Alliant Energy
4902 North Biltmore Lane
P.O. Box 77007
Madison, WI 53707-1007

1-800-ALLIANT (800-255-4268)
alliantenergy.com

April 2, 2025

Submitted via electronic mail

Mr. Tony Peterson
Wisconsin Department of Natural Resources
141 NW Barstow St Ste 180
Waukesha, WI 53188-3789

Subject: Plan of Operations Modification Request
Development of Contact Water Swale as Disposal Space
I-43 Ash Disposal Facility (License #2853)
Wisconsin Power and Light Company
Sheboygan, WI

Dear Mr. Peterson,

On behalf of Wisconsin Power and Light Company (WPL), Alliant Energy is submitting the enclosed Plan of Operations Modification Request, prepared by SCS Engineers, for development of disposal space within the existing contact water swale at the I-43 Ash Disposal Facility located near Sheboygan, WI. WPL is proposing this project to ensure sufficient capacity to support ongoing operations at the nearby Edgewater Generating Station.

Thank you very much for your consideration. If you have any questions regarding this request, please call me at (608) 458-3853.

Regards,

Jeff Maxted
Manager – Environmental Services
Alliant Energy

CC: Mark Peters – Wisconsin DNR
Keith DeBlaey – WPL
Phil Gearing – SCS Engineers

April 2, 2025
File No. 25222259.00

Mr. Tony Peterson
Wisconsin Department of Natural Resources
141 NW Barstow St Ste 180
Waukesha, WI 53188-3789

Subject: Plan of Operation Modification Request
Contact Water Swale Liner Conversion
Edgewater I-43 Ash Disposal Facility, License #2853
Sheboygan, Sheboygan County, Wisconsin

Dear Mr. Peterson:

On behalf of Wisconsin Power and Light Company (WPL), SCS Engineers (SCS) prepared this Plan Modification Request for the Edgewater I-43 Ash Disposal Facility, License No. 2853, in Sheboygan, Wisconsin. This Plan Modification Request covers information requesting approval to convert the existing contact water swale on the south side of Phase 3 and the west side of Phase 4, Module 1 to landfill liner. This Plan Modification Request is being submitted separately from the February 1, 2023, Coal Combustion Residuals (CCR) Code Update Plan of Operation Modification Request, and subsequent addenda submitted previously to the Wisconsin Department of Resources (DNR).

If you have any questions regarding this addendum, please contact Jeff Maxted with Alliant Energy at (608) 458-3853.

Sincerely,

Madison Thompson
Project Engineer
SCS Engineers

Phil Gearing, PE
Senior Project Manager
SCS Engineers

MJT/REO/PEG

cc: Mark Peters, Wisconsin DNR
Jeff Maxted, Alliant Energy
Matt Bizjack, Alliant Energy
Keith DeBlaey, WPL

Encl. Plan of Operation Modification Request Contact Water Swale Liner Conversion

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Plan of Operation Modification Request
Contact Water Swale Liner Conversion

I-43 Ash Disposal Facility
Sheboygan, Wisconsin

Prepared for:

Wisconsin Power and Light Company
Edgewater Generating Station
3739 Lakeshore Drive
Sheboygan, Wisconsin 53081-7233

SCS ENGINEERS

25222259.00 | April 2, 2025

2830 Dairy Drive
Madison, WI 53718-6751
608-224-2830

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CERTIFICATIONS

“I, Phillip E. Gearing, hereby certify that I am a licensed professional engineer in the State of Wisconsin in accordance with the requirements of ch. A-E 4, Wis. Adm. Code; that this document has been prepared in accordance with the Rules of Professional Conduct in ch. A-E 8, Wis. Adm. Code; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with applicable requirements in chs. NR 500 to 538, Wis. Adm. Code."

This Plan Modification Request is not intended to demonstrate full alignment with NR 514.045 and is being submitted separately from the February 1, 2023, CCR Code Update Plan of Operation Modification Request, and subsequent addenda.

________________________, Senior Project Manager, E-45115
Signature, title, and P.E. number

April 2, 2025
Date

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1.0 INTRODUCTION

On behalf of Wisconsin Power and Light Company (WPL), SCS Engineers (SCS) prepared this Plan of Operation Modification (Plan Mod) Request for the Edgewater I-43 Ash Disposal Facility, License No. 2853, in Sheboygan, Wisconsin. WPL is requesting approval to convert the existing contact water swale on the south side of Phase 3 and the west side of Phase 4, Module 1 to landfill liner. This Plan Modification Request is being submitted separately from the February 1, 2023, CCR Code Update Plan of Operation Modification Request, and subsequent addenda.

2.0 PROPOSED DESIGN REVISIONS AND RATIONALE

WPL is requesting DNR approval for revisions to the landfill liner system to support ongoing plant operations until the Edgewater Generating Station converts to using natural gas as fuel in 2028. WPL is requesting approval to convert the existing contact water swale on the south side of Phase 3 and the west side of Phase 4, Module 1 to landfill liner. The contact water swale is currently constructed with the same materials as the Phase 3, Module 2 liner system. Converting the contact water swale to liner will allow additional CCR placement without constructing new liner.

The Edgewater I-43 Ash Disposal Facility design is currently approved under the alternative design criteria for landfills designed primarily for the disposal of high-volume industrial waste, as allowed by NR 504.10. This request addresses design changes to the I-43 Disposal Facility to comply with NR 504.12, which went into effect in August 2022. A description of each design change, and a discussion of updated or current information regarding approved alternative design features that will remain a part of the I-43 Disposal Facility design, are provided in the following sections. Future module development will need to be in compliance with NR 504.12 and would be addressed in a future Plan Modification Request.

3.0 CONTACT WATER SWALE LINER CONVERSION

3.1 PERMITTED LIMITS OF WASTE

The existing contact water swale is within the currently permitted limits of waste and within an area approved for waste placement. An expansion of the limits of waste is not being proposed. The approved limits of waste and proposed limits of waste are shown on **Plan Sheet 3**.

3.2 HISTORY OF CONTACT WATER SWALE CONSTRUCTION

Below is a list of past construction documentation, which have been approved by the DNR.

Contact Water Swale Construction Documentation – Western Portion (Approved March 10, 2010)

- Quality Assurance Testing for Phase 3 Module 1 Preparation, January 2010, prepared by Miller Engineers & Scientists.
  - This Documentation Report includes description of work and documentation for construction of the “ash contact” water holding basin and associated ditches.
  - The ash contact water ditch and holding basin was constructed with clay liner fill (approximately 45,500 cubic yards) to provide a minimum thickness of 5 feet on all surfaces of the ditch and basin.
  - Section 4.2: material quality assurance testing discussion.
  - Appendix C: items related to the Contact Water Ditch and Holding Basin including:

    - Site Photographs
    - Table 1 C: 5 feet Compacted Clay Liner Lab Test Results
    - Atterberg Test Results
    - Moisture Density Relationship (Proctor) Test Results
    - Grain Size and Gradation Analyses
    - Flex/Wall Permeability Test Results
    - Table 2C: Report of Field Density Test Results for Contact Water Ditch and Holding Basin

- Phase 3 Module 1 Preparation Record Drawing Set, January 2010, prepared by Miller Engineers & Scientists.
  - Sheet 3 of 14 shows the prepared subgrade and top of clay liner elevations as well as the clay liner thickness for the Northern Ash Contact Water Holding Basin.
  - Sheet 4 of 14 shows the prepared subgrade and top of clay liner elevations as well as the clay liner thickness for the Interior Ash Contact Runoff Diversion Ditch.

Contact Water Swale Construction Documentation - Eastern Portion (Approved November 6, 2014)

- Construction Documentation Report, Phase 4, Module 1 Liner Construction, November 2014, prepared SCS.
  - This Documentation Report includes description of work and documentation for construction of contact water swale.
  - The contact water swale was constructed with clay liner fill to provide a minimum thickness of 5 feet.
  - Section 4.2 includes Compacted Clay Liner and Contact Water Swale clay liner placement, nuclear density testing, clay sampling and testing, and clay liner thickness documentation discussion.
  - Table 3b includes the clay thickness documentation for the Contact Water Swale.
  - The Appendix also includes:
    - Construction Photographs
    - Clay Liner and Clay Proctor Laboratory Test Results
    - Storm Water Calculations for the Contact Water Swale

- Phase 4 Module 1 Liner Construction Documentation Drawing Set, October 2014, prepared by SCS.
  - Sheet 4 of 9 shows the prepared subgrade elevations for the east portion of the Contact Water Swale.
  - Sheet 5 of 9 shows the base grade elevations for the east portion of the Contact Water Swale.
  - Sheet 9 of 9 shows details for the east portion of the Contact Water Swale.

Contact Water Swale Construction Documentation – Removal of 1 foot of Clay and Geosynthetic Liner and Geotextile placement (Approved March 18, 2016)

- Construction Documentation Report, Phase 3, Module 2 Liner and Area 1 Final Cover Construction, February 2016, prepared by SCS.
  - The existing Contact Water Basin and Swale were modified to remove the top 12 inches of clay from the existing 5-foot clay liner, a geosynthetic liner and geotextile was installed, and a 12-inch-thick layer of aggregate was constructed above the liner materials.

- Section 6.0 discusses construction of the existing Contact Water Basin and Swale.
- Section 7.0 discusses material test results, including contact water basin and swale geomembrane liner, geotextile and electric resistivity testing.
- Table 5A shows the Contact Water Swale and Basin Grades, including the maximum elevation of existing clay after 1-foot of excavation, the contact water stone layer elevation and the contact water stone thickness.
- Figure 12 depicts the Contact Water Basin and Swale stone sample locations.
- The Appendix also includes:
  - Construction Photographs
  - Clay Liner Laboratory Test Results
  - Aggregate Test Results
  - Geosynthetics Quality Control Data
  - Geosynthetics Personnel Resumes
  - Subgrade Acceptance Form
  - Tensiometer Certifications
  - Geomembrane Installation Forms
  - Geomembrane Field Testing

- Construction Documentation, Phase 3, Module 2 Liner and Area 1 Final Cover Drawing Set, February 2016, prepared by SCS.
  - Sheet 14 of 24 shows the Contact Water Basin and Swale geomembrane panel layout.
  - Sheet 15 of 24 shows the Contact Water Basin and Swale finished grades.

3.3 CONTACT WATER SWALE CLAY LINER TESTING

The existing clay liner within the contact swale will be tested to demonstrate that it is in good condition and suitable for CCR disposal. The methods that will be used for testing are included in Section 16.0 of the updated Construction Quality Assurance (CQA) Plan (**Appendix A**). Proposed testing locations are shown in Figure 1 of the CQA Plan.

The proposed swale liner testing plan includes acceptance criteria. If the acceptance criteria are not met, the contact water swale liner will be repaired in accordance with the process described within the testing plan and the Details provided on **Plan Sheet 11**.

WPL will provide the clay testing results to the DNR and request concurrence from the department prior to proceeding with the conversion of the contact water swale into lined disposal space.

3.4 LANDFILL DESIGN DEMONSTRATION UNDER NR 504.12

3.4.1 Compliance With NR 504.12 (3)

NR 504.12 (3)(a)

> *A new CCR landfill or a lateral expansion of a CCR landfill shall be designed, constructed, operated, and maintained with a composite liner that meets the requirements under s. NR 504.06 (2) and (3) and a leachate collection and removal system that meets the requirements under s. NR 504.06(5). The composite liner shall consist of 2 components; the upper component shall consist of a nominal 60−mil or thicker geomembrane liner, and the lower component shall consist of a minimum 4−foot−thick layer of compacted clay. A GCL and soil*

barrier may be used in place of the clay layer of a composite liner in accordance with s. NR 504.06 (7).

The converted contact water swale is designed with a composite liner in accordance with NR 504.06 (2) and the alternative design criteria for landfills designed primarily for the disposal of high-volume industrial waste, as allowed by NR 504.10.

The typical contact water swale composite liner system may be constructed as shown on **Plan Sheet 12, Detail 4.** The typical composite liner system consists of the following layers from bottom to top:

- Four feet of compacted clay soil with a hydraulic conductivity of no more than 1×10^{-7} cm/sec.
- Sixty-mil thick High-density polyethylene (HDPE) geomembrane.
- Leachate drainage layer.

A composite liner alternative design, as shown on **Plan Sheet 12, Detail 5**, consists of the following layers from bottom to top:

- Two feet of compacted clay soil with a hydraulic conductivity of no more than 1 x 10-7 cm/sec.
- Geosynthetic clay liner (GCL).
- Sixty-mil-thick HDPE geomembrane.
- Leachate drainage layer.

The clay liner, GCL, and geomembrane will meet the specifications in NR 504.06 (2), NR 504.06(3), and NR 504.06(7), respectively, and as described in the revised CQA Plan in **Appendix A.** Refer to **Appendix B** for a parametric static veneer slope stability calculation and a calculation for the internal shear strength requirement for the GCL. The liner components are stable based on the assumptions provided in the calculations.

A geotextile cushion may be placed directly above the geomembrane dependent on the material used for the drainage layer. If a sand sized material is used as a drainage layer, a geotextile cushion is not required. If the drainage layer material is a gravel or similar sized material, a geotextile cushion will be required.

Revised geotextile cushion puncture resistance calculations are provided in **Appendix B.** As required by NR 504.06(5)(dm), the geotextile properties were selected to demonstrate that the geotextile can resist puncture by the drainage blanket material (if gravel is used) and coarse aggregate bedding for the leachate collection system.

NR 504.12 (3)(a)(1)

"The leachate collection and removal system shall be designed, constructed, operated, and maintained to limit the leachate head level on the liner to one foot or less."

The contact water swale liner conversion includes installing a leachate collection pipe in the flow line of the contact water swale along with coarse aggregate graded filter, and leachate drainage layer over the pipe as shown on **Plan Sheet 5** and Details on **Plan Sheet 11.** The leachate line will drain to a new leachate collection sump at the west end of the swale as shown on **Plan Sheet 5** and details on **Plan Sheet 13.** Leachate collected in the sump will be pumped to the Contact Water Basin as shown on **Plan Sheet 5** and Details on **Plan Sheet 10** and **Sheet 14.**

Leachate collection system material specifications are provided in the revised CQA Plan provided in **Appendix A.** Leachate system calculations for sump volume, pump capacity, and leachate capacity are provided in **Appendix C.** The proposed leachate collection system will limit leachate head level to 1 foot or less per the performed calculations. Details of the leachate collection system for the contact water swale are provided on **Plan Sheet 11, Details 2** and **4.**

NR 504.12 (3)(a)(2)(a)

> *"Chemically resistant to the CCR and any non–CCR waste managed in the CCR landfill and the leachate expected to be generated."*

The leachate collection and removal system consists of HDPE pipe, leachate drainage layer, drainage filter, coarse aggregate bedding, and geotextile as shown on **Plan Sheet 11, Details 2** and **4.**

The leachate pipe will consist of HDPE, the same material as the HDPE geomembrane. Both the HDPE pipe and the geomembrane are resistant to the CCR and CCR-generated leachate.

The drainage filter and coarse aggregate bedding are imported granular soils. The granular soils used in the leachate collection and removal system meet the same Wis. Adm. Code standards as the granular soils used in municipal solid waste landfills. Unlike municipal solid waste landfill leachate, the CCR leachate is not acidic so the granular soils are chemically resistant to the CCR and CCR-generated leachate.

The geotextile may consist of polypropylene, polyester, or polyethylene. Based on testing by the manufacturers and other researchers, these materials are resistant to municipal solid waste landfill leachate that is much more aggressive and acidic than CCR leachate. Therefore, the geotextile is chemically resistant to the CCR and CCR-generated leachate.

NR 504.12 (3)(a)(2)(b)

> *"Of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying waste, waste cover materials, and equipment used at the CCR landfill."*

During the design of the Contact Water Swale, the HDPE leachate collection and removal pipe was evaluated for pipe strength using construction/operation loads and post-closure loads to determine the required materials of construction. Based on the pipe strength calculations in **Appendix B**, the HDPE pipes will have sufficient strength to prevent collapse under the pressures exerted by the CCR, cover materials, and equipment used in the operation of the CCR landfill, based on the equipment currently used to operate the existing CCR units at the facility.

NR 504.12 (3)(a)(3)

> *"The leachate collection and removal system shall be designed and operated to minimize clogging during the active life and during the long–term care of the landfill."*

The leachate collection and removal system is designed with a drainage filter. The filter minimizes the movement of fine particles into the leachate collection pipes to prevent clogging. Filter calculations are provided in the documentation report for module construction based on the specific gradation of material provided for coarse aggregate and drainage material. The leachate collection and removal system is designed with cleanout riser pipes as shown on Plan Sheet 5 to allow pipe cleaning and prevent long-term clogging. The leachate collection pipes are cleaned a minimum of once per year in accordance with Wis. Adm. Code.

NR 504.12 (3)(a)(4)

> *"The geomembrane component of the liner shall be installed in direct and uniform contact with the compacted clay soil component."*

The geomembrane will be installed in direct and uniform contact with the GCL (or alternatively clay, if 4 feet of clay is constructed). The GCL will be installed in direct and uniform contact with the compacted clay soil component.

NR 504.12 (3)(a)(5)

> *"A liner that utilizes a GCL and soil barrier layer in accordance with s. NR 504.06 (7) shall be designed to have a liquid flow rate no greater than the liquid flow rate through 2 feet of compacted soil with a hydraulic conductivity of 1×10^{-7} cm/sec. The liquid flow rate comparison shall be made using the following equation, which is derived from Darcy's Law for gravity flow through porous media:*

$$Q/A = q = k\,(h/t + 1)$$

Where:
Q = flow rate (cubic centimeters / second).
A = surface area of the liner (squared centimeters).
q = flow rate per unit area (cubic centimeters / second / squared centimeter).
k = hydraulic conductivity of the liner (centimeters / second).
h = hydraulic head above the liner (centimeters).
t = thickness of the liner (centimeters)."

The liner in the contact water swale may utilize a GCL component and 2 feet of compacted soil with a hydraulic conductivity of 1×10^{-7} cm/sec, therefore meets this requirement. In lieu of a GCL the liner will be constructed with 4 feet of compacted soil with the same hydraulic conductivity.

NR 504.12 (3)(b)

> *"A new CCR landfill or a lateral expansion of a CCR landfill shall be designed and constructed with a subbase grade that is located no less than 5 feet above the upper limit of the uppermost aquifer, or shall demonstrate that there will not be an intermittent recurring or sustained hydraulic connection between any portion of the base of the CCR landfill and the uppermost aquifer due to normal fluctuations in groundwater elevations, including the seasonal high water table."*
>
> *Note: A new CCR landfill or lateral expansion of a CCR landfill is also required to comply with s. NR 504.06 (2) (b) or (4) for zone–of–saturation landfills. The definition of an uppermost aquifer can be found under s. NR 500.03 (246m).*

The uppermost aquifer below the CCR landfill is the Niagara Dolomite, and CCR monitoring wells at the site are screened within this unit. Boring logs for the CCR monitoring wells indicate that the dolomite aquifer surface at the site is over 100 feet below ground surface, at an elevation of approximately 565 to 605 feet amsl, and the dolomite aquifer unit is overlain by unconsolidated material consisting primarily of clay.

The high groundwater elevation associated with the uppermost aquifer below the CCR landfill is at an approximate elevation of 651.58 to 661.58 feet above mean sea level (amsl) [maximum range for MW-301 through MW-306 CCR wells], based on a review of groundwater elevations measured in CCR monitoring wells at the CCR landfill, for the period from April 2016 to January 2025 (**Table 1**). The highest water level elevation measured at a CCR monitoring well associated with the CCR landfill was 661.58 feet amsl recorded at MW-305, which is an upgradient monitoring well located approximately 1,800 feet south of Phase 4 Module 1.

Sheet 4 shows the lowest subbase grades in the contact water swale liner conversion, which represent the top of subbase soils and bottom of the clay liner. The lowest subbase elevation is approximately 672 feet amsl.

Based on this information, the converted contact water swale area is located at least 5 feet above the upper limit of the uppermost aquifer.

NR 504.12 (3)(c)

> *"A new CCR landfill or a lateral expansion of a CCR landfill may not be constructed over a closed CCR surface impoundment."*

The existing CCR landfill has not been constructed over a closed CCR surface impoundment nor will the new contact water swale area be constructed over a closed CCR surface impoundment.

3.4.1.1 Compliance With NR 504.12 (4)

NR 504.12 (4)(a)

> *"A new or existing CCR landfill or a lateral expansion of a CCR landfill shall be designed and constructed with a final cover system that meets the requirements under s. NR 504.07."*

The final cover system has been designed in accordance with NR 504.07 (see **Detail 6**, **Plan Sheet 12**) and specified in the revised CQA Plan (**Appendix A**). The cover will consist of the following components, from bottom to top:

- Two feet of compacted clay soil with a hydraulic conductivity of no more than 1 x 10^{-7} cm/sec
- Forty-mil-thick LLDPE geomembrane
- Geonet geocomposite drainage layer
- Two and a half feet of rooting zone material
- Six inches of topsoil

Portions of Phase 3, Module 1 and Phase 4, Module 1 have been capped with the previously approved final cover system (Area 1 and Area 2 on **Plan Sheet 2**). **Detail 43**, **Plan Sheet 12** shows the existing to proposed final cover transition detail.

The geocomposite drainage layer properties are specified in the CQA Plan. Unit gradient calculations were performed to confirm that water infiltrating the final cover will be contained within the drainage layers (geocomposite) and will not result in unstable final cover slope conditions.

In accordance with NR 504.07 (6)(a), drainage analyses were performed to assess the design and construction requirements for the final cover. The pipe flow calculations confirm that the toe drain pipes are suitable to collect and discharge flow from the drainage layers. Toe drain outlet pipes will be installed at a maximum spacing of one per 200 feet of toe drain.

Details of the final cover drainage piping are provided on **Plan Sheet 7**. Drain sock geotextile calculations for sand drainage layer pipes will be performed as described in the CQA Plan (**Appendix A**).

Refer to **Appendix B** and **D** for drainage layer transmissivity, drainage, and final cover stability calculations; and surface water management system calculations, respectively.

NR 504.12 (4)(b)

> *"The owner or operator of a new or existing CCR landfill or a lateral expansion of a CCR landfill may propose an alternative final cover system design within a written closure plan in accordance with s. NR 504.10"*

An alternative final cover system design is not proposed.

3.5 SLOPE STABILITY

Interim waste slopes and final grade waste slopes were evaluated in terms of global slope stability to determine the slope stability safety factors (**Appendix B**). Slope stability safety factors meeting the recommended minimum values were calculated based on the analyses. Slope stability was evaluated to comply with NR 504.12, which went into effect in August 2022 and future module development will need to be in compliance with NR 504.12. Future development would be addressed in a future Plan Modification Request.

3.6 CAPACITY

Current total approved airspace of constructed Modules for I-43:

- **Phase 3, Module 1:** 127,400 cubic yards
- **Phase 3, Module 2:** 276,750 cubic yards
- **Phase 4, Module 1**: 73,300 cubic yards

Total capacity added is approximately:

- **Contact Water Swale Liner Conversion**: 127,400 cubic yards

Documentation for volume calculations are provided in **Appendix E.** The disposal capacity volume calculations were performed using the AutoCAD Civil 3D program.

The current I-43 permitted air space is 1,210,450 cubic yards, as approved in the WDNR June 4, 2015 Plan of Operation Update approval letter. Based on the revised design, the total site capacity after construction of the contact water swale will be 604,850 cubic yards.

Table 1

Water Level Summary

Table 1. Water Level Summary
WPL - I43 / SCS Engineers Project #25224069.00

Well Number	Ground Water Elevation in feet above mean sea level (amsl)					
	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306
Top of Casing Elevation (feet amsl) - resurveyed 12/12/2023	697.19	702.81	719.47	692.12	717.97	693.61
Top of Casing Elevation (feet amsl)	696.96	702.57	719.25	691.97	717.67	--
Screen Length (ft)	5.0	5.0	5.0	5.0	5.0	5.0
Total Depth (ft from top of casing)	134.56	144.33	144.65	119.49	122.97	138.31
Top of Well Screen Elevation (ft)	567.40	563.24	579.60	577.48	600.46	560.30
Measurement Date						
April 26, 2016	653.54	653.56	653.59	655.90	--	NI
June 20, 2016	652.01	651.89	651.80	653.79	--	NI
August 9, 2016	649.68	649.30	649.37	651.55	--	NI
October 19, 2016	652.32	652.38	652.18	654.00	--	NI
December 19, 2016	652.85	652.79	652.82	654.26	--	NI
January 5, 2017	652.86	652.82	652.80	654.15	--	NI
January 23, 2017	652.98	664.97*	652.92	654.37	--	NI
February 23, 2017	653.14	653.10	653.10	654.49	658.02	NI
April 7, 2017	654.43	654.72	654.55	654.85	659.65	NI
June 6, 2017	654.11	654.12	654.14	655.70	659.70	NI
August 1, 2017	652.64	652.55	652.50	654.49	658.54	NI
October 23, 2017	652.03	652.05	652.03	653.65	657.22	NI
April 3, 2018	651.28	651.25	651.30	652.86	656.24	NI
October 4, 2018	650.71	650.70	650.70	652.26	655.89	NI
April 8-9, 2019	653.06	654.06	654.06	655.59	659.03	NI
October 8, 2019	653.26	653.21	653.27	654.77	658.77	NI
November 26, 2019	--	--	655.56	--	--	NI
April 7, 2020	656.59	656.47	656.46	658.16	661.58	NI
May 20, 2020	--	655.81	--	--	--	NI
October 13, 2020	652.16	652.17	652.20	654.17	658.08	NI
December 18, 2020	653.91	653.88	--	--	--	NI
April 13, 2021	654.56	654.57	654.53	656.36	659.69	NI
June 16, 2021	649.78	649.75	--	--	--	NI
October 26, 2021	650.76	650.88	650.90	652.54	655.86	NI
April 11-13, 2022	651.65	651.62	651.58	653.08	657.58	NI
June 16, 2022	--	650.55	--	--	--	NI
October 4, 2022	648.87	648.85	648.89	650.51	654.40	NI
February 14, 2023	651.61	651.60	651.61	653.17	656.25	NI
March 22, 2023	652.44	652.43	652.42	654.04	657.48	NI
April 24-25, 2023	653.26	653.25	653.31	654.83	658.22	NI
May 25, 2023	651.28	651.24	651.30	653.17	657.54	NI
June 26, 2023	648.06	648.05	648.07	649.86	655.07	NI
July 26, 2023	647.08	647.02	647.17	649.15	652.09	NI
October 11, 2023	648.65	648.67	648.65	650.24	654.22	NI
November 14, 2023	649.98	649.97	649.95	651.37	654.89	NI
November 14, 2023 elevations based on re-surveyed TOC	650.21	650.21	650.17	651.52	655.19	NI
April 15, 2024	652.95	652.93	652.96	654.82	658.53	NI
July 19, 2024	653.41	653.41	653.39	655.04	659.29	--
August 8, 2024	650.96	650.98	650.96	653.07	657.85	651.58
October 2, 2024	650.21	650.48	650.15	652.01	656.60	650.47
January 16, 2025	652.30	652.34	652.32	653.92	657.50	652.27
Bottom of Well Elevation (ft)	562.40	558.24	574.60	572.48	594.70	555.30

Notes: -- = not measured
*: The calculated groundwater elevation at MW-302 on January 23, 2017 appears to reflect an error in recording the pre-purge depth to water during sampling.

