenance activities shall prohibit the growth of invasive species in wetland areas.

*****END OF SECTION*****