Created by: RM Date: 1/10/2020
Last rev. by: MDB Date: 3/25/2025
Checked by: RM Date: 3/25/2025

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Plan Sheets

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Sheet 3	Existing Grades
Sheet 4	Base Grades
Sheet 5	Leachate Collection System
Sheet 6	Waste Grades
Sheet 7	Final Cover Grades
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Sheet 12	Details
Sheet 13	Details
Sheet 14	Details
Sheet 15	Details

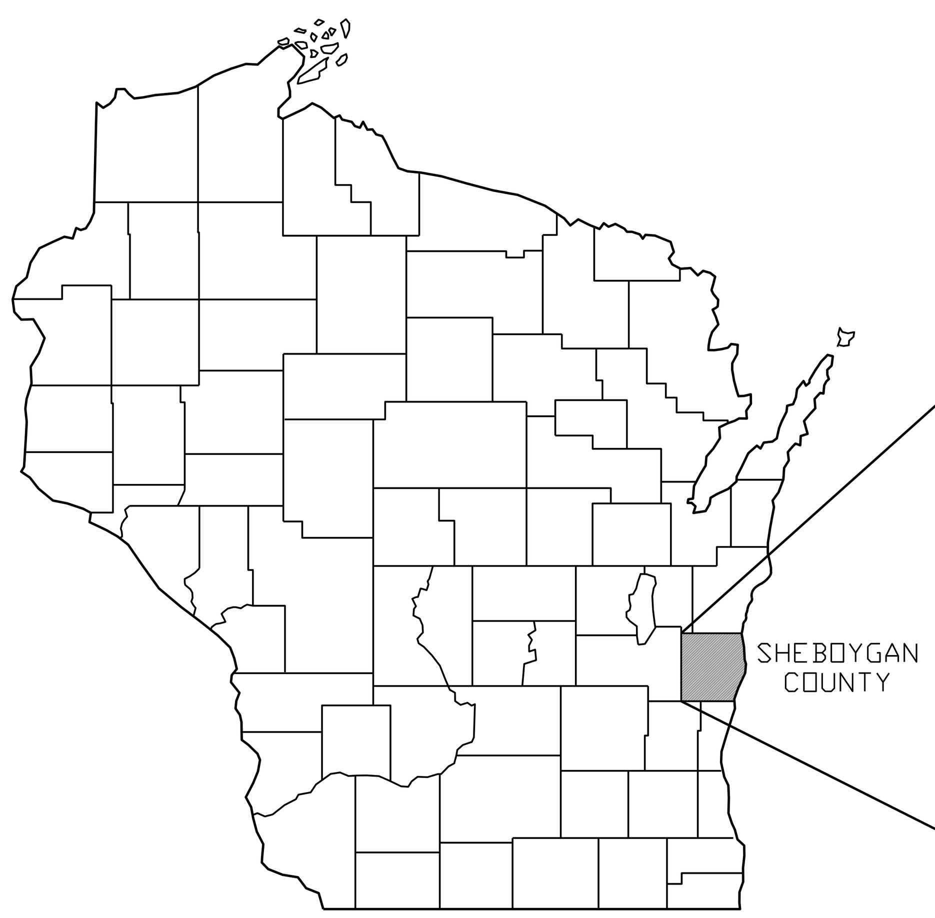
PLAN MODIFICATION
CONTACT WATER SWALE CONVERSION
EDGEWATER GENERATING STATION

EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

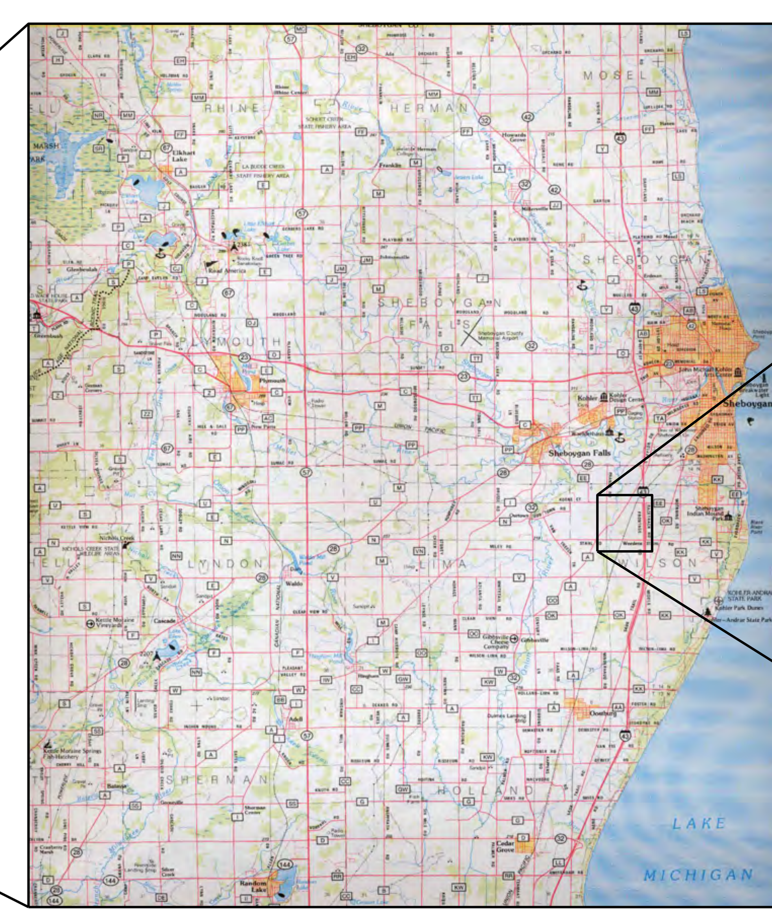
PREPARED FOR: WISCONSIN POWER AND LIGHT COMPANY
SHEBOYGAN, WISCONSIN

PREPARED BY: SCS ENGINEERS
MADISON, WISCONSIN

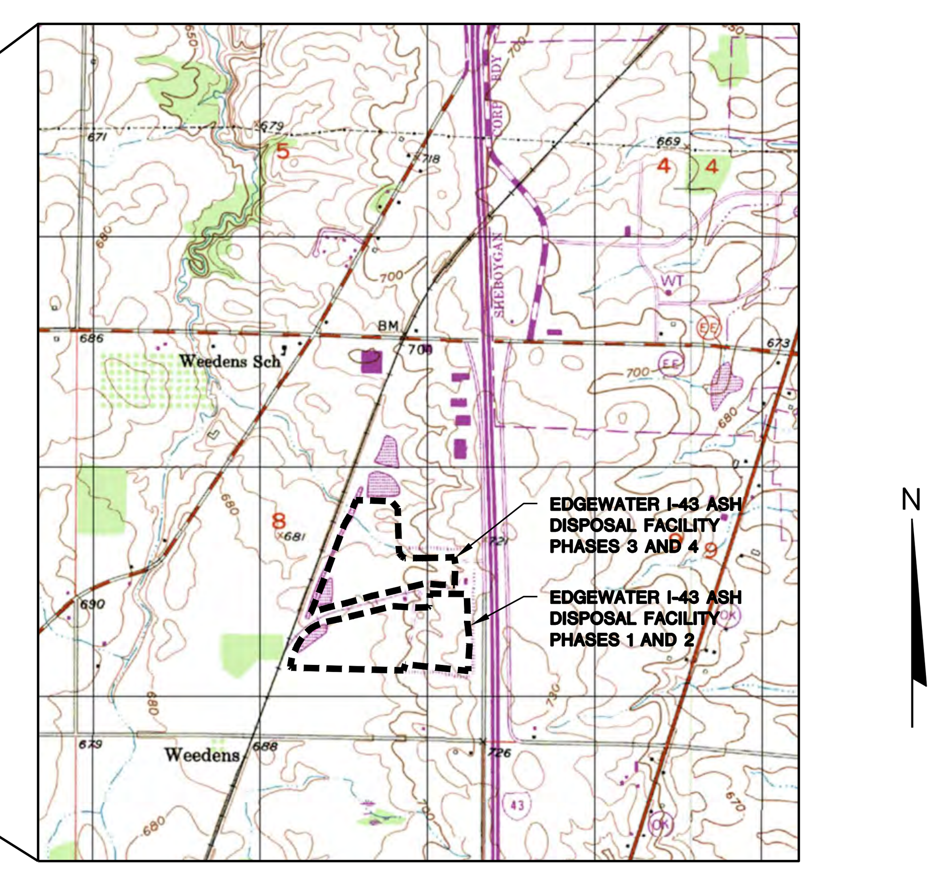
DATE: APRIL 2025



WISCONSIN



VICINITY LOCATOR MAP



SITE LOCATOR MAP

APPROXIMATE SCALE: 1"=2,000'

INDEX

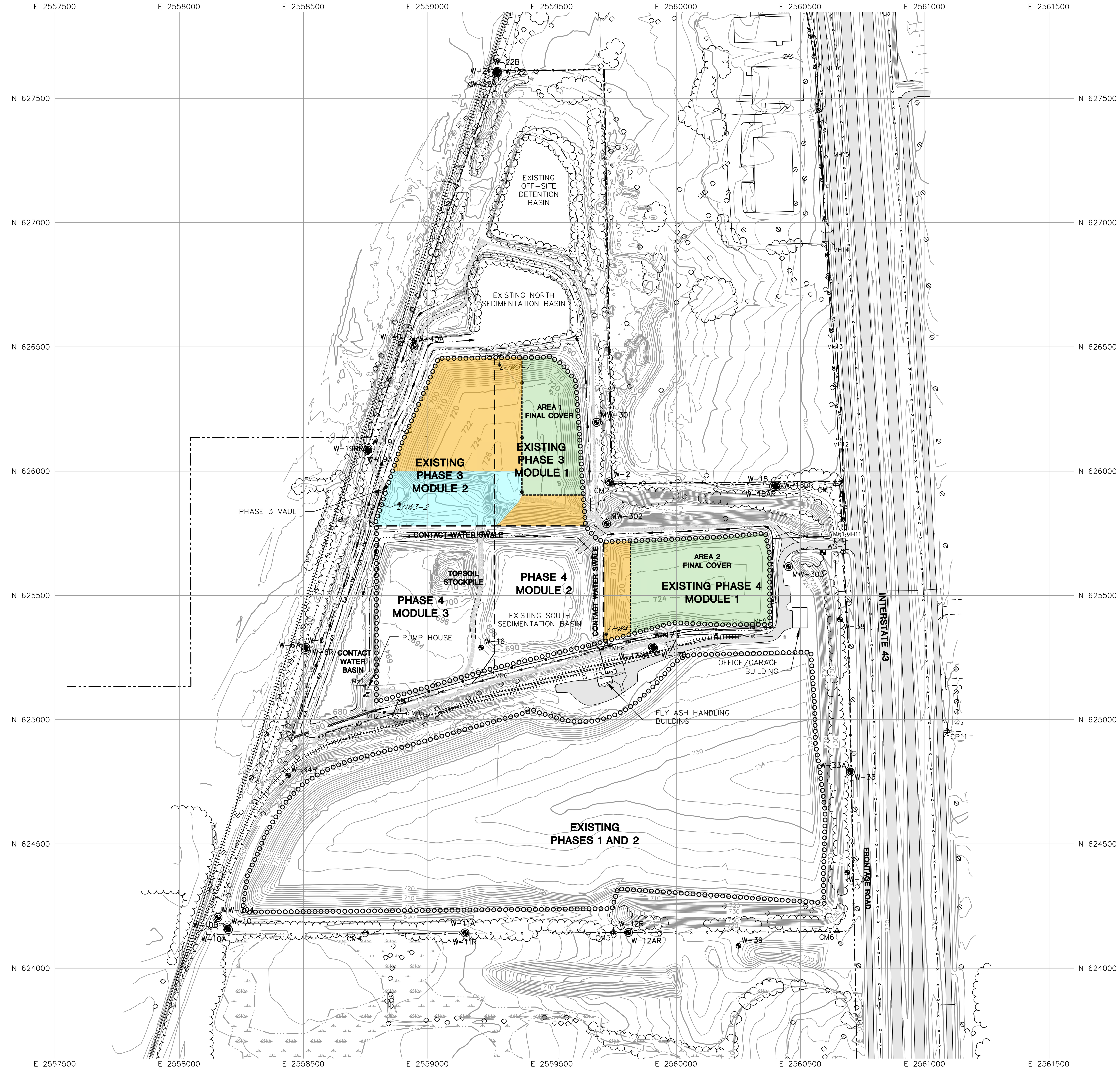
PROJECT NO.	25222259.00	DRAWN BY:	KP/RR
DRAWN:	01/05/2024	CHECKED BY:	PEG/MJT
REVISED:	04/02/2025	APPROVED BY:	PEG 04/02/25

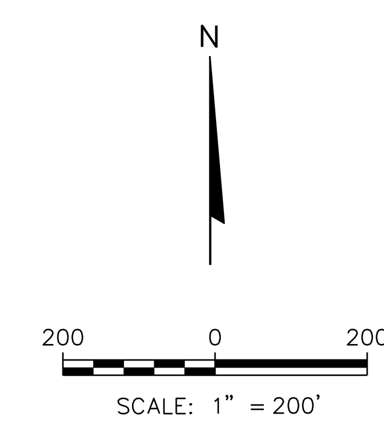
CLIENT: WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

SITE: PLAN MODIFICATION CONTACT WATER SWALE CONVERSION
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

TITLE SHEET





LEGEND

- APPROXIMATE PROPERTY LINE
- APPROVED LIMITS OF WASTE
- APPROVED MODULE LIMITS
- LIMITS OF AREA 1 AND AREA 2 FINAL COVER
- EXISTING GRADE (2' CONTOUR)
- EXISTING GRADE (10' CONTOUR)
- EDGE OF WATER
- SWALE
- WETLAND
- CULVERT
- MANHOLE
- CONTACT WATER TRANSFER PIPE
- ABANDONED 3" DIA. HDPE PIPE
- CONTACT WATER FORCEMAIN
- ELECTRIC/INSTRUMENTATION
- UNDERGROUND ELECTRIC
- OVERHEAD ELECTRIC
- SANITARY SEWER
- TREELINE/TREES
- PAVED ROAD
- UNPAVED ACCESS ROAD
- RAILROAD TRACKS
- FENCE
- UTILITY/LIGHT POLE
- CONTROL MONUMENT
- MONITORING WELL
- PIEZOMETER
- LEACHATE HEADWELL
- LEACHATE VAULT
- LEACHATE CLEANOUT
- LEACHATE HEADWELL
- PRIVATE WATER SUPPLY WELL
- EXISTING FINAL COVER
- EXISTING INTERMEDIATE COVER
- ACTIVE CCR PLACEMENT AREA

CONTROL MONUMENT DATA		
MONUMENT NO.	STATION	ELEVATION
CM2	625946.374 N 2559742.153 E	700.043
CM3	625949.279 N 2560641.785 E	717.041
CM4	624143.955 N 2558747.460 E	687.448
CM5	624146.909 N 2559747.214 E	705.621
CM6	624149.566 N 2560647.002 E	723.265
CP11	624955.750 N 2561090.840 E	731.060

NOTES:

1. BASE MAP PREPARED BY KBM, INC. BASED ON AERIAL TOPOGRAPHIC SURVEY FLOWN DECEMBER 1, 2014. BASE MAP PREPARED USING WISCONSIN STATE PLANE COORDINATES. ELEVATIONS BASED ON USGS NATIONAL GEODETIC VERTICAL DATUM, 1929. UPDATED WITH 2015 CONSTRUCTION AS-BUILT GRADES, 2016 CONSTRUCTION AS-BUILT GRADES FOR PHASE 4, MODULE 1 BY SCS ENGINEERS, DECEMBER 23, 2020 DRONE SURVEY OF PHASE 3, MODULE 2 ASH GRADES AND FUTURE PHASE 4 AREAS BY RYAN INCORPORATED CENTRAL, APRIL 11, 2022 PHASE 3 MODULE 2 SURVEY BY SCS ENGINEERS.
2. CONTOUR INTERVAL IS 2 FEET.
3. MONITORING WELL LOCATIONS BASED ON WELL INFORMATION FORM COORDINATES AND EXISTING CONDITIONS MAP F11 PREPARED BY WARZYN, INC. USING LOCAL COORDINATES.
4. WETLAND LIMITS BASED ON WETLAND DELINEATION REPORT, WISCONSIN POWER AND LIGHT COMPANY, EDGEWATER LANDFILL SITE, TOWN OF WILSON, SHEBOYGAN COUNTY, WISCONSIN, JUNE 25, 2010, NATURAL RESOURCES CONSULTING, INC. (NRC).

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WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

ENGINEER

PLAN MODIFICATION CONTACT WATER SWALE CONVERSION
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

SITE

EXISTING CONDITIONS

SHEET
2 OF 15

NOTES:

1. SEE SHEET 2 FOR ADDITIONAL BASE MAP LEGEND ITEMS AND NOTES.
2. EXISTING CONTOURS WITHIN CONTACT WATER SWALE REPRESENT TOP OF COURSE AGGREGATE.
3. CONTOURS WITHIN LIMITS OF WASTE REPRESENT TOP OF CLAY LINER (BASE GRADES)

LEGEND

- APPROVED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- APPROVED MODULE LIMITS
- EXISTING CLAY LINER LIMITS
- EXISTING GRADE (2' CONTOUR)
- 690 EXISTING GRADE (10' CONTOUR)
- EXISTING CULVERT
- LIMITS OF CONSTRUCTED GEOMEMBRANE LINER
- FM EXISTING LEACHATE FORCEMAIN
- E/I EXISTING ELECTRIC AND INSTRUMENT CONDUITS
- UE EXISTING UNDERGROUND ELECTRIC
- OE EXISTING OVERHEAD ELECTRIC
- DOCUMENTED BASE GRADE (2' CONTOUR)
- 690 DOCUMENTED BASE (10' CONTOUR)
- EXISTING PERFORATED LEACHATE COLLECTION PIPE
- EXISTING NON-PERFORATED LEACHATE PIPE
- EXISTING LEACHATE HEADWELL
- EXISTING LEACHATE VAULT
- EXISTING LEACHATE CLEANOUT

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SITE

EXISTING GRADES

SHEET
3 OF 15

LEGEND

- APPROVED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- APPROVED MODULE LIMITS
- PROPOSED ASH LIMITS
- EXISTING GRADE (2' CONTOUR)
- EXISTING GRADE (10' CONTOUR)
- EXISTING CULVERT
- EXISTING LEACHATE FORCEMAIN
- EXISTING ELECTRIC AND INSTRUMENT CONDUITS
- PROPOSED GRADE (2' CONTOUR)
- PROPOSED GRADE (10' CONTOUR)
- EXISTING BASE GRADE (2' CONTOUR)
- EXISTING BASE GRADE (10' CONTOUR)
- PAVED ROAD
- UNPAVED ROAD

NOTES:

1. SEE SHEET 2 FOR ADDITIONAL BASE MAP LEGEND ITEMS AND NOTES.
2. EXISTING GRADES WITHIN CONTACT WATER SWALE/BASIN REPRESENT TOP OF 1' STONE LAYER.
3. CONTACT WATER SWALE BASE GRADES REPRESENT TOP OF EXISTING 4-FOOT CLAY LINER.
4. PROPOSED GRADES REPRESENT TOP OF CLAY FOR CONTACT WATER SWALE SUMP AND BERM (BASE GRADES).

N

40 0 40

SCALE: 1" = 40'

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TOWN OF WILSON, WISCONSIN

SITE

BASE GRADES

SHEET
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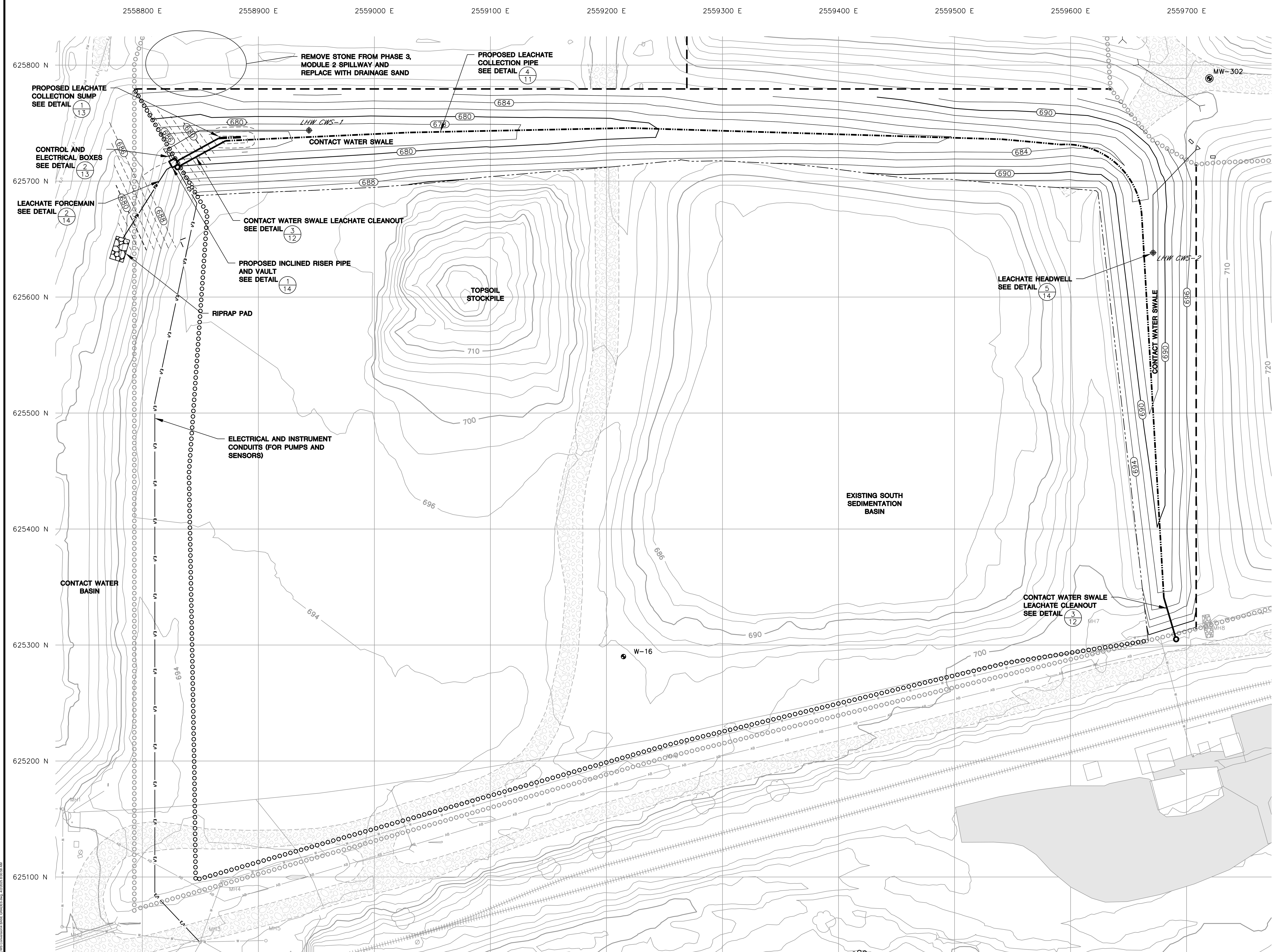

LEGEND

- APPROVED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- APPROVED MODULE LIMITS
- PROPOSED ASH LIMITS
- EXISTING GRADE (2' CONTOUR)
- EXISTING GRADE (10' CONTOUR)
- EXISTING CULVERT
- EXISTING LEACHATE FORCEMAIN
- EXISTING ELECTRIC AND INSTRUMENT CONDUITS
- PROPOSED GRADE (2' CONTOUR)
- PROPOSED GRADE (10' CONTOUR)
- EXISTING BASE GRADE (2' CONTOUR)
- EXISTING BASE GRADE (10' CONTOUR)
- PROPOSED LEACHATE COLLECTION LINE
- PROPOSED CLEANOUT
- PROPOSED LEACHATE FORCEMAIN
- PROPOSED ELECTRIC AND INSTRUMENT CONDUITS
- PROPOSED LEACHATE HEADWELL
- PAVED ROAD
- UNPAVED ROAD

NOTES:

1. SEE SHEET 2 FOR ADDITIONAL BASE MAP LEGEND ITEMS AND NOTES.
2. EXISTING GRADES WITHIN CONTACT WATER SWALE/BASIN REPRESENT TOP OF 1' STONE LAYER.
3. CONTACT WATER SWALE BASE GRADES REPRESENT TOP OF EXISTING 4-FOOT CLAY LINER.
4. PROPOSED GRADES REPRESENT TOP OF CLAY FOR THE CONTACT WATER SWALE SUMP AND BERM (BASE GRADES).

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TOWN OF WILSON, WISCONSIN

SITE

LEACHATE COLLECTION

SHEET
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PROJECT NO. 25222259.00 | DRAWN BY: KP/RR
DRAWN: 01/05/2024 | CHECKED BY: PEG/MJT
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WASTE GRADES

SHEET 6 OF 15

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SITE
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EDGEWATER I-43 ASH DISPOSAL FACILITY
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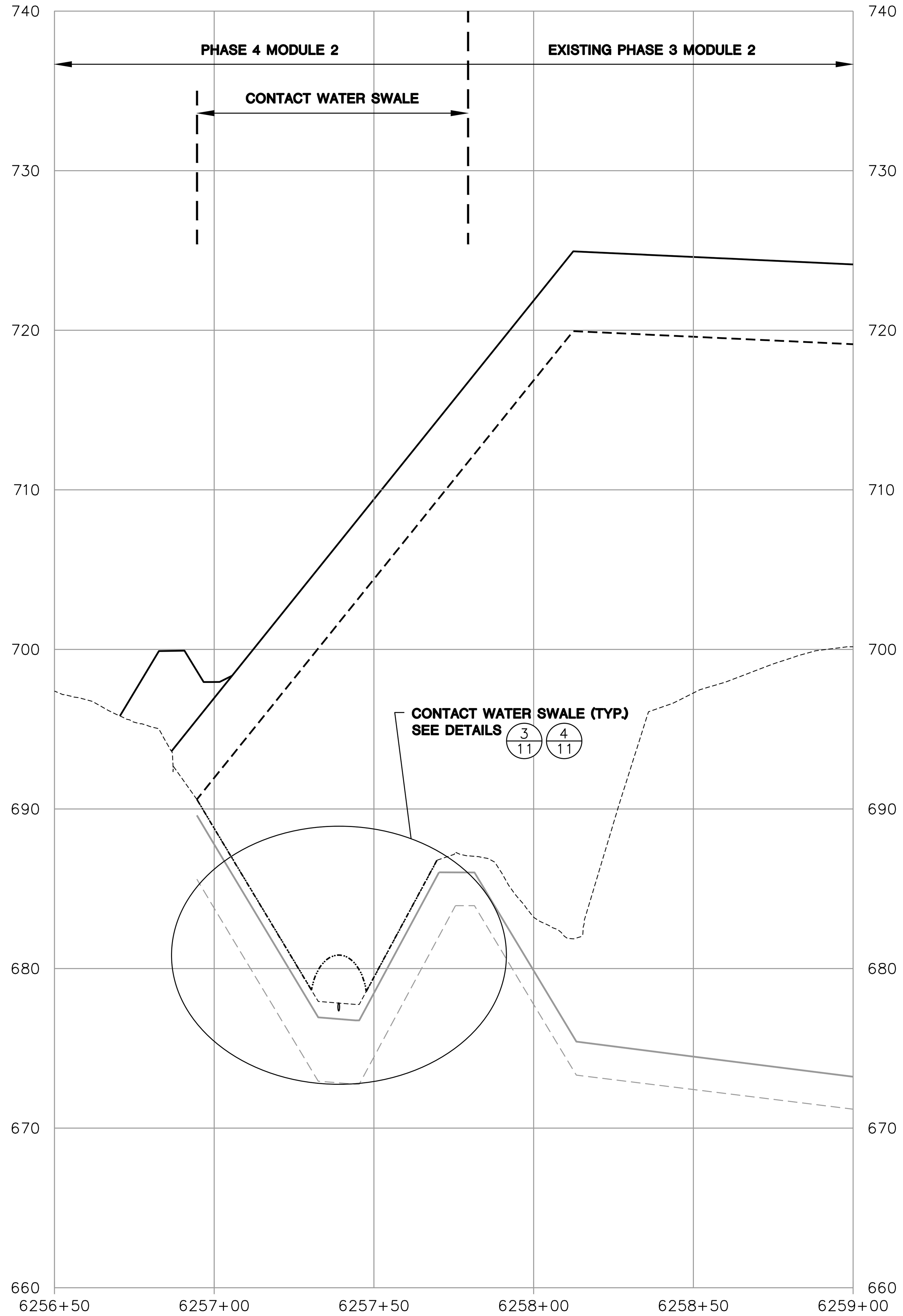
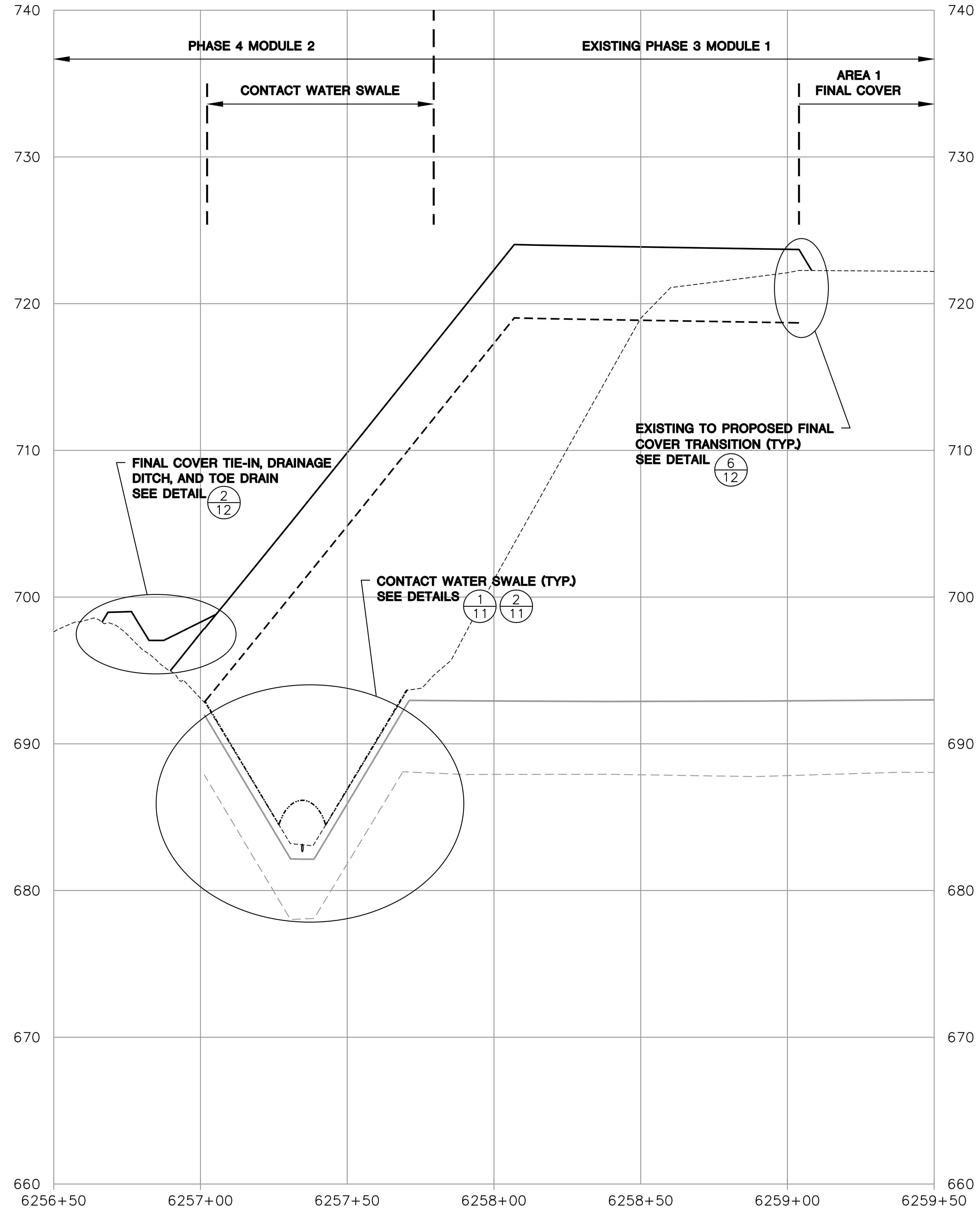
FINAL COVER GRADES

SHEET
7 OF 15



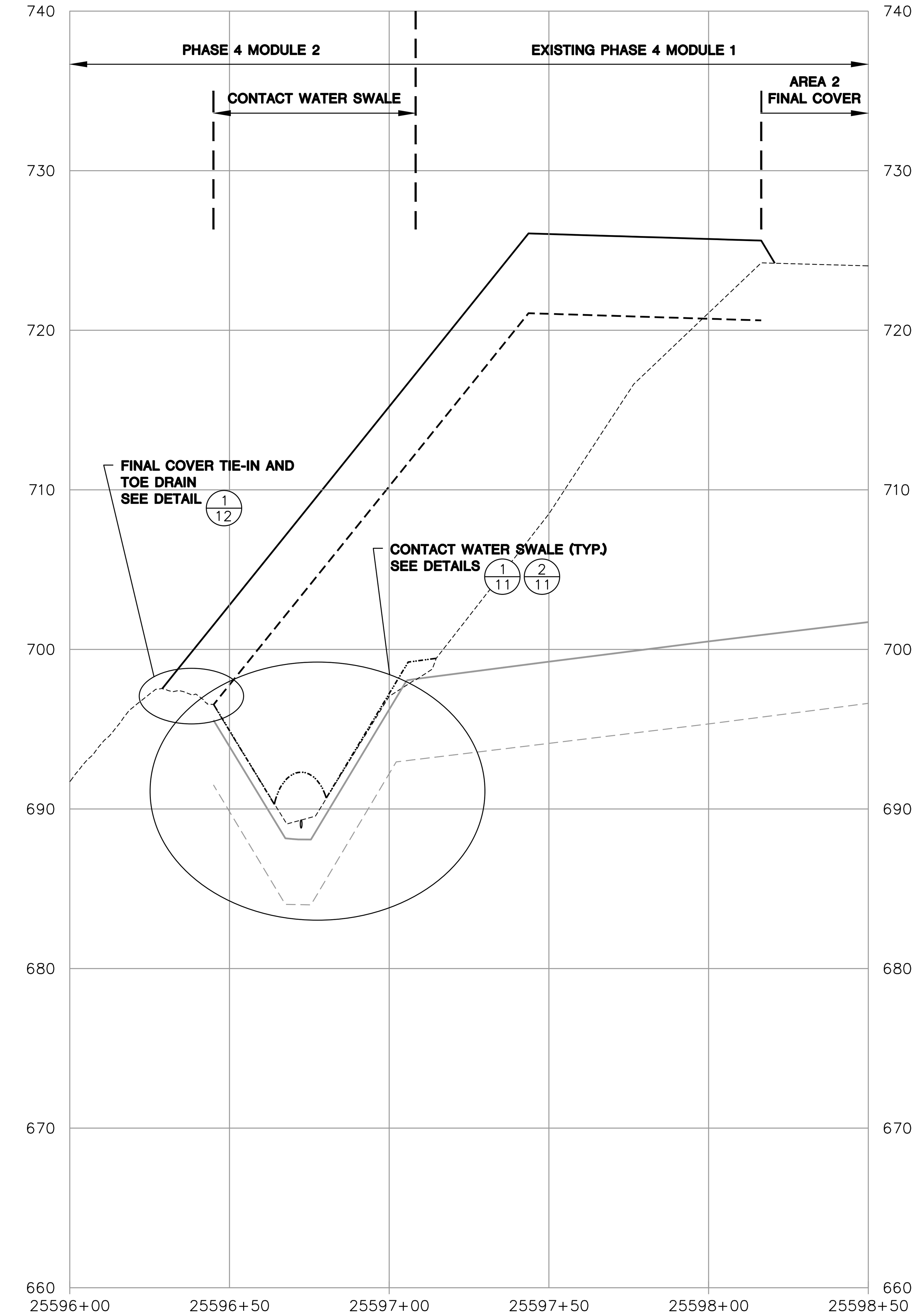
SECTION A-A'

(PHASE 3, MODULE 2 @ 2559000 E)



SECTION B-B'

(PHASE 3, MODULE 1 @ 2559500 E)

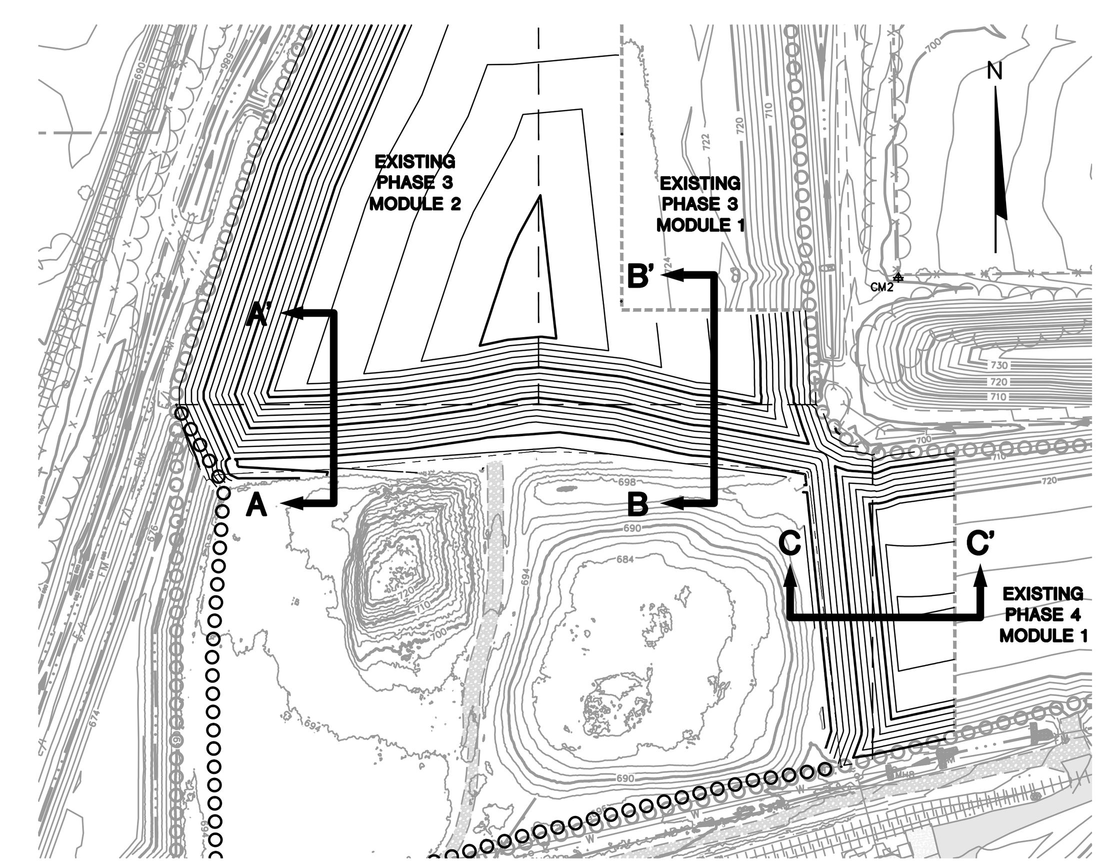


SECTION C-C'

(PHASE 4, MODULE 1 @ 62500 N)

LEGEND

- EXISTING GRADE
- DOCUMENTED BASE GRADE
- DOCUMENTED SUBBASE GRADE
- PROPOSED FINAL GRADE
- PROPOSED TOP OF ASH GRADE
- PROPOSED TOP OF DRAINAGE LAYER



CROSS SECTION LOCATION

SCALE: 1" = 200'

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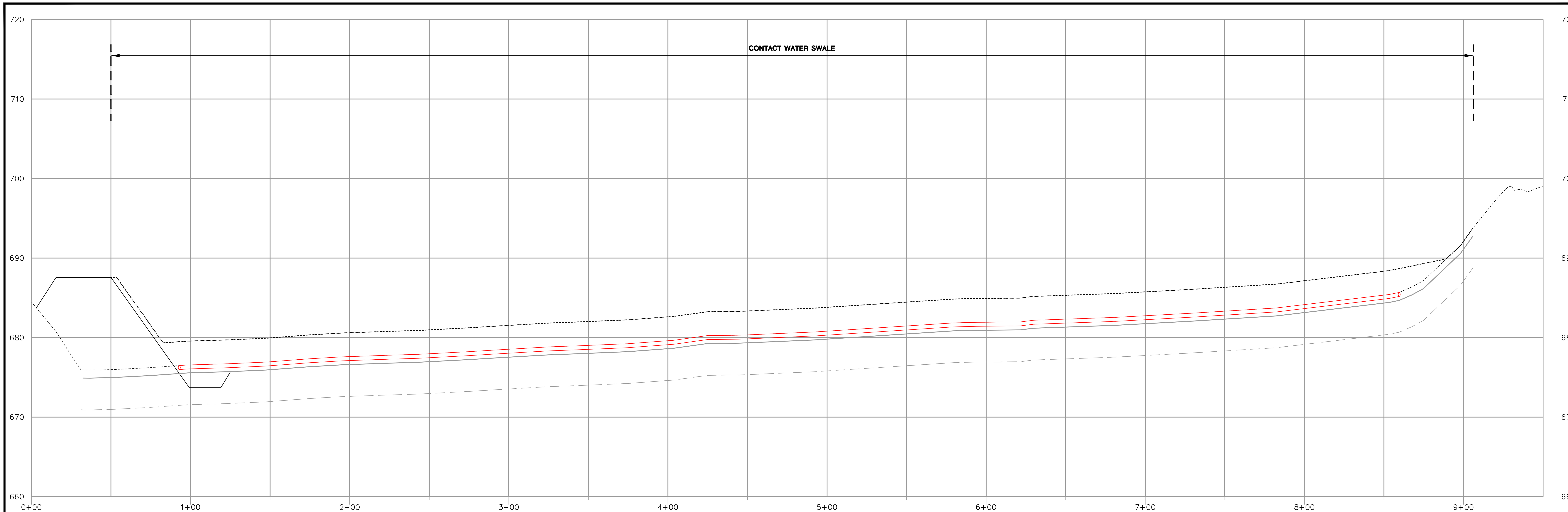
SITE: PLAN MODIFICATION CONTACT WATER SWALE CONVERSION
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

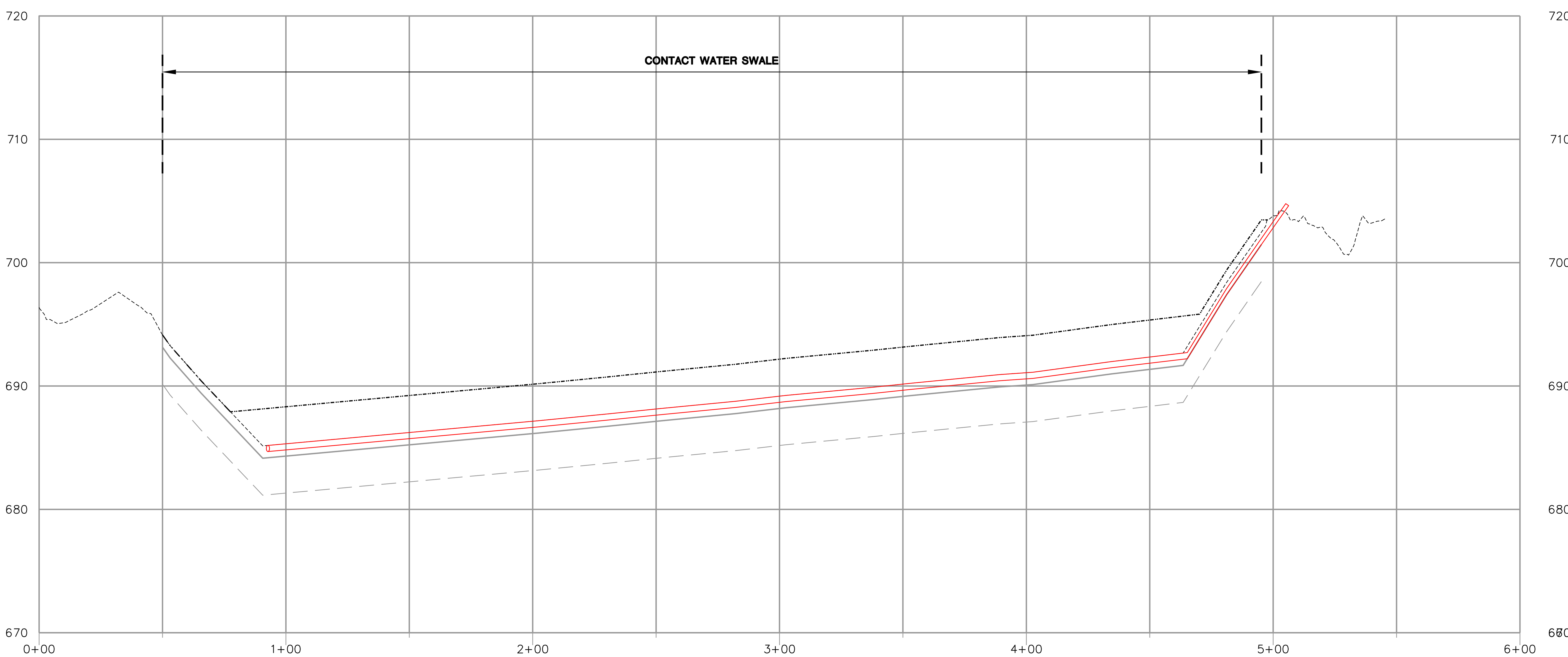
CROSS SECTIONS

SHEET 8 OF 15



SECTION D-D'

(LEACHATE COLLECTION PIPE CENTERLINE – NORTH CONTACT WATER SWALE)

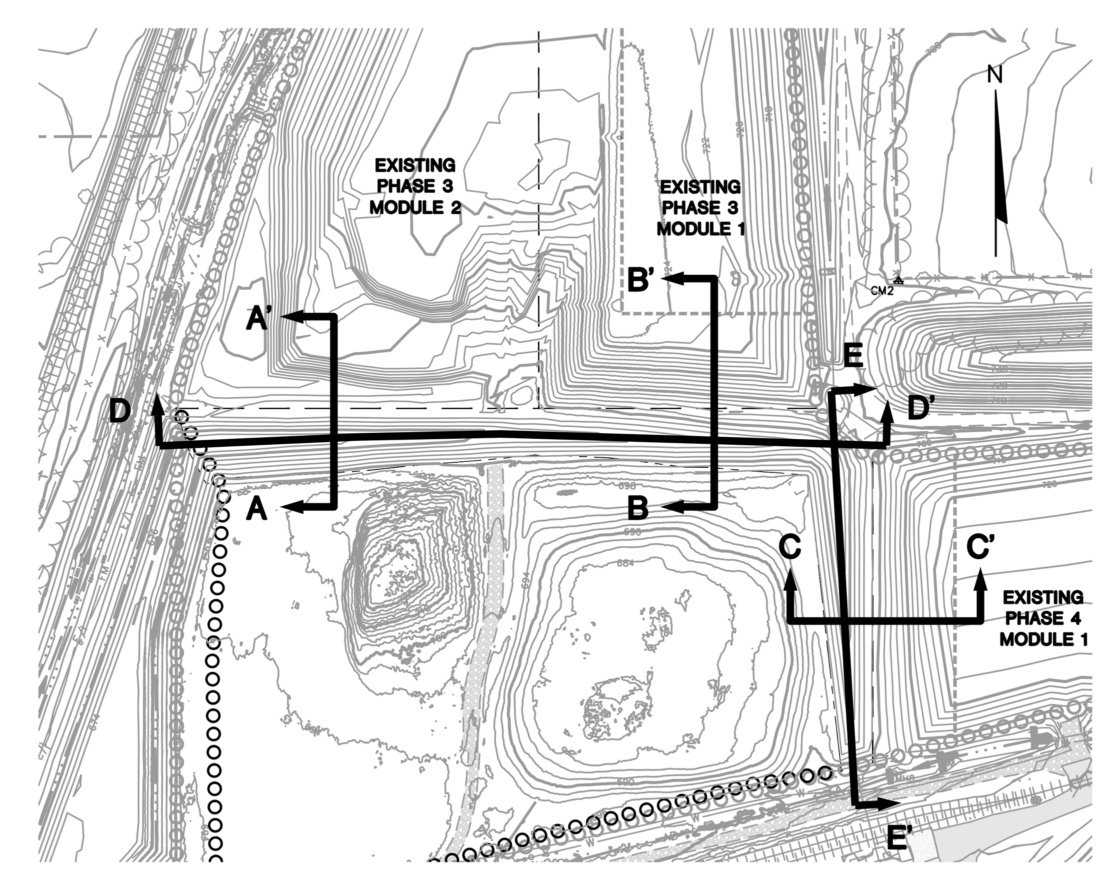


SECTION E-E'

(LEACHATE COLLECTION PIPE CENTERLINE – EAST CONTACT WATER SWALE)

LEGEND

- EXISTING GRADE
- DOCUMENTED BASE GRADE
- DOCUMENTED SUBBASE GRADE
- PROPOSED BASE GRADE
- PROPOSED LEACHATE COLLECTION PIPE
- PROPOSED TOP OF DRAINAGE LAYER



CROSS SECTION LOCATION

SCALE: 1" = 200'

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SITE

CROSS SECTIONS

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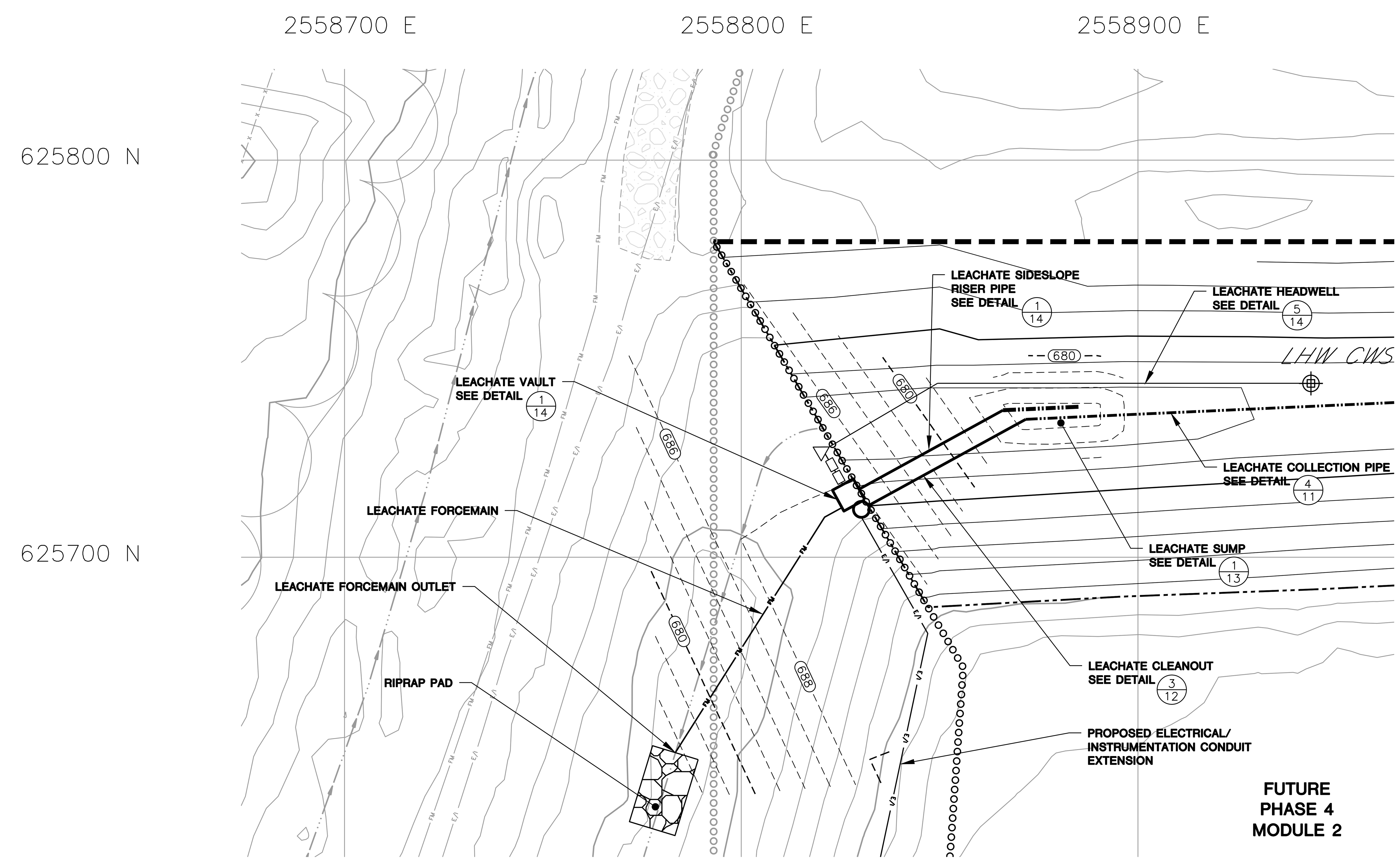


PLAN LEGEND

- APPROVED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- APPROVED MODULE LIMITS
- PROPOSED ASH LIMITS
- EXISTING GRADE (2' CONTOUR)
- EXISTING GRADE (10' CONTOUR)
- EXISTING BASE GRADE (2' CONTOUR)
- EXISTING BASE GRADE (10' CONTOUR)
- EXISTING LEACHATE FORCEMAIN
- EXISTING ELECTRIC AND INSTRUMENT CONDUITS
- PROPOSED GRADE (2' CONTOUR)
- PROPOSED GRADE (10' CONTOUR)
- PROPOSED LEACHATE COLLECTION LINE
- PROPOSED CLEANOUT
- PROPOSED LEACHATE FORCEMAIN
- PROPOSED ELECTRIC AND INSTRUMENT CONDUITS
- PROPOSED LEACHATE HEADWELL

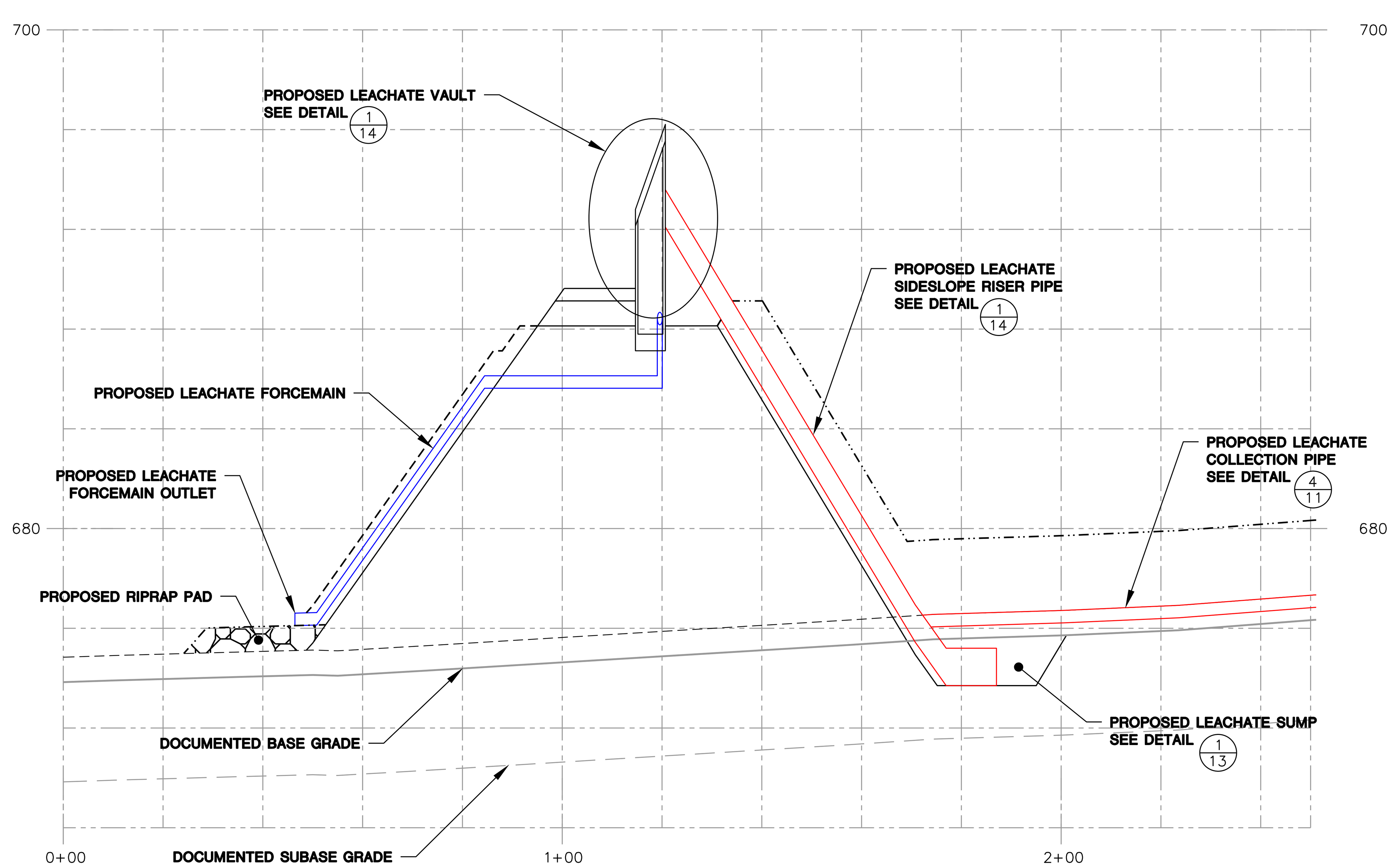
NOTES:

1. SEE SHEET 2 FOR ADDITIONAL BASE MAP LEGEND ITEMS AND NOTES.
2. PROPOSED GRADES REPRESENT PROPOSED CONTACT WATER SWALE SUMP AND BERM GRADES AND ARE AT TOP OF CLAY (BASE GRADES).

N

40 0 40

SCALE: 1" = 40'



PROPOSED LEACHATE FORCEMAIN

PROFILE LEGEND

- EXISTING GRADE
- DOCUMENTED BASE GRADE
- DOCUMENTED SUBBASE GRADE
- PROPOSED BASE GRADE
- PROPOSED LEACHATE COLLECTION PIPE
- PROPOSED LEACHATE FORCEMAIN PIPE
- PROPOSED TOP OF DRAINAGE LAYER
- PROPOSED TOP OF STONE

20 0 20

SCALE: 1" = 20'
5X VERTICAL EXAGGERATION

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SITE

LEACHATE FORCEMAIN PLAN AND PROFILE

SHEET
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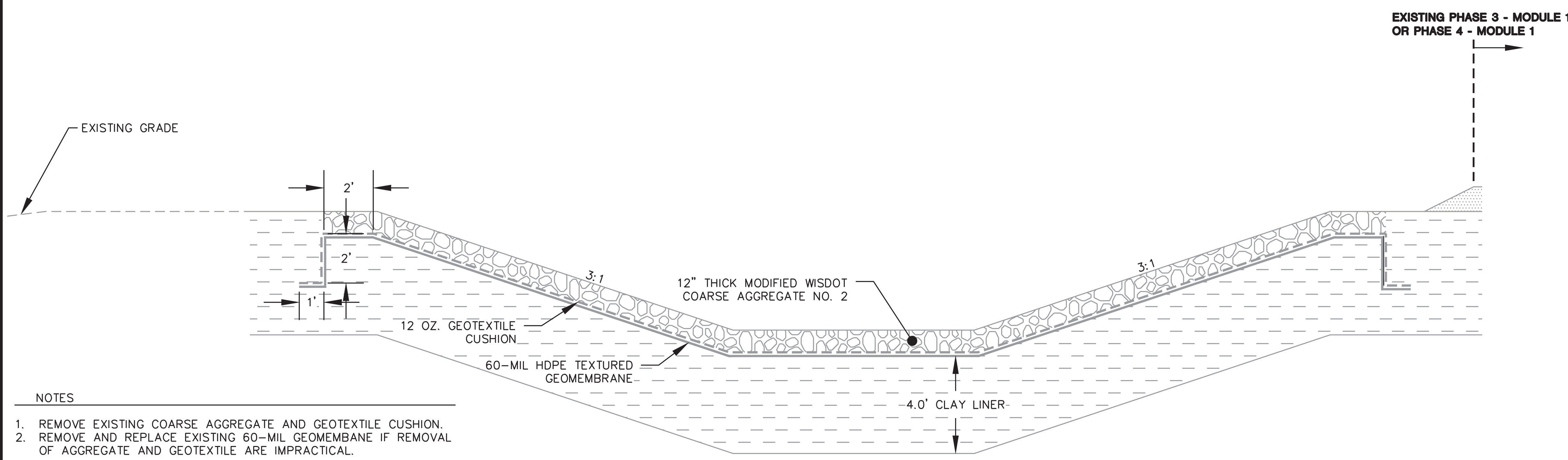
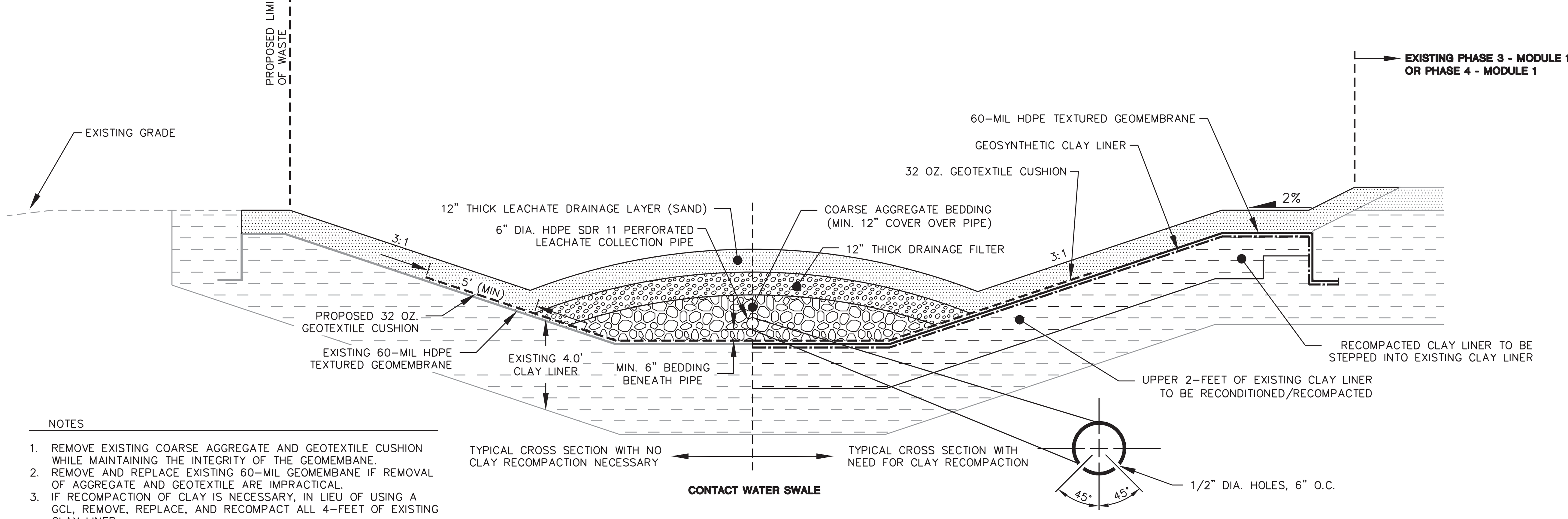


NOTES

1. REMOVE EXISTING COARSE AGGREGATE AND GEOTEXTILE CUSHION.
2. REMOVE AND REPLACE EXISTING 60-MIL GEOMEMBANE IF REMOVAL OF AGGREGATE AND GEOTEXTILE ARE IMPRACTICAL.

EXISTING CONTACT WATER SWALE - PHASE 3 - MODULE 1 AND PHASE 4 - MODULE 1

1 / 11 NOT TO SCALE

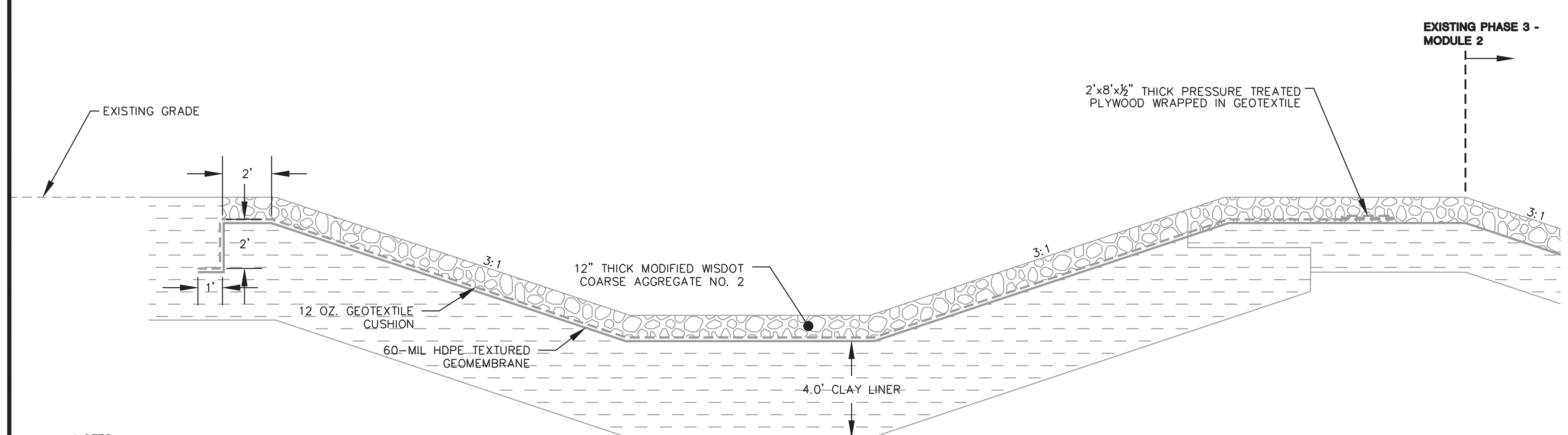


NOTES

1. REMOVE EXISTING COARSE AGGREGATE AND GEOTEXTILE CUSHION WHILE MAINTAINING THE INTEGRITY OF THE GEOMEMBANE.
2. REMOVE AND REPLACE EXISTING 60-MIL GEOMEMBANE IF REMOVAL OF AGGREGATE AND GEOTEXTILE ARE IMPRACTICAL.
3. IF RECOMPACTION OF CLAY IS NECESSARY, IN LIEU OF USING A GCL, REMOVE, REPLACE, AND RECOMPACT ALL 4-FEET OF EXISTING CLAY LINER.

PROPOSED CONTACT WATER SWALE - PHASE 3 - MODULE 1 AND PHASE 4 - MODULE 1 TIE-IN

2 / 11 NOT TO SCALE

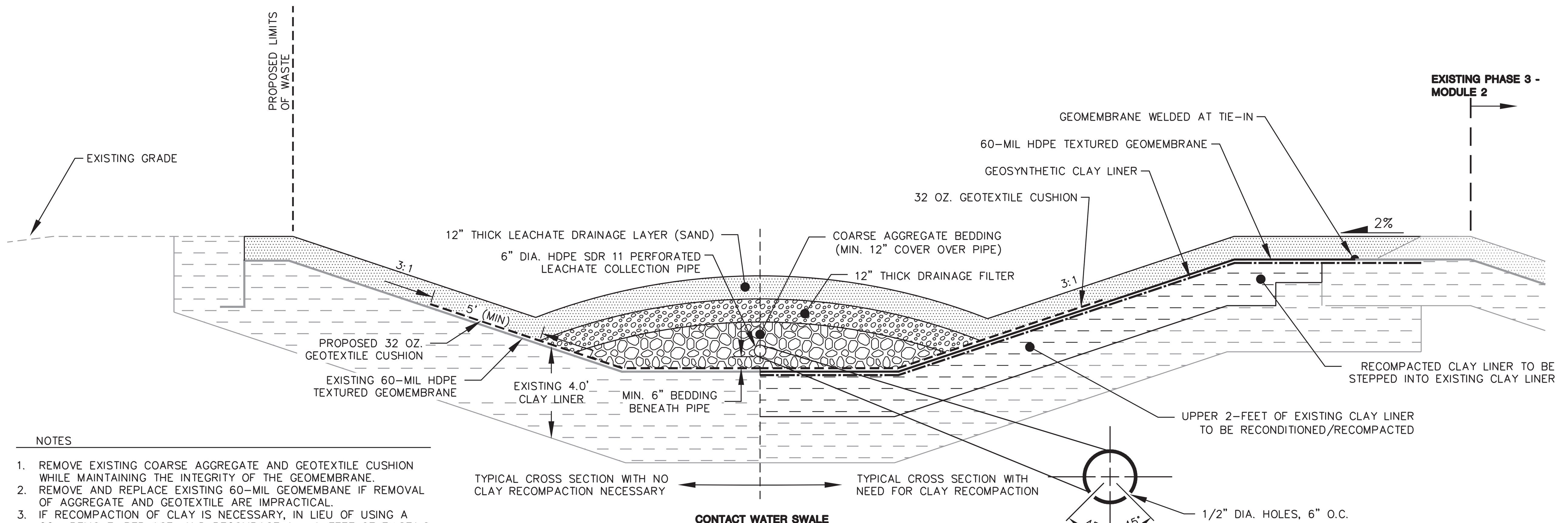


NOTES

1. REMOVE EXISTING COARSE AGGREGATE AND GEOTEXTILE CUSHION.
2. REMOVE AND REPLACE EXISTING 60-MIL GEOMEMBANE IF REMOVAL OF AGGREGATE AND GEOTEXTILE ARE IMPRACTICAL.

EXISTING CONTACT WATER SWALE - PHASE 3 - MODULE 2

3 / 11 NOT TO SCALE

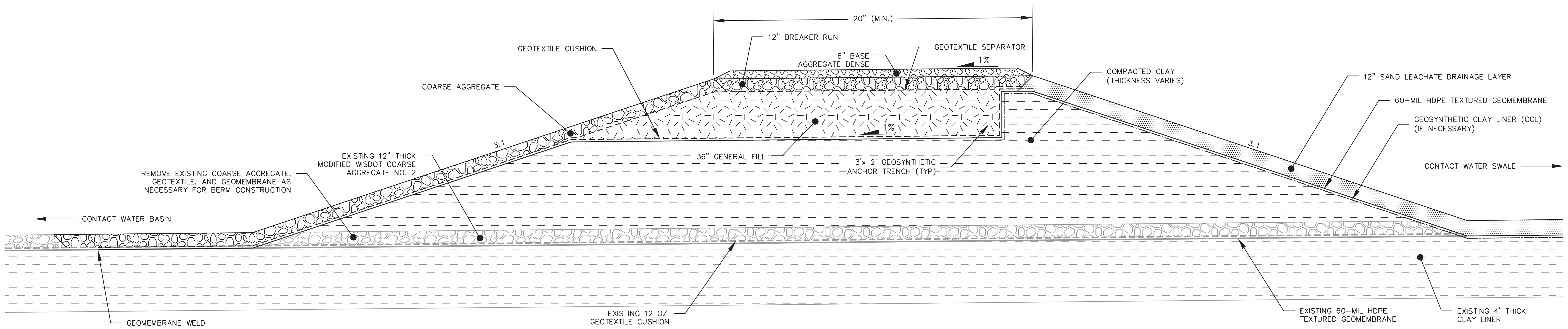


NOTES

1. REMOVE EXISTING COARSE AGGREGATE AND GEOTEXTILE CUSHION WHILE MAINTAINING THE INTEGRITY OF THE GEOMEMBRANE.
2. REMOVE AND REPLACE EXISTING 60-MIL GEOMEMBANE IF REMOVAL OF AGGREGATE AND GEOTEXTILE ARE IMPRACTICAL.
3. IF RECOMPACTION OF CLAY IS NECESSARY, IN LIEU OF USING A GCL, REMOVE, REPLACE, AND RECOMPACT ALL 4-FEET OF EXISTING CLAY LINER.

PROPOSED CONTACT WATER SWALE - PHASE 3 - MODULE 2 TIE-IN

4 / 11 NOT TO SCALE



CONTACT WATER SWALE BERM

5 / 11 NOT TO SCALE

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SITE

DETAILS

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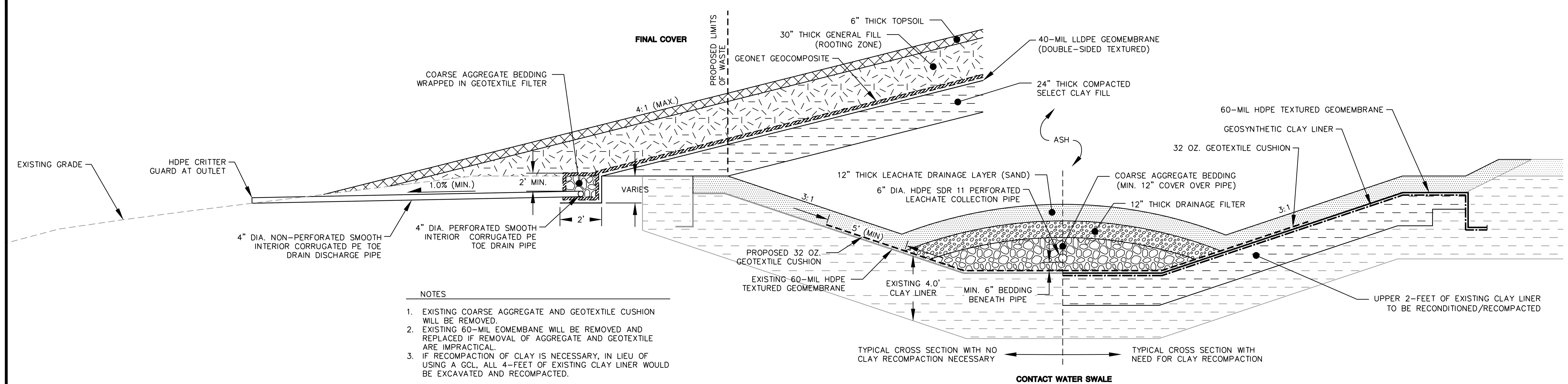
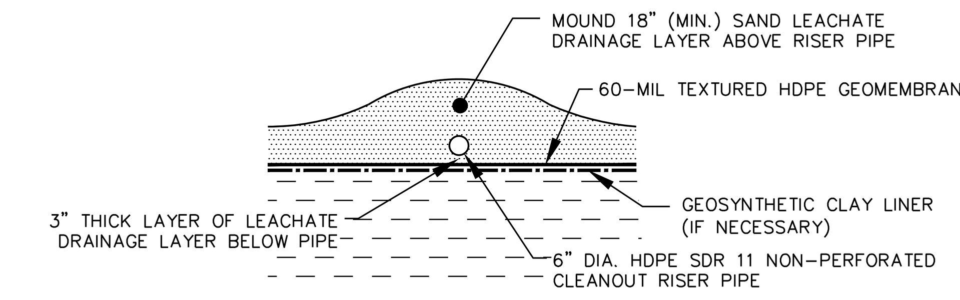


NOTES

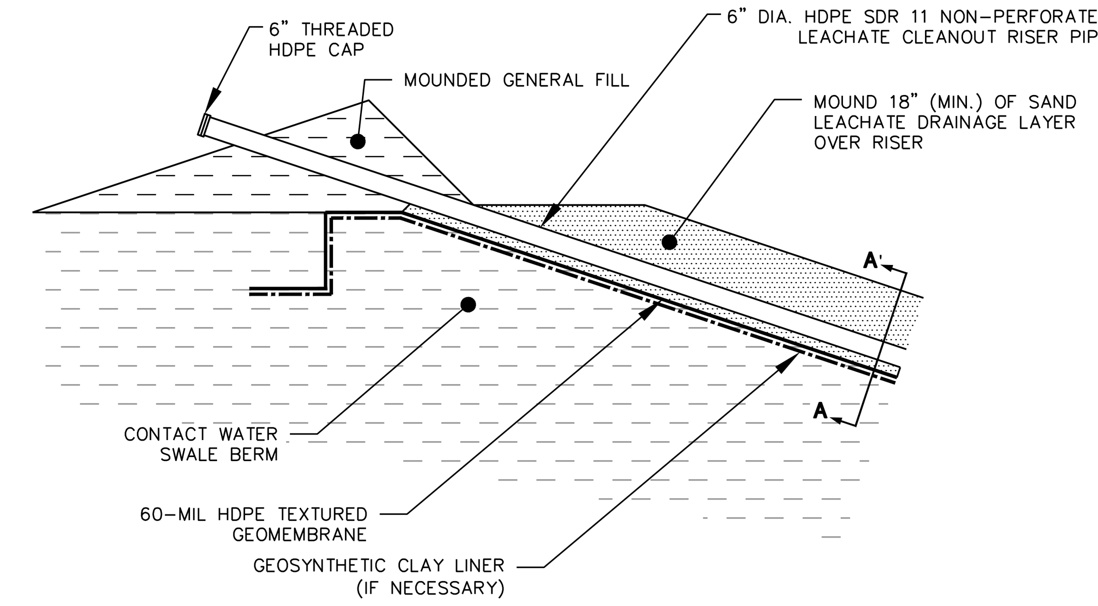
1. EXISTING COARSE AGGREGATE AND GEOTEXTILE CUSHION WILL BE REMOVED.
2. EXISTING 60-MIL EOMEMBANE WILL BE REMOVED AND REPLACED IF REMOVAL OF AGGREGATE AND GEOTEXTILE ARE IMPRACTICAL.
3. IF RECOMPACTION OF CLAY IS NECESSARY, IN LIEU OF USING A GCL, ALL 4-FEET OF EXISTING CLAY LINER WOULD BE EXCAVATED AND RECOMPACTED.

1/12 CONTACT WATER SWALE LINER CONVERSION - FINAL COVER TIE-IN AND TOE DRAIN

NOT TO SCALE

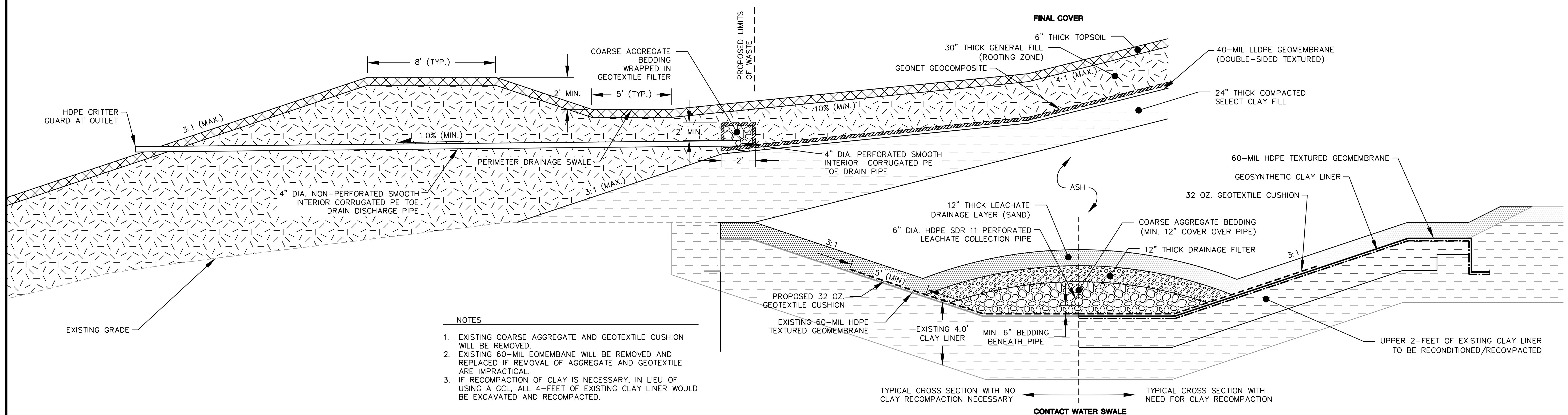


CROSS SECTION A-A'



3/12 LEACHATE CLEANOUT

NOT TO SCALE



NOTES

1. EXISTING COARSE AGGREGATE AND GEOTEXTILE CUSHION WILL BE REMOVED.
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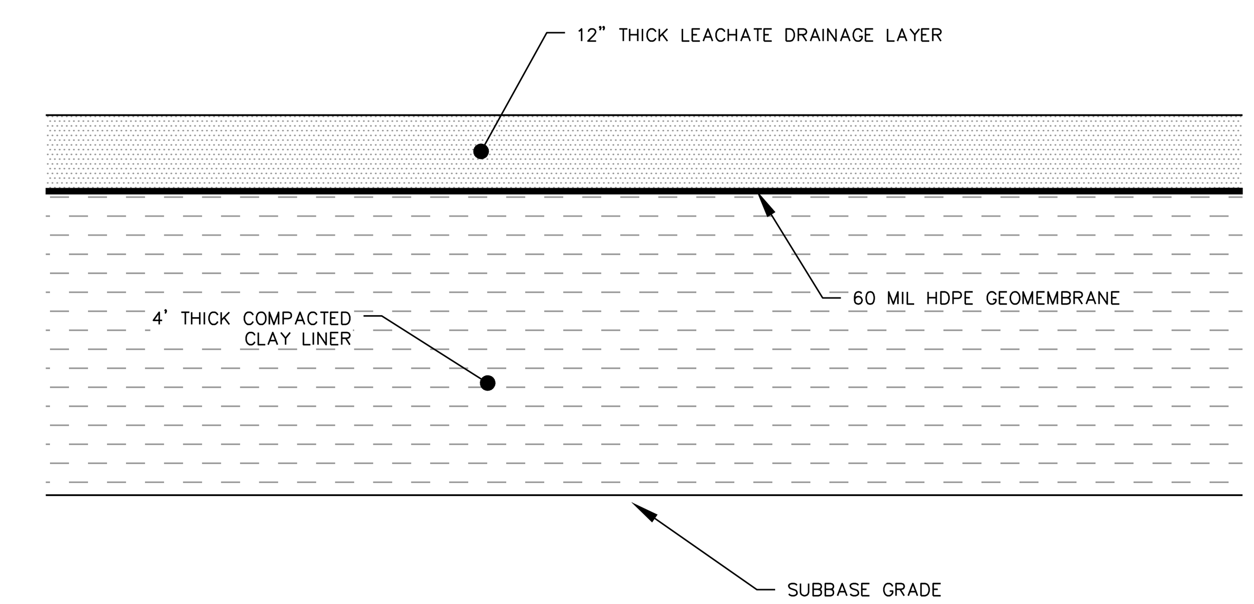
3. IF RECOMPACTION OF CLAY IS NECESSARY, IN LIEU OF USING A GCL, ALL 4-FEET OF EXISTING CLAY LINER WOULD BE EXCAVATED AND RECOMPACTED.

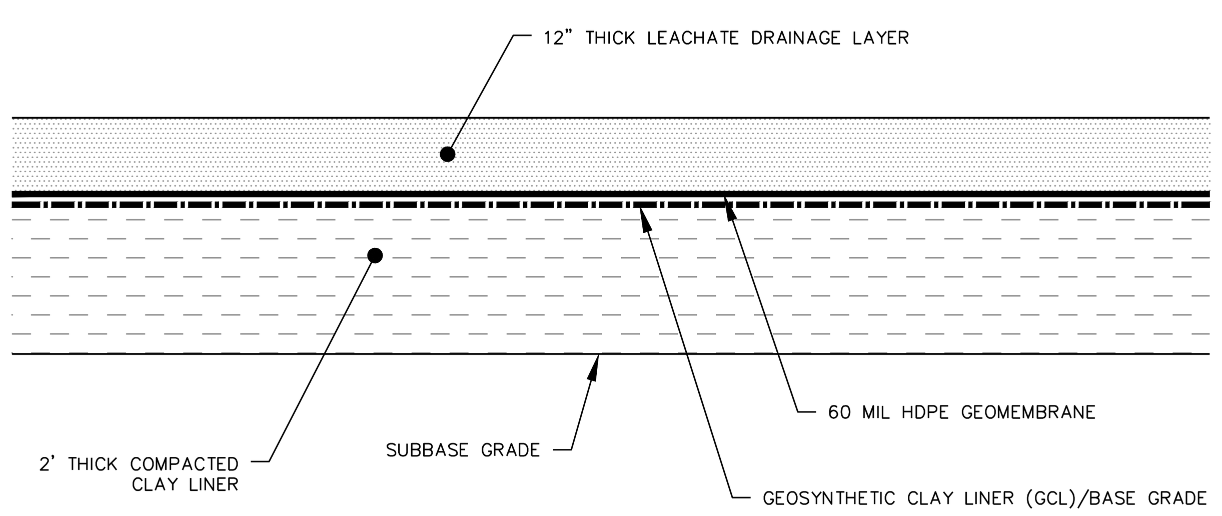
2/12 CONTACT WATER SWALE - FINAL COVER - DRAINAGE DITCH AND TOE DRAIN TIE-IN

NOT TO SCALE



4/12 COMPOSITE LINER (4-FOOT CLAY LINER)

NOT TO SCALE



5/12 COMPOSITE LINER (2-FOOT CLAY LINER WITH GCL)

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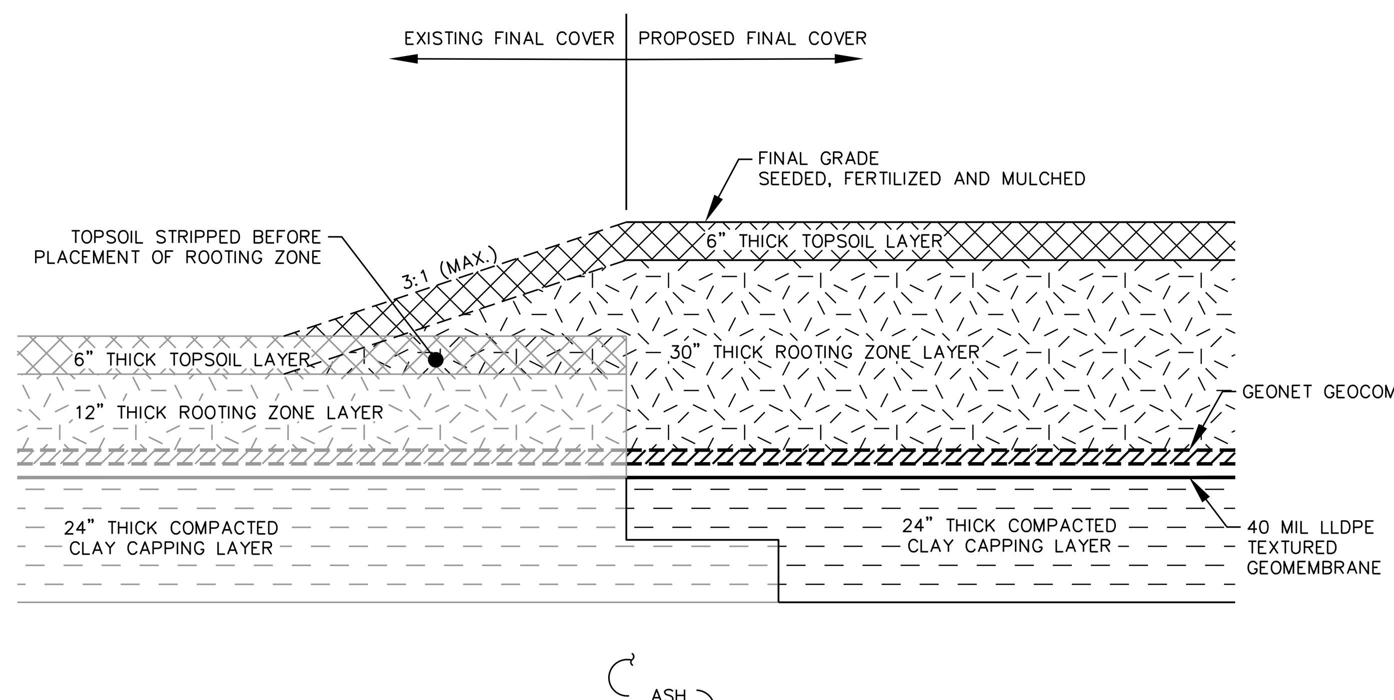
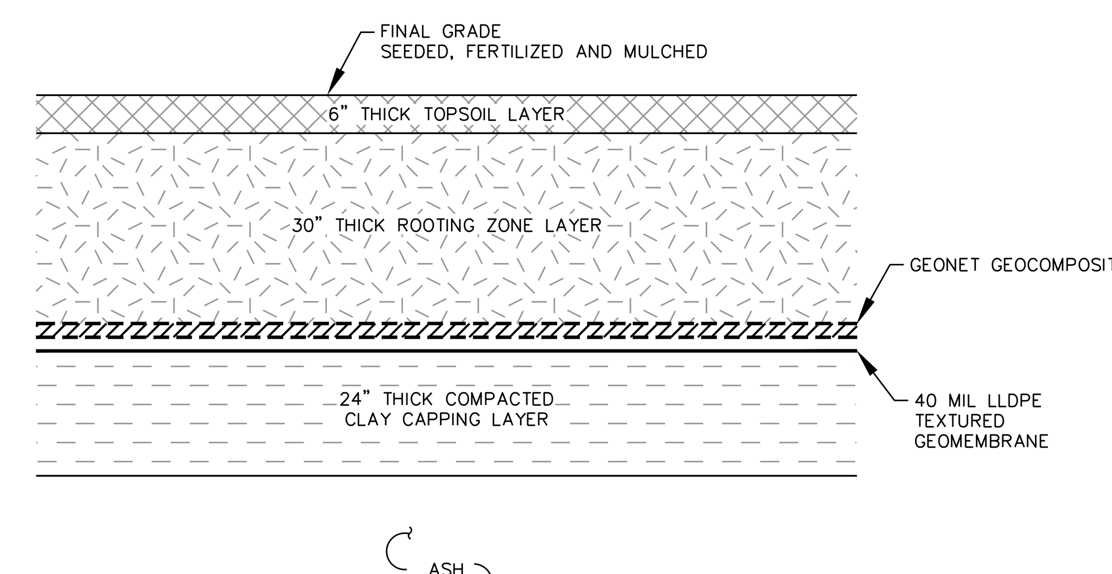


6/12 EXISTING TO PROPOSED FINAL COVER TRANSITION

NOT TO SCALE



7/12 FINAL COVER

NOT TO SCALE

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WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

ENGINEER

PLAN MODIFICATION CONTACT WATER SWALE CONVERSION
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
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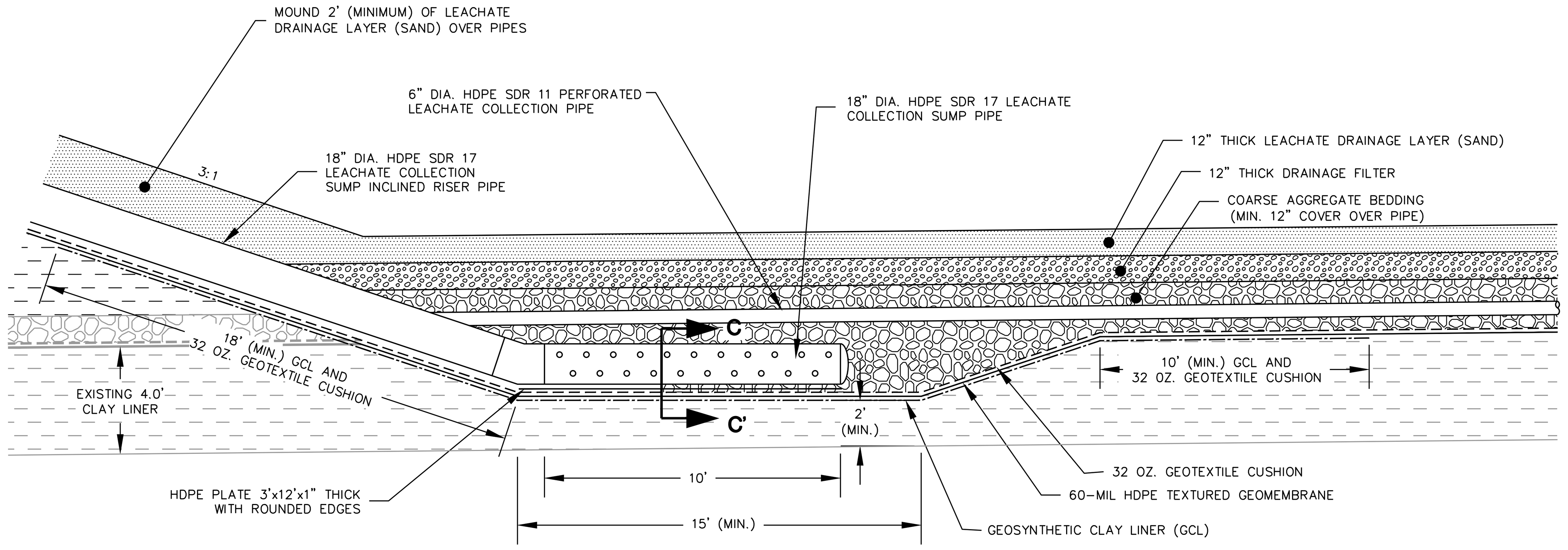
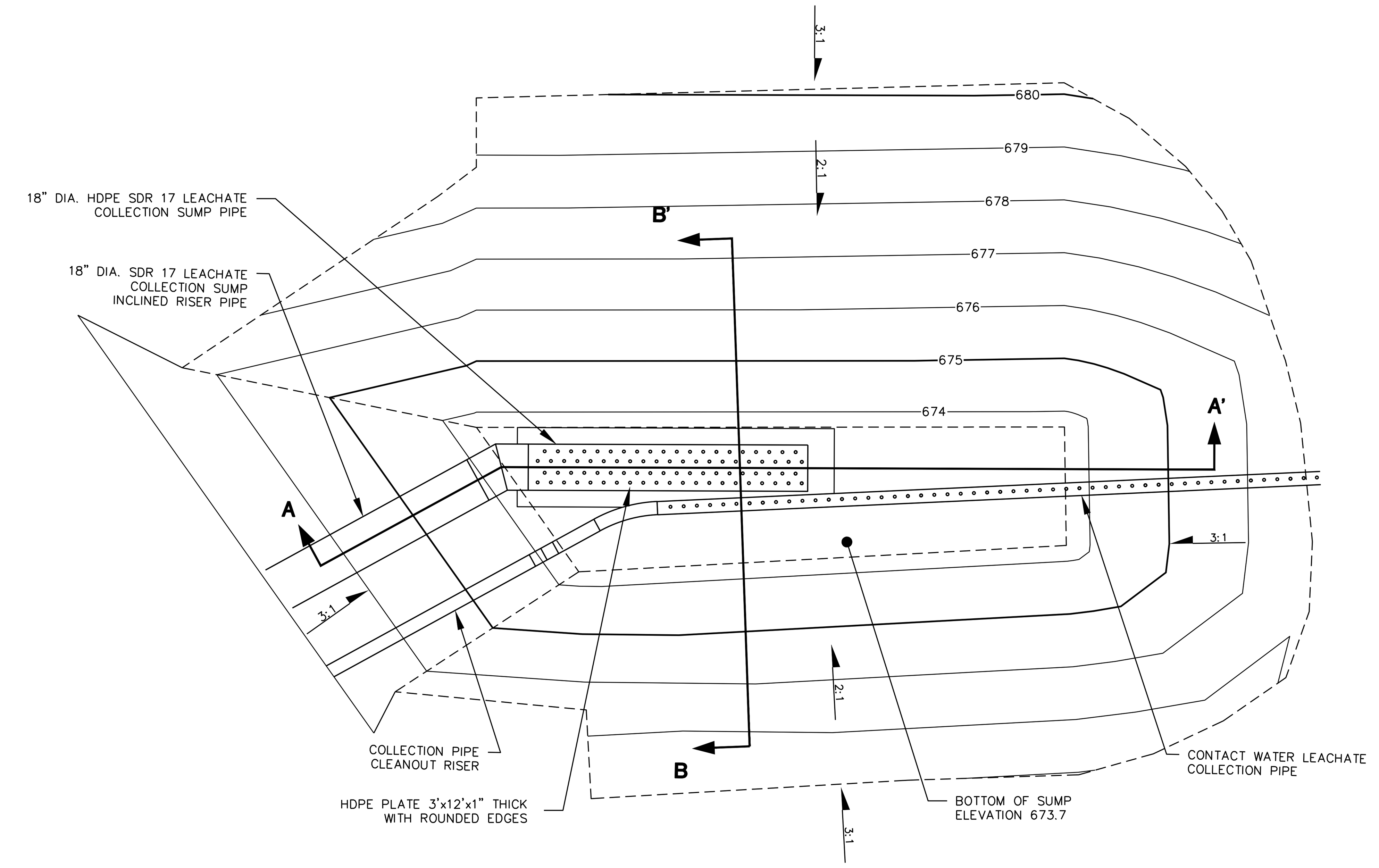
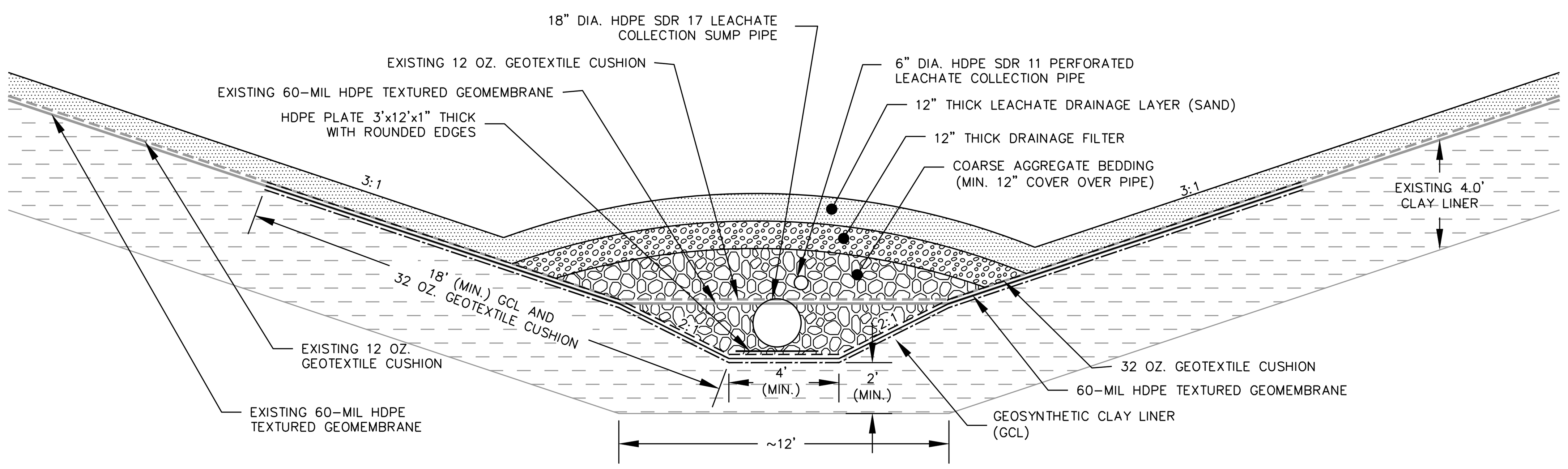


SECTION A-A'



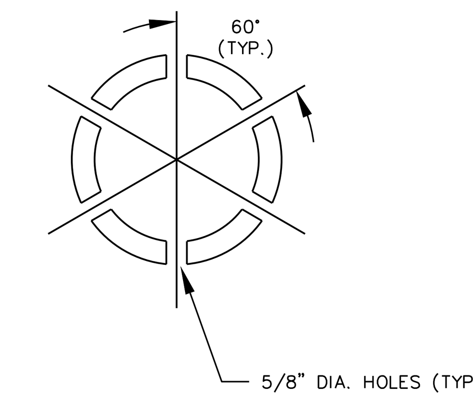
PLAN VIEW



SECTION B-B'

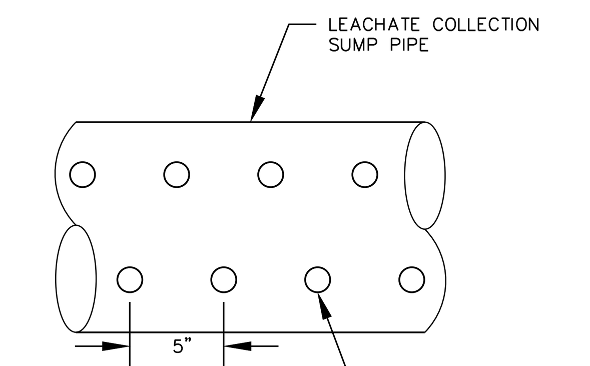
NOTE:

1. REMOVE EXISTING COARSE AGGREGATE, GEOSYNTHETICS, AND 2-FEET OF CLAY LINER FOR SUMP CONSTRUCION.
2. ALL 90° ELBOWS ON LEACHATE PIPING TO CONSIST OF LONG SWEEP ELBOWS OR TWO 45° ELBOWS.



SECTION C-C'

(NOT TO SCALE)

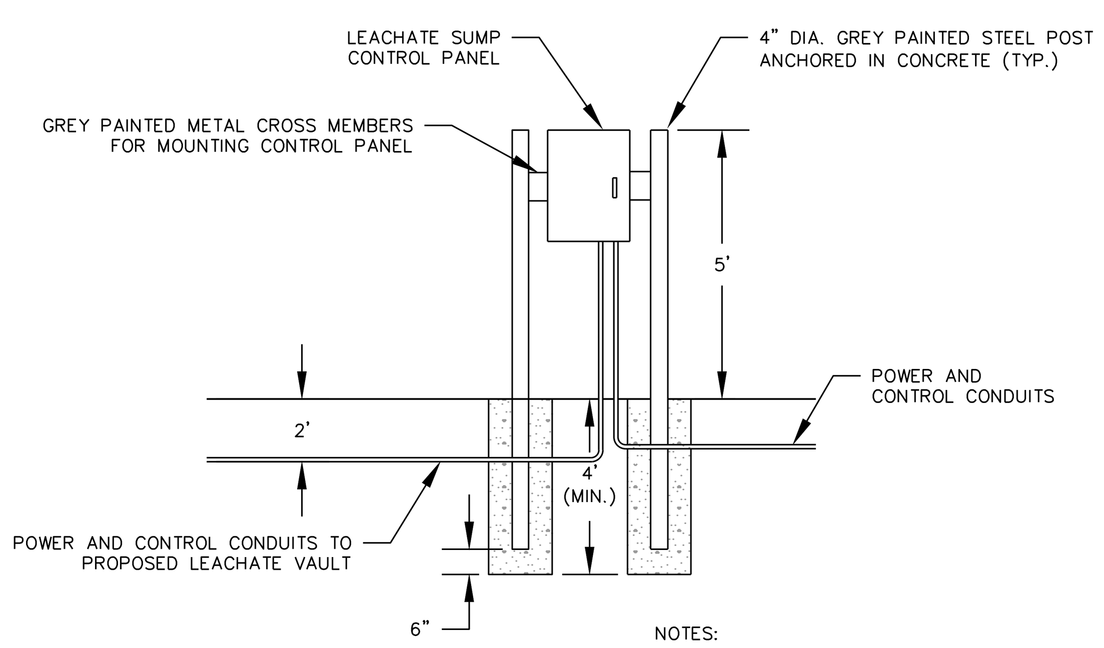


LEACHATE COLLECTION SUMP PERFORATION

(NOT TO SCALE)

1/13 **LEACHATE COLLECTION SUMP**

NOT TO SCALE

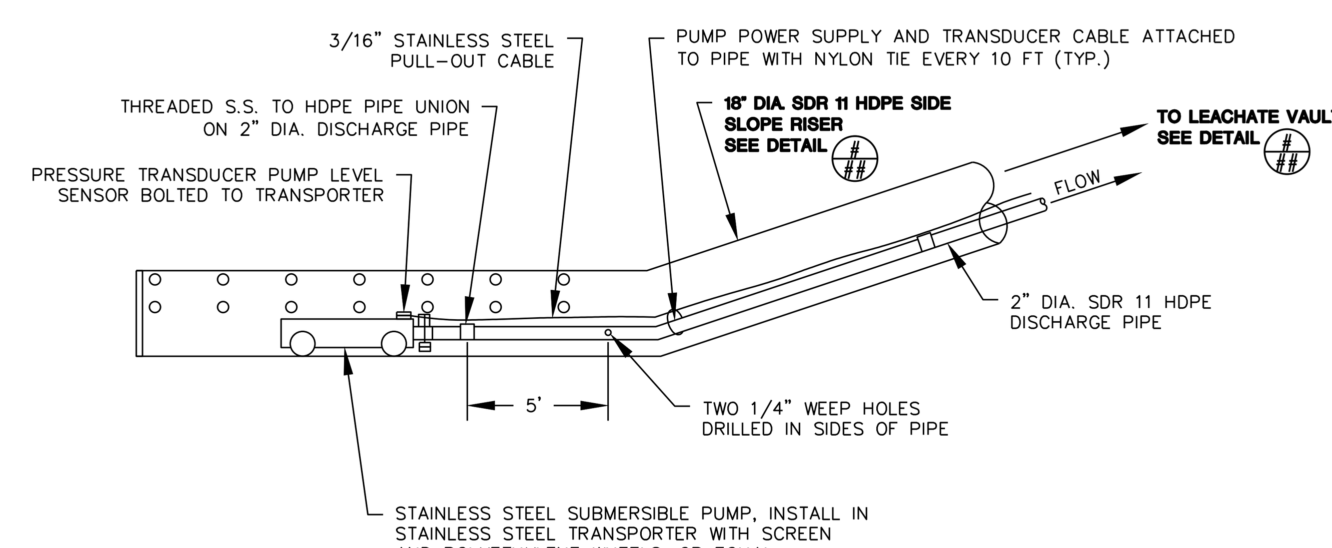


NOTES:

1. PUMP OPERATION TO BE SET AS FOLLOWS:
   PUMP OFF LEVEL: 1-FOOT ABOVE PRESSURE TRANSDUCER PUMP LEVEL SENSOR.
   PUMP ON LEVEL: 3-FEET ABOVE PRESSURE TRANSDUCER PUMP LEVEL SENSOR.
   ALARM LEVEL: 4-FEET ABOVE PRESSURE TRANSDUCER PUMP LEVEL SENSOR.

2/13 **LEACHATE PUMP CONTROL PANEL**

NOT TO SCALE



3/13 **LEACHATE INCLINED RISER PUMP**

NOT TO SCALE

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DRAWN:	01/05/2024	CHECKED BY:	PEG/MJT
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WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

ENGINEER

PLAN MODIFICATION CONTACT WATER SWALE CONVERSION
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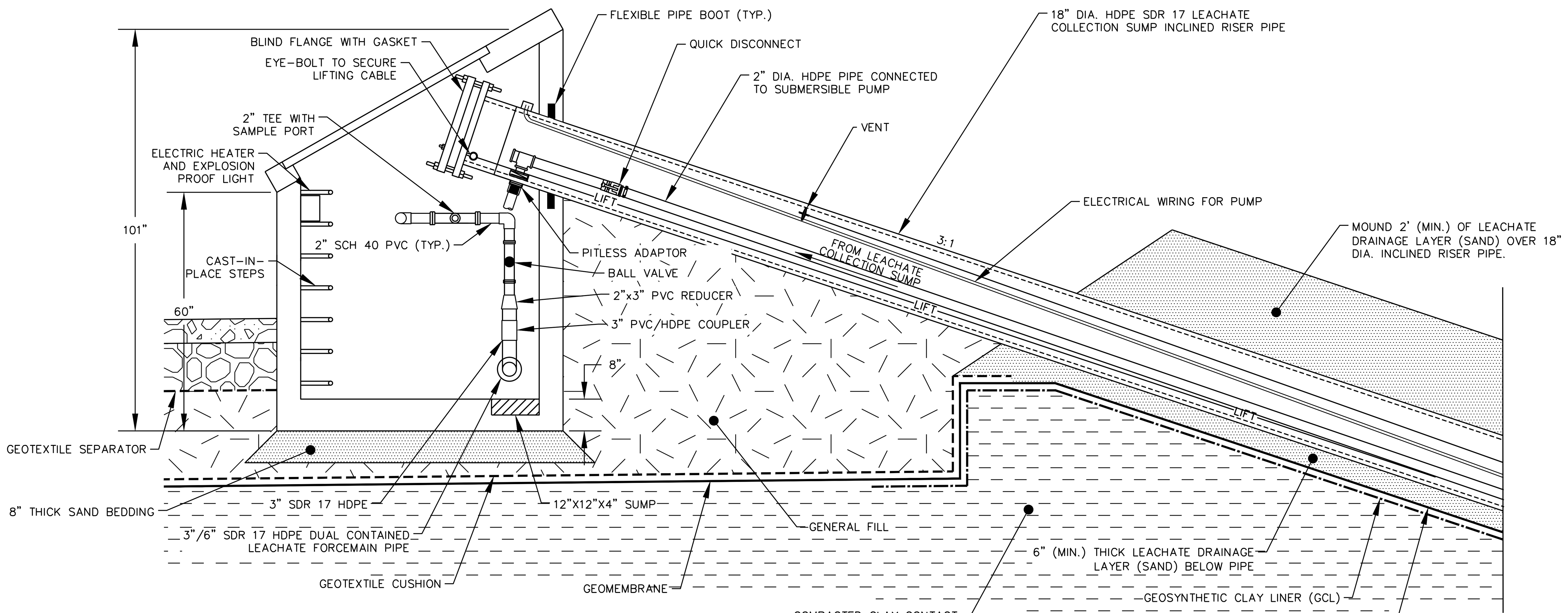
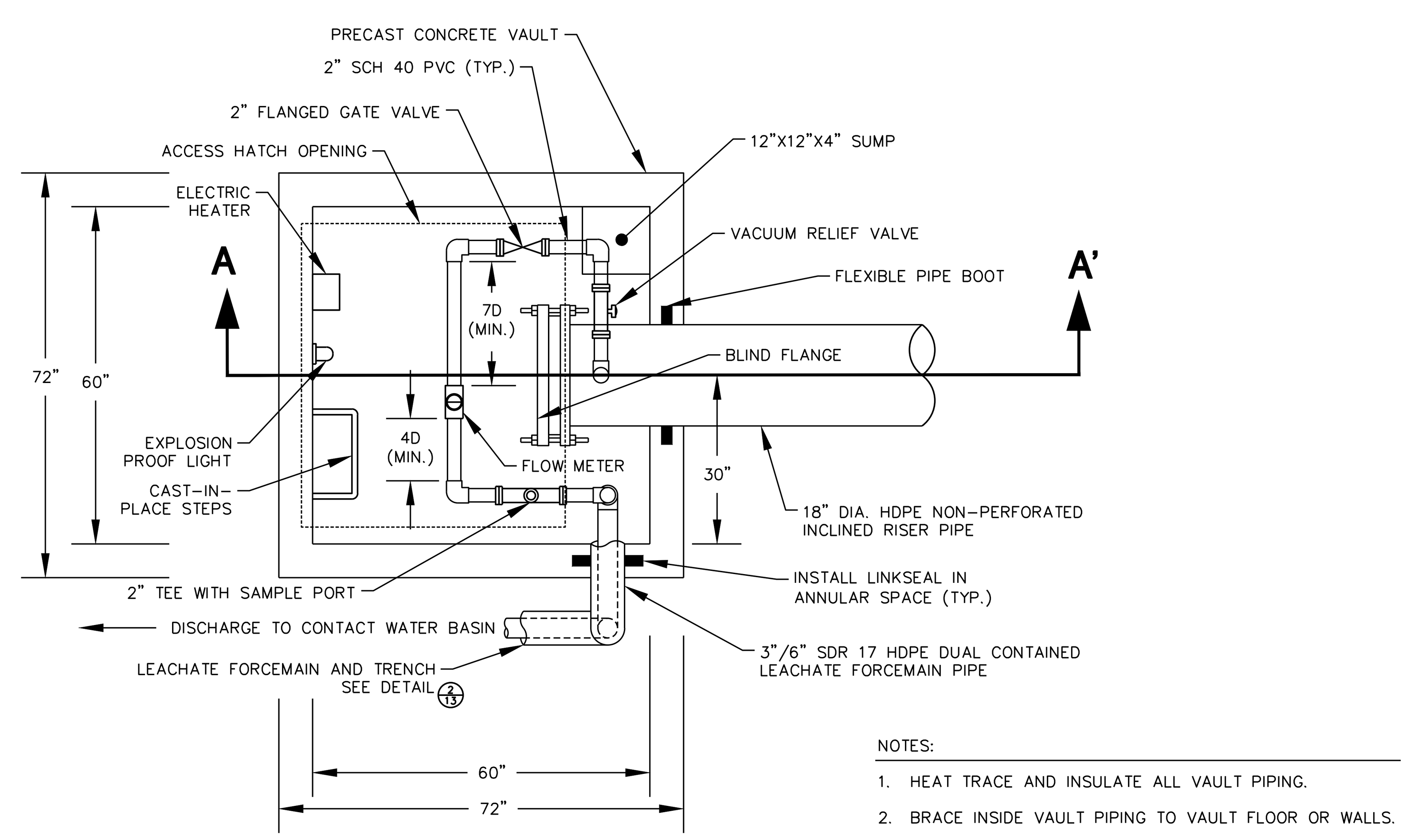


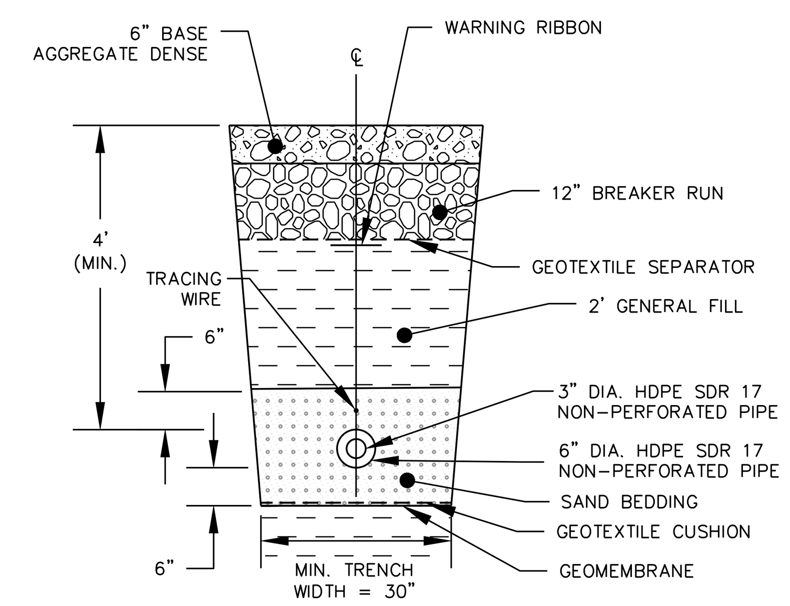
SECTION A-A'



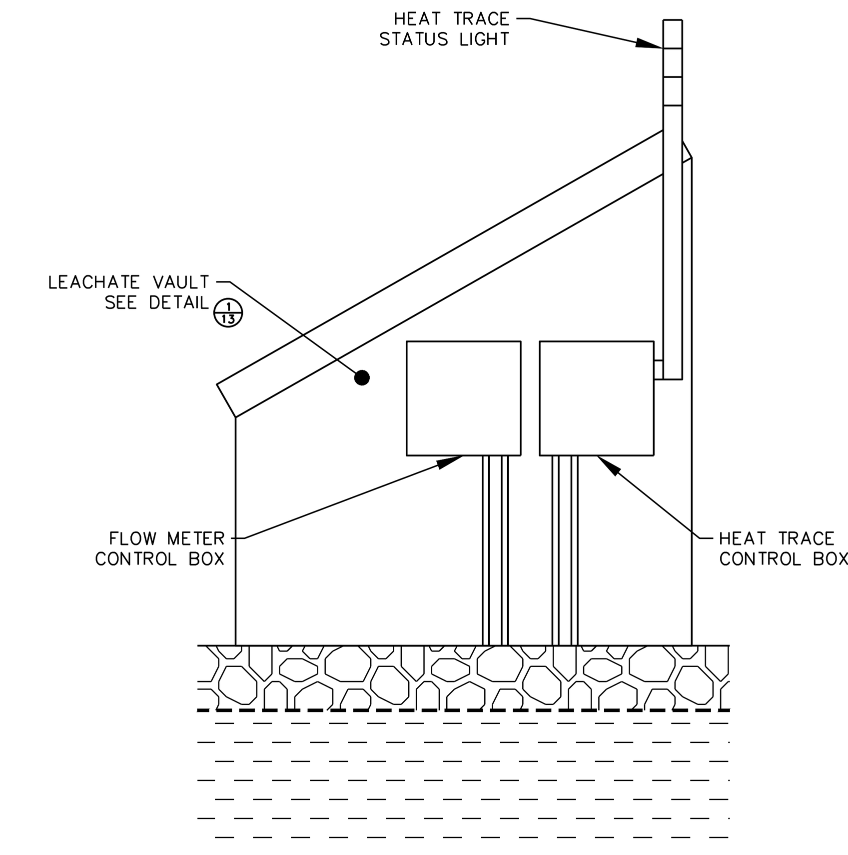
NOTES:
1. HEAT TRACE AND INSULATE ALL VAULT PIPING.
2. BRACE INSIDE VAULT PIPING TO VAULT FLOOR OR WALLS.

PLAN VIEW

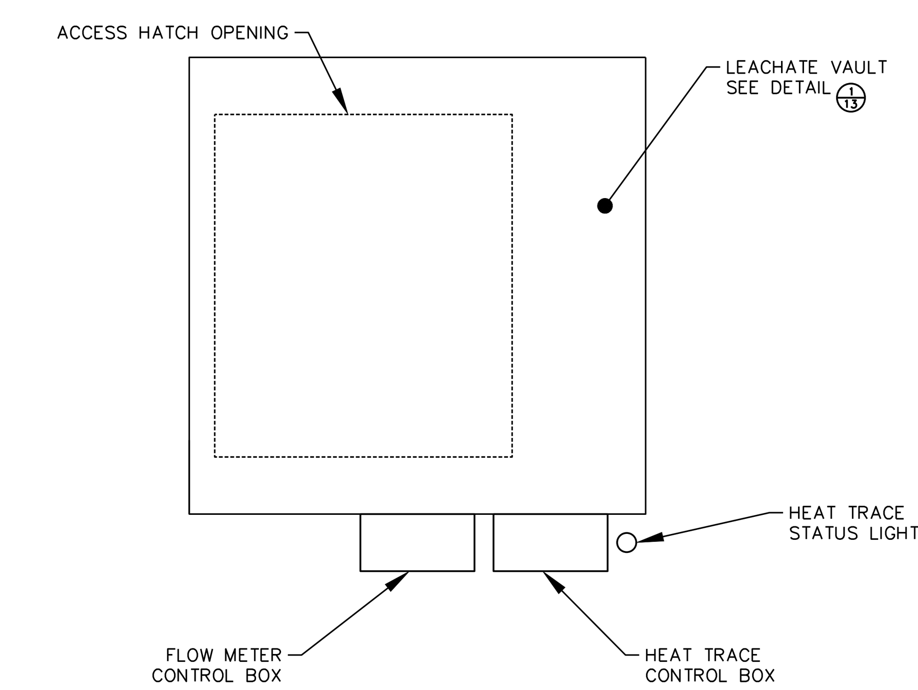
1/14 INCLINED RISER PIPE AND LEACHATE VAULT
NOT TO SCALE



2/14 LEACHATE FORCEMAIN AND TRENCH
NOT TO SCALE

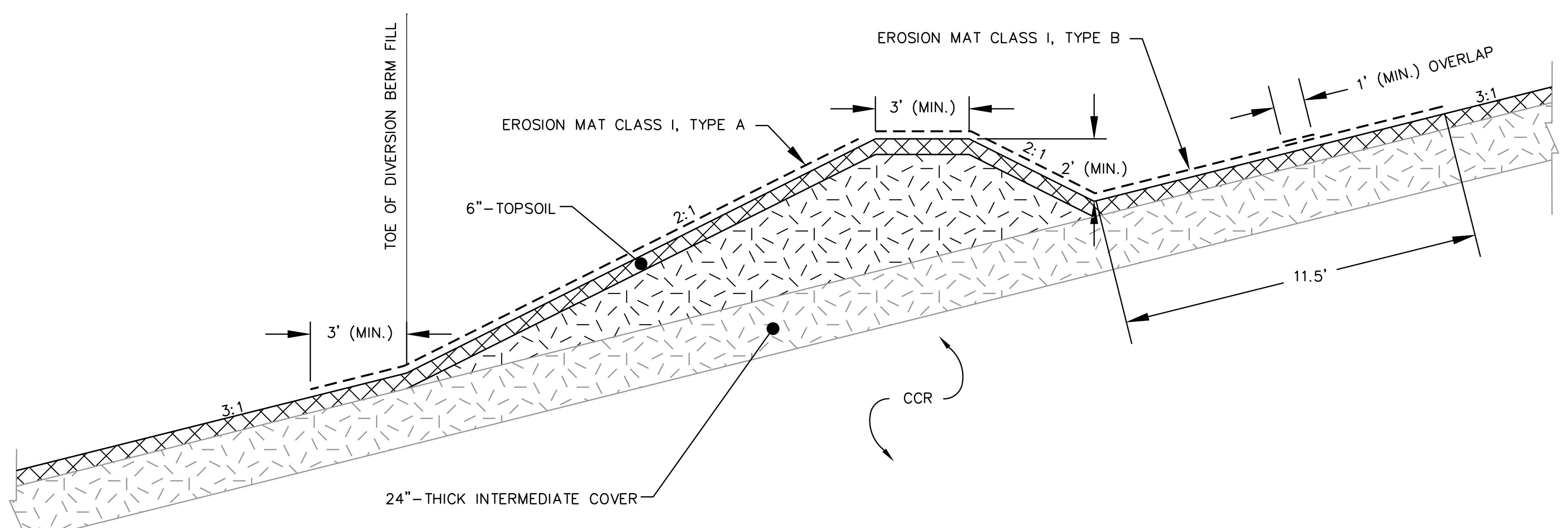


PROFILE VIEW

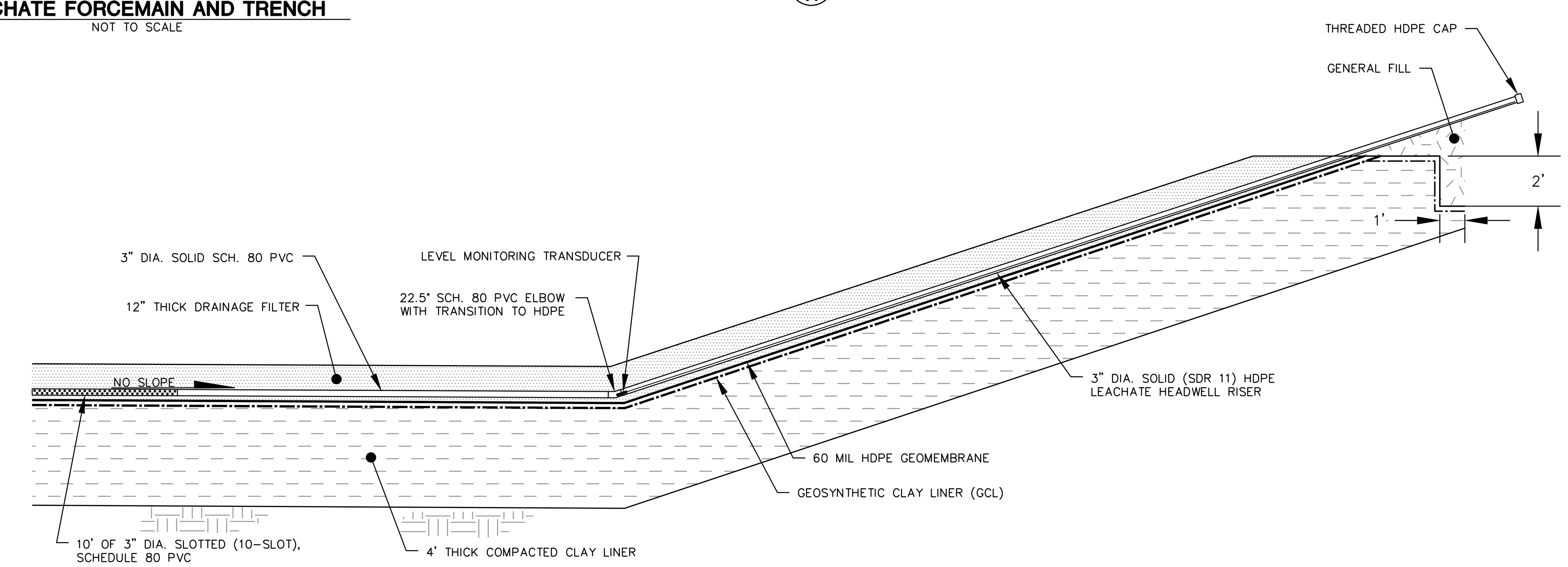


PLAN VIEW

3/14 LEACHATE VAULT CONTROL BOXES
NOT TO SCALE



4/14 TEMPORARY DIVERSION BERM
NOT TO SCALE



5/14 LEACHATE HEADWELL
NOT TO SCALE

PROJECT NO.	25222259.00	DRAWN BY:	KP/RR		
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EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081
CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830
ENGINEER

PLAN MODIFICATION CONTACT WATER SWALE CONVERSION
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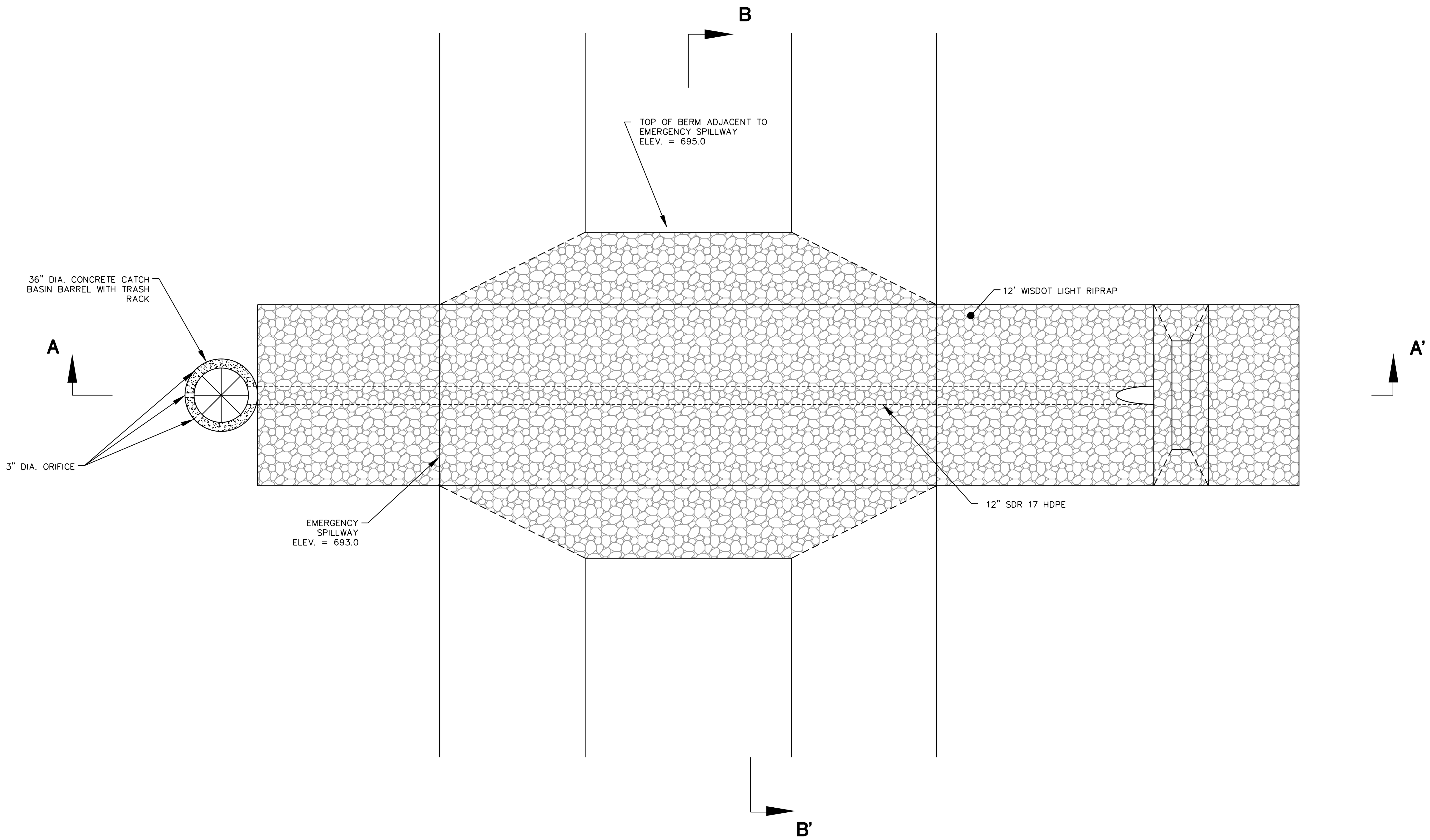

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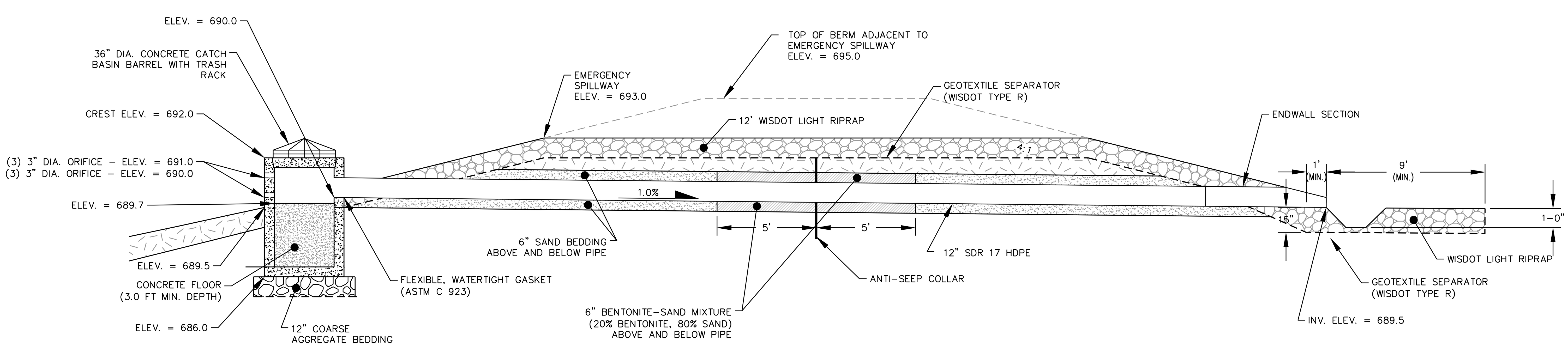
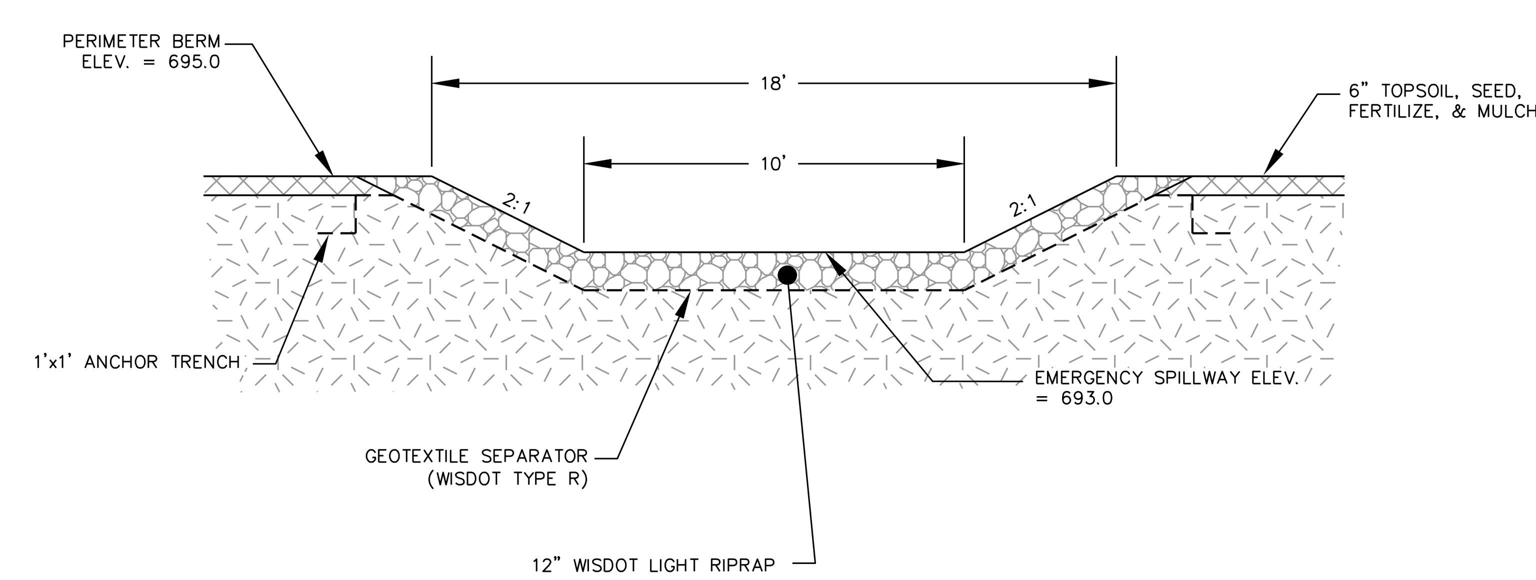


NOTE: IF ANTI-SEEP COLLAR IS CONSTRUCTED CAST IN PLACE, PERFORM ACCORDING TO PART 3.2, CAST IN PLACE CONCRETE.



1/15 **SOUTH SEDIMENTATION BASIN OUTLET STRUCTURE**

NOT TO SCALE

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CLIENT: WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

SITE: PLAN MODIFICATION CONTACT WATER SWALE CONVERSION
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

DETAILS

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Appendix A

Construction Quality Assurance/Quality Control Plan

Construction Quality Assurance/Quality Control Plan

I-43 Ash Disposal Facility
Sheboygan, Wisconsin

Prepared for:

Wisconsin Power and Light Company
Edgewater Generating Station
3739 Lakeshore Drive
Sheboygan, Wisconsin 53081

SCS ENGINEERS

25224280.00 | March 2025

2830 Dairy Drive
Madison, WI 53718-6751
608-224-2830

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this Construction Quality Assurance (CQA) Plan is to address the quality assurance during the construction of the ash disposal facility cover and liner at the Wisconsin Power and Light Company – I-43 Ash Disposal Facility, including all earthen materials (select clay fill, rooting zone material, and topsoil) and geosynthetic materials (geosynthetic clay liner [GCL], geocomposite, geotextile, and geomembrane).

This CQA Plan provides procedures that will ensure that all components of the cover and liner systems are constructed in a manner that will maximize their performance requirements and will safeguard components from damage during construction.

The scope of this CQA Plan includes general CQA requirements concerning roles, responsibilities, and qualifications of the parties involved; the preconstruction meeting, general inspection, and documentation procedures; and the documentation report. This CQA Plan establishes requirements for the construction procedures and observation, field and laboratory testing frequency and methods, and acceptance for each component of the cover and liner systems.

This plan is intended to serve as a guide and can be modified to reflect current industry standards with regard to laboratory testing methods, testing procedures, testing requirements, and applicable regulations. Any changes from this plan will be discussed in the documentation report as required.

The following sources were used in developing this plan:

- Geosynthetic Research Institute, GRI Test Method GCL 3, "Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs)," revision 5, November 21, 2019.

- Geosynthetic Research Institute, GRI Test Method GT 12(a), "Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials," revision 2, March 3, 2016.

- Geosynthetic Research Institute, GRI Test Method GM 13, "Standard Specification for Test Methods, Test Properties, and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes," revision 18, April 5, 2024.

- Geosynthetic Research Institute, GRI Test Method GM 17, "Standard Specification for Test Methods, Test Properties, and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes," revision 16, October 4, 2024.

- Geosynthetic Research Institute, GRI Test Method GM 19a, "Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes," revision 10, March 18, 2021.

- Geosynthetic Research Institute, GRI Test Method GM 6, "Standard Practice for Pressurized Air Channel Test for Dual Seamed Geomembranes," revised 2017.

- American Society for Testing and Materials, Annual Book of ASTM Standards, most recent version.

- EPA Technical Guidance Document EPA/530-SW-86-031 titled "Construction Quality Assurance for Hazardous Waste Land Disposal Facilities."

- NR 500 and NR 141, Wisconsin Administrative Code.

- Wisconsin Department of Transportation, Standard Specifications for Highway and Structure Construction.

- American Association of State Highway and Transportation Officials, AASHTO M43, Standard Specification for Sizes of Aggregate for Road and Bridge Construction.

1.2 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control are defined as follows:

- Quality assurance – A planned and systematic pattern of all means and actions designed to provide adequate confidence that material or services meet contractual and regulatory requirements. This is typically performed to ensure that delivered materials or services are of desired quality.

- Quality control – Those actions that provide a means to measure and regulate the characteristics of a material or service to meet contractual and regulatory requirements. This typically is performed by or for the provider of the materials or services as a control mechanism on the quality of the provider's efforts.

In the context of this CQA Plan, the terms are further defined as follows:

- Quality assurance refers to the means and actions employed by the CQA Officer to ensure conformity of the systems' installation with the CQA Plan, the construction specifications, and the construction plans.

- Quality control refers to those actions taken by the manufacturer, fabricator, or construction/installer to provide materials and workmanship that meet the requirements of the CQA Plan, the construction plans, and the construction specifications. Some testing efforts required by this CQA Plan may serve as both quality control and quality assurance measures.

1.3 GENERAL TESTING REQUIREMENTS

This CQA Plan includes references to test procedures of the American Society for Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI). Test procedure references are always to the latest approved version up to the date of this document, unless specifically stated otherwise in this document.

Testing will be performed in strict accordance with the referenced test procedure and the description included in this plan, unless indicated otherwise. Any deviations to test procedures called out in this plan must be approved, in writing, by the CQA officer or owner prior to commencement of any work.

2.0 CQA ROLES, RESPONSIBILITIES, AND QUALIFICATIONS

2.1 CQA OFFICER

The CQA officer will supervise and be responsible for all observations, testing, and related construction documentation as described in this CQA Plan. The CQA officer will be responsible for preparing the construction acceptance report to certify substantial compliance with the appropriate permit and regulatory agency. The CQA officer will be a professional engineer registered in the state of Wisconsin.

The CQA officer may delegate daily observation, documentation, testing, and sampling duties to a qualified technician or engineer with experience in the assigned aspect of construction that will serve as the Resident Project Representative (RPR). Although these duties may be delegated, the CQA officer will retain the responsibility for these activities.

2.2 RESIDENT PROJECT REPRESENTATIVE

The RPR will carry out daily observation, documentation, testing, and sampling duties under the direct supervision of the CQA officer. The RPR will be a qualified technician or engineer with experience in the assigned aspect of construction, and will observe and document construction and installation procedures. The RPR will prepare daily summary reports, routinely transmit the reports to the CQA officer, and immediately notify the CQA officer of problems or deviations from the CQA Plan or construction plans and specifications. Reporting, documentation, and resolution of problems and deficiencies, will be carried out as described in Section 4.0. The RPR will not have authority to approve design or specification changes without the consent of the CQA officer and the owner.

2.3 SOILS TESTING LABORATORY

The soils testing laboratory retained will be experienced in construction soil testing in accordance with ASTM and other applicable standards. The selected laboratory will be responsive to the project needs by providing test results within reasonable time frames. This will include providing verbal communication on the status of ongoing tests and immediate communication of test results as needed to facilitate ongoing construction. Final laboratory reports will be certified by the soil testing laboratory and submitted to the CQA officer.

2.4 GEOSYNTHETICS TESTING LABORATORY/LABORATORIES

The geosynthetics testing laboratory/laboratories will have experience in testing geosynthetics in accordance with standards developed by ASTM, GRI, and other applicable test standards. The selected laboratory/laboratories will be responsive to the project needs by providing test results within reasonable time frames. Final laboratory reports will be certified by the geosynthetics testing laboratory/laboratories and will be submitted to the CQA officer.

2.5 CONSTRUCTION CONTRACTOR

The construction contractor's role will be to furnish earthwork, construction, and piping installation; and to provide overall construction responsibility for the completion of the final cover component. The construction contractor will be experienced in landfill construction. The term "contractor" is used interchangeably with "construction contractor" in this plan.

2.6 GEOSYNTHETICS INSTALLER

The geosynthetics installers are the companies hired by the contractor to install the geosynthetic components referenced in this plan, and to perform the nondestructive seam testing of the geomembranes required by this plan. The term "installer" is used throughout this plan when reference is made to the tasks and responsibilities of a geosynthetics installer.

The installer will be trained and qualified to install the various geosynthetic components covered by this plan. The installer of the geomembrane will be approved and/or licensed by the manufacturer, and will submit a copy of the approval letter or license to the CQA officer and/or owner.

Prior to confirmation of any contractual agreements, the installer of the geomembranes will provide the CQA officer and/or the owner with the following written information, which must be approved by the CQA officer and/or owner.

- Corporate background and information.

- Installation capabilities:
  - Information on equipment and personnel.
  - Resumes of personnel.
  - Quality control manual for installation.

- A list of at least 10 completed facilities, totaling a minimum of 2,000,000 square feet for which the installer has completed the installation of polyethylene geomembrane. For each installation, the following information will be provided:
  - Purpose of facility, its location, and date of installation.
  - Project manager, designer, manufacturer, and fabricator (if any).
  - Thickness and type of polyethylene geomembrane and the surface area of the installed geomembrane.

The installer of the geomembranes will provide a copy of the tensiometer certification, indicating the date in which the tensiometer was calibrated prior to start of any seaming operations. The installer is responsible for delays caused to the project until tensiometer certification is delivered to the RPR.

Tensiometers used in the state of Wisconsin are required to be calibrated within 90 days prior to the start of the project. The installer is responsible to meet this requirement and must supply a copy of the certification at the time of mobilization to the job site.

All personnel performing geomembrane-seaming operations will be qualified by experience and by successfully passing seaming tests for the seaming methods to be used. At least one seamer shall have experience seaming a minimum of 1,000,000 square feet of polyethylene geomembrane using the same type of seaming apparatus in use at the site. The most experienced seamer, the "master seamer," will provide direct supervision, as required, over less experienced seamers. No field seaming will take place without a master seamer present.

The installer of the geomembranes will provide the CQA officer with a list of proposed seaming and testing personnel, and their professional records, prior to the installation of the geomembranes. The CQA officer and owner will review this document. The CQA officer and/or owner will not accept any proposed seaming personnel deemed insufficiently experienced. The installer will designate one representative as the superintendent, who will represent the installer at all site meetings and who will be responsible for acting as the installer's spokesman on-site.

3.0 PRECONSTRUCTION ACTIVITIES

3.1 PRECONSTRUCTION MEETING

Prior to commencement of each phase of construction at the ash disposal facility, a preconstruction meeting will be held. This meeting will include the parties involved in the construction, including the CQA officer or designated representative, the RPR, the construction contractor, and the owner.

The purpose of this meeting is to begin the planning and coordination of construction tasks, to identify potential problems that might cause difficulties and/or delays in construction, to properly interpret the design intent, and to present the CQA Plan to all of the parties involved. It is important that the rules regarding testing, repairs, etc., be known and accepted by each party to this plan.

Specific topics considered for this meeting include the following:

- Review critical design details of the project, including the plans and specifications.
- Review measures for surface water runoff and siltation control.
- Make appropriate modifications to the CQA Plan (if necessary).
- Review the roles and responsibilities of each party.
- Review lines of authority and communication.
- Review methods for documenting and reporting and for distributing documents and reports.
- Review requirements of the soil testing laboratory and the geosynthetics testing laboratory regarding sample sizes, methods of collection, and shipment. Also, review turn times for sample data and their implications on the construction schedule, pending receipt of acceptance data.
- Review the number and locations of the tests required for soil and geosynthetic components.
- Review methods of subbase grade surface preparation and approval prior to GCL and geomembrane placement.
- Outline procedures for packaging and storing archive samples.
- Review repair procedures.
- Review the time schedule for all operations.
- Establish procedures for deployment of materials over completed geomembrane, emphasizing protection of the geomembrane.
- Observe where the site survey benchmarks are located, and review methods for maintaining vertical and horizontal control.

- Review permit documentation requirements.
- Review the survey documentation tables and plans that identify the locations where survey documentation information is required.
- Conduct a site walk-around to review material storage locations and general conditions relative to construction.
- Set up a time and place for regular construction progress meetings.

Minutes prepared by the CQA officer or other party designated by owner will be distributed to all parties involved in the construction project.

3.2 GEOSYNTHETIC PRECONSTRUCTION SUBMITTAL

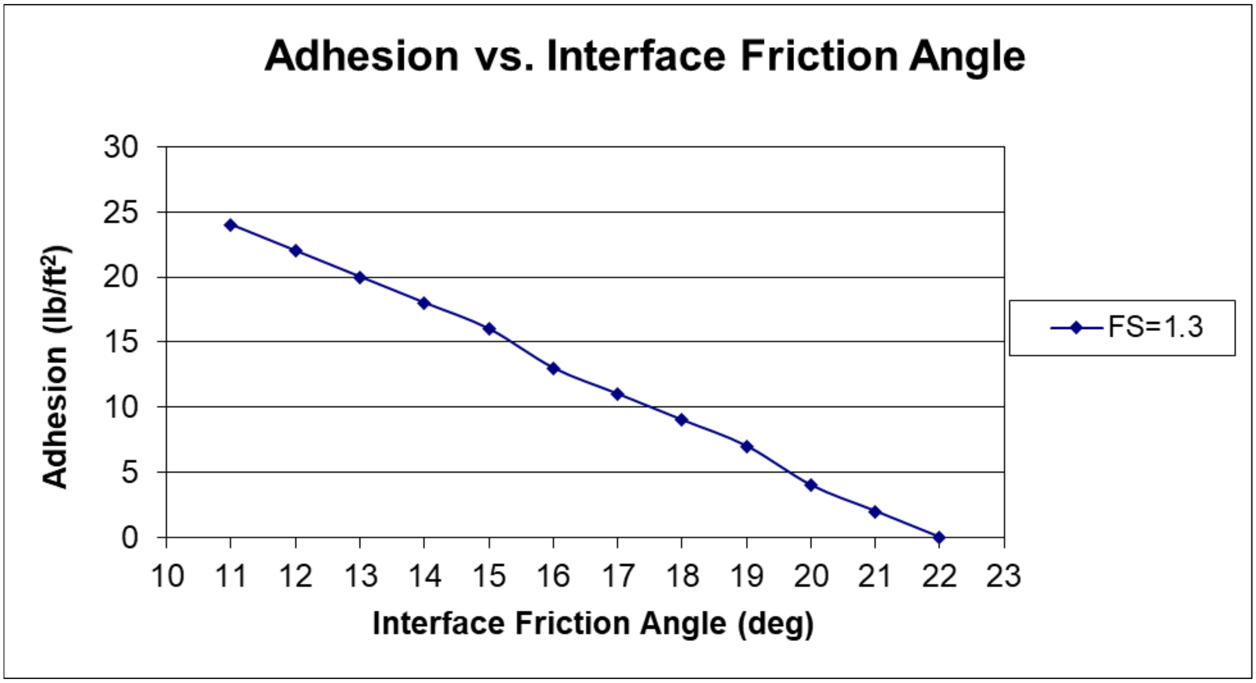
Prior to the installation of geosynthetic materials, a preconstruction submittal will be prepared and submitted to the Wisconsin Department of Natural Resources (DNR). The submittal will contain, at a minimum, the following:

- Identification of the fabricators and installers selected for the geomembrane and other geosynthetics.
- Information on the chosen geosynthetic products.
- Certification from the GCL manufacturer that the GCL product is free of broken-off needles from the needle punching process.
- Final version of the CQA Plan, incorporating input from the selected installer, and documenting qualifications of the third-party construction quality assurance firm and testing laboratories.
- Any modifications to the installation plan, with final proposed version of the panel layout diagram and any revisions to the details of seaming, patching, penetrations, use of prefabricated specialty sections, or repair methods.
- Any changes in geosynthetics acceptance values, test method references, and/or test procedures.
- Results of direct shear testing (ASTM D5321 or D6243) performed on the applicable geosynthetic interfaces and other required tests, as presented in the table below. This table also specifies the required minimum acceptance values required for the testing.

Table 1. (3-1) Direct Shear and Transmissivity Tests

Construction Item	Required Peak Interface Friction Angle or Other Testing	Minimum Required Acceptance Value(1)
Liner System Construction	Select Clay Fill/GCL(8)	(7)
	GCL/Textured HDPE Geomembrane(8)	(7)
	Select Clay Fill/Textured HDPE Geomembrane(2)	(7)
	Textured HDPE Geomembrane/Leachate Drainage Layer(3)	(7)
	Textured HDPE Geomembrane/Geotextile Cushion(3)	(7)
	Geotextile Cushion/Leachate Drainage Layer(3)	(7)
	GCL Hydrated Internal Shear Strength(8)	59 psf
Contact Water Basin	Select Clay Fill/Textured HDPE Geomembrane(2)	(7)
	Textured HDPE Geomembrane/Geotextile Cushion(3)	(7)
	Geotextile Cushion/WisDOT Coarse Aggregate No. 2(3)	(7)
Final Cover Construction	Select Clay Fill/Textured LLDPE Geomembrane(2)	20.6°
	Textured LLPE Geomembrane/Geonet Geocomposite	20.6°
	Geonet Geocomposite/Rooting Zone Soil(4)	20.6°
	Geonet Geocomposite Transmissivity (3% slopes)(5)	2.5×10^{-3} m²/sec
	Geonet Geocomposite Transmissivity (4H:1V slopes)(6)	1.6×10^{-4} m²/sec

Notes:
1. Direct shear testing of wet interface at normal stresses of 200, 400, and 600 pounds per square feet (psf). Use a maximum shear rate of 0.004 inch/minute for interfaces with soil or GCL.
2. Select clay fill compacted to 90 percent of modified Proctor maximum dry density at moisture contents of at least 2 percent wet of optimum.
3. Interface friction testing with geotextile cushion is required for the contact water basin and for the landfill liner if a geotextile cushion will be installed between the geomembrane liner and the leachate drainage layer. Drainage layer material and Wisconsin Department of Transportation (WisDOT) Coarse Aggregate No. 2 will be prepared by lightly tamping.
4. Rooting zone soil prepared by lightly tamping.
5. Transmissivity testing at normal stress of 400 psf and hydraulic gradient of 0.03 for geocomposite sandwiched between LLDPE geomembrane and lightly tamped rooting zone soil.
6. Transmissivity testing at normal stress of 400 psf and hydraulic gradient of 0.25 for geocomposite sandwiched between LLDPE geomembrane and lightly tamped rooting zone soil.
7. Required test values are shown on the adhesion vs. interface friction angle figure below.
8. GCL hydrated for 48 hours under 300 psf and for 24 hours under load prior to shear. Select clay fill compacted wet of optimum to 90 percent of modified Proctor maximum dry density or 95 percent of standard Proctor maximum dry density.



Direct shear testing is to be performed for each construction event unless the materials to be used are the same as those that were tested for a previous construction event. The CQA officer and owner shall determine whether testing is required for each construction event.

3.3 GEOSYNTHETIC PRECONSTRUCTION MEETING

Prior to placement of geosynthetics, a geosynthetic preconstruction meeting will be held. This meeting will include the parties involved in the construction, including the CQA officer, the RPR, the construction contractor, the geosynthetic installer, the owner, and possibly a DNR representative.

The purpose of this meeting is to establish the lines of communication; define the contractor's role and responsibility during the geosynthetic deployment; and review the proposed panel layout, planned seaming methods, installer's Construction Quality Control (CQC) Plan, and this CQA Plan defining the rules regarding testing, repairs, etc.

Specific topics considered for this meeting include the following:

- Review critical design details of the project, including plans and specifications.
- Review contractor's plan for surface water control.
- Make appropriate modifications to the CQA Plan (if necessary).
- Review the roles and responsibilities of each party.
- Review the lines of authority and communication.
- Review methods for documenting, reporting, and distributing documents and reports.
- Review requirements of the Geosynthetic Testing Laboratory regarding sample sizes, methods of collection, and shipment. Review turn times for samples and their implications on the construction schedule.
- Review the number and frequency of tests.
- Review methods of subbase grade or grading layer surface preparation and approval prior to geosynthetic placement.

- Establish rules for writing on the geosynthetic (i.e., who is authorized to write, what can be written, and which color of ink).
- Outline procedures for packing and storing of samples.
- Review geosynthetic panel layout drawing and numbering system.
- Establish appropriate times for trial seams, size of destructive tests, and chain of custody for destructive samples.
- Review repair procedures.
- Review the time schedule for all operations.
- Review final walk-through procedures.
- Review proposed method to deploy materials over geosynthetic material.
- Review survey requirements prior to installer de-mobilizing from site.
- Set timetable for regular construction meeting.

Minutes prepared by the CQA officer or other party designated by the owner will be distributed to all parties involved in the construction project.

4.0 GENERAL CONSTRUCTION OBSERVATION AND DOCUMENTATION

This section describes general documentation procedures to be implemented, including the use of forms, the identification and resolution of problems or deficiencies, and photographic documentation.

4.1 PROGRESS MEETINGS

Progress meetings will be held regularly at a location set by the owner. At a minimum, field supervisory and CQA personnel will attend the meeting. The purposes of the meeting are as follows:

- To review work activity and location since the last meeting.
- To review work schedule.
- To discuss possible problems.
- To review test data.
- To review data documentation requirements.

Minutes prepared by owner-designated representative will be transmitted to all parties involved.

4.2 DAILY REPORTS

A daily summary report will be prepared by the CQA officer, or the RPR, under the direct supervision of the CQA officer, for each day of activity and will include the following information:

- Date, project name, location, report preparer’s name, and the names of representatives on-site performing CQA.

- Time work starts and ends each construction workday, along with the duration and reason for work stoppages (i.e., weather delay, equipment shortage or problem, labor shortage, etc.).

- Data on weather conditions, including temperature, wind speed and direction, cloud cover, and precipitation.

- Installer's work force.

- Chronological description of work in progress, including locations and type of work performed.

- Summary of meetings held and a list of those in attendance.

- Summary of relevant conversations that pertain to the project and who conversations were with.

- Discussion of problems/deficiencies identified and the corrective actions taken.

- Identification of laboratory samples collected, marked, and delivered to laboratory, or clear reference to the document containing such information.

Each representative will prepare field data sheets containing the following information:

- Test number, sample location, and test required.
- The procedures used.
- Field test results.
- Personnel involved in the documentation and sampling activities.
- Signature of the person performing the documentation.

4.3 FORMS, CHECKLISTS, AND DATA SHEETS

Forms developed for the purpose of documenting the construction are to be supplied to the owner prior to the start of construction and/or installation for review and approval. Additional forms developed during the course of the project to document specific aspects of the project will also be supplied to the owner for review and approval.

4.4 PROBLEM/DEFICIENCY IDENTIFICATION AND CORRECTIVE ACTION

Problem and/or deficiency identification and corrective action will be documented in the daily summary report when a construction material or activity is observed or tested that does not meet the requirements set forth in this CQA Plan. The summary report should clearly reference other reports, photographs, or forms that contain data or observations leading to the determination of the problem or deficiency. Problem and/or deficiency identification and corrective action documentation may include the following information:

- A description of the problem or deficiency, including reference to supplemental data or observations responsible for determining the problem or deficiency.

- The location of the problem or deficiency, including how and when the problem or deficiency was discovered, and an estimate of how long the problem or deficiency has existed.

- A list of possible causes of the problem or deficiency.

- A recommended corrective action for resolving the problem or deficiency. If the corrective action has already been implemented, then the observations and documentation to show that the problem or deficiency has been resolved must be included. This written portion is to include all parties involved in the corrective action. If the problem or deficiency has not been resolved by the end of the day that it was discovered, the daily summary report must clearly state that it is an unresolved problem or deficiency. Subsequent daily summary reports will indicate the status of the problem or deficiency until it is resolved.

If the problem or deficiency has not been resolved, the CQA officer and the preparer will discuss the necessary corrective actions. The CQA officer will work with the owner and the contractor to implement actions as necessary to resolve the problem or deficiency. A description of such problems or deficiencies and corrective actions implemented will be included in the Construction Documentation Report.

The CQA officer, working with the owner and the contractor, will determine if the problem or deficiency is an indication of a situation that may require changes to the plans or specifications and/or the CQA Plan. The CQA officer and the owner must approve revisions to the plans or specifications or the CQA Plan. DNR will be consulted prior to making changes to the CQA Plan or specifications, if needed, to obtain their concurrence. Documentation of changes will be incorporated into the Construction Documentation Report.

4.5 PHOTOGRAPHIC DOCUMENTATION

Photographs will be taken to document all aspects of the installation, problems, deficiencies, and corrective actions. Photographs in any format will be stored in a permanent protective file by the CQA officer or the RPR. All photographs in all formats are to be turned over to the owner upon completion of the Construction Documentation Report. The owner will designate whom the photographs are returned to.

For photographs provided in the final documentation report, the following information will be recorded:

- Date and time.
- Location where photograph was taken, including information regarding the orientation of the photograph. (e.g., looking north).
- Description of the subject matter.
- Unique identifying number for reference in other reports.

4.6 SURVEYING

Documentation surveying requirements for each cover and liner system component are defined in the respective sections. All required thicknesses noted in each section are measured vertically. Personnel experienced in construction surveying will perform required surveying.

4.7 DOCUMENTATION REPORT

A report documenting all aspects of construction will be prepared. The report will be prepared in accordance with the requirements of NR 516. A Professional Engineer (PE) registered in the state of Wisconsin will certify the report.

5.0 SUBGRADE PREPARATION

5.1 GENERAL

This section includes the quality assurance requirements for preparation of the subgrade prior to placement of the liner system, including placement, compaction, and grading of general fill soil if required to establish the subbase grade below the liner. General fill soil will consist of inorganic soil with primarily clay-size particles from site excavations. General fill soil in direct contact with the geomembrane will have a maximum particle size of 2 inches. All subbase field tests, soil sample types, and survey measurements will be recorded in the daily summary reports (see Section 4.2) as record construction data, including locations (by coordinates) and elevations of all field tests and laboratory sample points. Test pits or soil borings will be performed on a 100-foot grid to a minimum depth of 5 feet to determine if granular or silty soils are present as per NR 504.06(4)(d). Any granular or silty soils within 5 feet of subbase grades will be removed and replaced with compacted select clay fill.

5.2 PROCEDURES AND OBSERVATION

The RPR will observe the subgrade preparation activities and will document relevant observations to support certification of the following requirements:

- The RPR will observe the liner system subbase preparation to document that the compacted subbase is in substantial conformance with the placement specifications.
- If fill is placed for the subbase, the RPR will periodically observe loads of general fill for general conformance to material specifications and may randomly sample loads. The RPR will perform routine conformance sampling as defined in Section 5.3 (Sampling Requirements and Acceptance Criteria).
- No frozen soil will be used for backfilling. Any frozen soil in the compaction work area will be removed.
- Loose lift thickness for general fill soil compaction will not exceed 12 inches.
- Unacceptable compaction density as defined by Section 5.3 (Sampling Requirements and Acceptance Criteria), will be reported to the CQA officer by the RPR. Corrective action will consist of moisture-conditioning of the soil and/or additional compactive effort, as necessary.
- General fill placed for the liner system subbase will be placed in accordance with Section 5.2.

Field densities using methods described in Section 5.3.1 will be measured to document that the in-place soil is in substantial conformance with the required density.

5.3 SAMPLING REQUIREMENTS AND ACCEPTANCE CRITERIA

Field and laboratory sampling frequencies are based on the area or volume of material placed, as specified in s. NR 516.07. This section describes the required analyses, methods, sample frequencies, and acceptance limits. The RPR will perform field tests and will collect soil samples for laboratory analysis.

5.3.1 Field Testing

The following field testing methods will be used by the RPR during construction:

Parameter	Test Method
Soil density and moisture content	ASTM D6938

Field density and moisture content tests will be performed on a 100-foot grid pattern for each 1-foot-thickness of compacted subbase general fill placed. The grid pattern will be offset on alternate lifts. In confined areas where compaction equipment is hindered or hand compaction is necessary, a minimum of two field density and moisture content tests will be performed for each 1-foot-thickness of subbase fill. The RPR will conduct a minimum of one field density test per 5,000 cubic yards.

5.3.2 Field Testing Acceptance Criteria

Acceptance criteria for field density will require soil compaction to a minimum of 90 percent of the Modified Proctor (ASTM D1557) maximum dry density, or a minimum of 95 percent of the Standard Proctor (ASTM D698) maximum dry density.

5.3.3 Laboratory Testing

Routine laboratory testing of the subbase fill will be performed on samples of the subbase fill borrow area. Soil characteristics will be determined from representative samples.

Representative (grab) samples will be obtained on the basis of three criteria. First, an initial sample will be obtained from the subbase fill borrow source and analyzed prior to construction. This will confirm soil characteristics and provide an initial maximum dry density and optimum moisture content for field moisture/density testing. Second, routine samples will be obtained for every 5,000 cubic yards placed. Third, in the event that changes in physical appearance or soil characteristics are observed, a sample will be obtained and analyzed. The maximum dry density and optimum moisture content values used for compaction testing may be adjusted during the course of subbase construction based on the results of the above sampling.

The following laboratory test method will be performed by the Soils Testing Laboratory on samples collected by the RPR:

Parameter	Test Method
Moisture/Density using Modified or Standard Proctor compaction	ASTM D1557 (a,b) or ASTM D698 (a,b)
Atterberg Limits	ASTM D4318
Grain-size analysis	ASTM D6913/D7928(c)

Notes:
(a) Five-point Proctor analysis required for first and second sampling criteria.
(b) A one-point Proctor analysis may be utilized for representative samples collected for the third sampling criteria (apparent changes in soil quality) to verify applicability of previously analyzed moisture-density relationships. If the result does not verify applicability, then a five-point analysis will be performed in accordance with the first sampling criteria.
(c) Distribution to be reported through the 0.002 mm particle size.

Samples of the borrow area or stockpiled soil will be collected by the RPR prior to the use of the material and whenever physical appearance or other changes are noticeable. These samples will be submitted to the Soils Testing Laboratory for the above testing.

5.4 SURVEYING

The subbase grades will be surveyed on a 50-foot grid pattern and at key locations. Key locations include breaks in grade, toes of slopes, midpoints, and tops of sideslopes. In the alignment for leachate collection lines, the bottom of trench elevations will be surveyed at 25 foot intervals (+0.1 foot tolerance), or every 50 feet if a total station or laser equipment is used.

6.0 ASH GRADING

6.1 GENERAL

This section includes the quality assurance requirements for preparation of ash surface prior to placement of the cover, including placement, compaction, and grading of ash, if required to establish the top of waste grades below the cover. Compacted ash fill (Section 6.0) will be used to establish the top of waste grades. All field tests and survey measurements will be recorded in the daily summary reports (see Section 4.2) as record construction data, including locations (by coordinates) and elevations of all field tests and laboratory sample points.

6.2 PROCEDURES AND OBSERVATION

The RPR will observe the subbase preparation activities and will document relevant observations to support certification of the following requirements:

- The RPR will observe the top of waste grade preparation to document that the compacted ash is in substantial conformance with the placement specifications.
- Upon completion of the final ash grades, the RPR will visually observe the final cover subgrade for signs of soft or yielding spots. Any soft or yielding spots will be excavated and replaced with compacted ash fill.
- Loose lift thickness for ash fill compaction will not exceed 12 inches.
- The top of the waste shall be smooth-drum rolled to provide a smooth surface. Ruts greater than 1 inch will be repaired by filling with ash fill and smooth-drum rolling.

6.3 SAMPLING REQUIREMENTS AND ACCEPTANCE CRITERIA

No samples or field or laboratory testing shall be performed on ash.

6.4 SURVEYING

The top of ash grades will be surveyed on a 50-foot grid pattern and at key locations. Key locations include breaks in grade, toes of slopes, midpoints, and tops of sideslopes.

7.0 SELECT CLAY FILL

7.1 GENERAL

This section includes the quality assurance requirements for placement, backfilling, and compaction of select clay fill. Compacted select clay fill will be used in constructing the landfill liner and cover.

The select clay fill will be obtained from on-site stockpiles.

All field tests, soil sample types, and survey measurements will be recorded in the daily summary reports (see Section 4.2) as record construction data, including locations (by coordinates) and elevations of all field tests and laboratory sample points.

7.2 PROCEDURES AND OBSERVATION

The RPR will observe compacted select clay fill construction activities and will document relevant observations to support certification of the following requirements:

- The RPR will confirm the uniformity of the excavated soil to be used as select clay fill. Soil placement will be monitored for segregation and removal of unsuitable material and for changes in soil type, color, texture, and moisture content.

- The construction contractor will segregate and/or remove unsuitable materials such as granular soil, silty or sandy clay not meeting acceptance criteria, boulders, cobbles, and organic material. A maximum clod size of 4 inches is allowed. Clods should be able to be broken down with normal construction equipment.

- The RPR will observe clay placement and will measure field densities and moisture contents, using methods described in Section 6.3 (Sampling Requirements and Acceptance Criteria), to document that the compacted clay cover is in substantial conformance with the placement specifications and that soil placement has been conducted in a manner to achieve a uniform, homogeneous clay mass.

- Voids created by nuclear density gauge (NDG) probes or Shelby tubes will be backfilled with granular bentonite.

- Compaction equipment used shall have a minimum static weight of 30,000 pounds.

- Clay layers will be constructed in lift heights no greater than 6 inches after compaction using footed compaction equipment having feet at least as long as the loose lift height.

- Each lift of clay will be sufficiently compacted to ensure that the clay is completely remolded.

- Areas of unacceptable hydraulic conductivity, density, or moisture content, as defined by Section 6.3 (Sampling Requirements and Acceptance Criteria), will be documented by the RPR. Corrective action will consist of moisture-conditioning of the soil and/or additional compactive effort as necessary. Methods for moisture-conditioning soil are described in the next bullet item. Following corrective actions, such areas will be retested.

- If necessary, surfaces of clay to receive successive lifts of clay will be moisture-conditioned, either by scarification and addition of water where desiccated, or by discing and air drying where saturated to promote effective bonding of lifts. Following scarification, water will be applied with a spray bar applicator or equivalent method to achieve uniform distribution.

- Clay placement will be performed in a manner to achieve continuous and complete keying together of clay cover construction areas. Stepped joints will be utilized to connect lateral segments of clay liner and cover construction by excavating a minimum of four steps with a minimum width of 15 feet along the edge of the existing module or phase and overlapping them.

- No frozen soil will be used for select clay fill liner or cover construction. Frozen soil in the compaction work area will be removed.

- Stones and other penetrating objects 2 inches or larger protruding from the surface of the base grade will be removed. The RPR will observe the base grade during this process and will document the removal of stones and other objects by the contractor. The top of the liner system base grade shall be smooth-drum rolled to provide a smooth surface for placement of the geomembrane. Ruts greater than 1 inch will be repaired by filling with acceptable general fill and smooth-drum rolling.

- Stones larger than 2 inches will be removed. The RPR will observe the cover or liner during this process and will document the removal of stones by the contractor. Voids made by the removal of stones will be filled with clay soil or bentonite, and the entire cover or liner surface will be rolled with a smooth-drum compactor. Ruts greater than 1 inch will be repaired by filling in with compacted select clay fill and smooth-drum rolling.

- Preconstruction planning will be undertaken to sequence construction activities to minimize the length of time any completed clay surface will be exposed prior to receiving protective cover. Protective cover will be provided by the installation of the rooting zone material for the final cover or drainage layer material for the liner.

7.3 SAMPLING REQUIREMENTS AND ACCEPTANCE CRITERIA

Field and laboratory sampling frequencies are based on the area or volume of material placed, as specified in s. NR 516.06. This section describes the required analyses, methods, sample frequencies, and acceptance limits. The RPR will perform field tests and will collect soil samples for laboratory analysis.

7.3.1 Field Testing

The following field testing methods will be used by the RPR during construction:

Parameter	Method
Moisture content and soil density	ASTM D6938

Field density and moisture content tests will be performed on a 100-foot grid pattern for each 1-foot-thickness of compacted select clay fill placed. The grid pattern will be offset on alternate lifts. In confined areas where compaction equipment is hindered or hand compaction is necessary, a minimum of two field density and moisture content tests will be performed for each 1-foot-thickness of clay placed.

7.3.2 Field Testing Acceptance Criteria

Acceptance criteria for field density will require soil compaction to a minimum of 90 percent of the Modified Proctor (ASTM D1557) maximum dry density, or a minimum of 95 percent of the Standard Proctor (ASTM D698) maximum dry density. Moisture content requirements will be at least 2 percent wet of optimum if using the Modified Proctor, and at least wet of optimum if using the Standard Proctor, in accordance with s. NR 504.06(2)(f)(3). The acceptable range will be based on Proctor moisture-density relationships and compaction versus permeability relationships.

7.3.3 Laboratory Testing

Routine laboratory testing of the clay liner and cover soil will be performed on samples from the clay borrow area/stockpile and on the in-place clay soil samples collected by the RPR. Samples for determining in-place properties will be collected by pushing Shelby tubes. Soil characteristics will be determined from representative samples and from Shelby tube samples.

7.3.4 Undisturbed Sampling Analysis

One undisturbed sample will be taken for each acre or less for every 1-foot-thickness of clay placed and will be submitted to the Soils Testing Laboratory.

The following analyses will be performed on all undisturbed samples obtained:

Parameter	Test Method
Moisture content and dry density	ASTM D2216/D7263
Atterberg limits	ASTM D4318
Grain-size analysis	ASTM D6913/D7928[a]

Notes:
[a] Distribution to be reported through 0.002 mm particle size.

One of every three undisturbed samples will also be analyzed for hydraulic conductivity as follows:

Parameter	Test Method[a]
Hydraulic conductivity	ASTM D5084 or SW 846 EPA Method 9100

Notes:
[a] Using effective stresses no greater than 5 psi and hydraulic gradients of 30 or less.

7.3.5 Representative Sample Analysis

Representative (grab) samples will be obtained on the basis of three criteria. First, an initial sample will be obtained from the clay borrow source/stockpile (if not used in construction of a prior module or phase) and analyzed prior to construction. This will confirm soil characteristics and provide an initial maximum dry density and optimum moisture content for field moisture/density testing. Second, routine samples will be obtained for every 5,000 cubic yards placed. Third, in the event that changes in physical appearance or soil characteristics are observed, a sample will be obtained and analyzed. The maximum dry density and optimum moisture content values used for compaction testing may be adjusted during the course of cover construction based on the results of the above sampling.

The following laboratory analyses will be performed on all representative samples obtained:

Parameter	Test Method
Moisture-density relationship using Modified/Standard Proctor compaction	ASTM D1557/D698 [a, b]
Atterberg limits	ASTM D4318
Grain-size analysis	ASTM D6913/D7928[c]

Notes:
[a] Five-point Proctor analysis required for first and second sampling criteria.
[b] A one-point Proctor analysis may be utilized for representative samples collected for the third sampling criteria (apparent changes in soil quality) to verify applicability of previously analyzed moisture-density relationships. If the result does not verify applicability, then a five-point analysis will be performed in accordance with the first sampling criteria.
[c] Distribution to be reported through the 0.002 mm particle size.

7.3.6 Laboratory Testing Acceptance Criteria

- A minimum 50 percent by weight which passes the 200 sieve.
- A saturated hydraulic conductivity of 1 x 10-7 cm/s or less, when compacted to 90 percent Modified or 95 percent Standard Proctor density or greater at a minimum moisture content 2 percent wet of optimum.
- An average liquid limit of 25 or greater, with no values less than 20.
- An average plasticity index of 12 or greater, with no values less than 10.

7.4 THICKNESS DOCUMENTATION

The top of clay cover grades will be surveyed on the same 50-foot grid pattern and at key locations surveyed for top of ash grades. Key locations include breaks in grade, toes of slopes, mid-points, and tops of sideslopes. The clay cover thickness will be determined at surveyed locations and reported in a tabular fashion. The minimum acceptable cover thickness will be 2 feet (+0.1 foot tolerance) measured vertically.

The top of clay liner grades will be surveyed on the same 50-foot grid pattern and at key locations surveyed for subbase grades. Key locations include breaks in grade, toes of slopes, mid-points, and tops of sideslopes. In the alignment for leachate collection lines, bottom of trench elevations will be surveyed at 25-foot intervals, or every 50 feet if a total station or laser equipment is used, in the same locations surveyed for trench undercuts. The clay liner thickness will be determined at surveyed locations and reported in a tabular fashion. The minimum acceptable liner thickness will be 2 feet (+0.1 foot tolerance) measured vertically.

8.0 DRAINAGE MATERIALS

8.1 GENERAL

Drainage material includes:

Liner System:

- Leachate drainage layer.
- Drainage filter layer (if needed).
- Coarse aggregate bedding (leachate collection lines and leachate sump).
- Sand bedding (leachate conveyance lines/forcemains).

Contact Water Basin:

- WisDOT Coarse Aggregate No. 2.

Final Cover System:

- Coarse aggregate bedding.

Leachate drainage layer material will consist of on-site screened bottom ash, imported sand, or imported gravel. Other drainage materials will consist of imported material. Limestone and dolomite stone will not be used in the liner system leachate collection materials unless no other suitable material is reasonably available.

All drainage material sample types and survey measurements will be recorded in the daily summary reports (see **Section 4.2**) as record construction data, including locations (by coordinates) of all laboratory sample points.

8.2 PROCEDURES AND OBSERVATIONS

The RPR will observe drainage material placement activities and will document relevant observations to support certification of the following requirements:

- The RPR will periodically observe loads of drainage material for general conformance to material specifications and may randomly sample loads. The RPR will perform routine conformance sampling as defined in **Section 8.3**.

- No trucks or heavy equipment will travel directly on the geosynthetics. Only low-ground pressure tracked equipment (less than 5 pounds per square inch [psi]) may operate over the geosynthetics when there is a minimum 12-inch-thick layer of drainage material in-place. Rubber-tired equipment may not travel over the geosynthetics unless a minimum of 3 feet of drainage material is in place. Procedures for deployment of drainage material overlying the geomembrane will be planned at the preconstruction meeting. Special requirements for geomembrane protection and equipment necessary to deploy materials must be approved by the CQA officer.

- Care will be exercised during placement of the drainage material to prevent undue damage to pipes and geosynthetics. Aggregate will not be dropped from a height greater than 3 feet above the pipe trench.

- A geotextile cushion will be placed between the geomembrane and the pipe bedding material or drainage material if the drainage material is gravel.

- A minimum of 6 inches of pipe bedding material will be placed under leachate collection pipes prior to pipe placement, and a minimum of 12 inches of bedding material will be placed over the top of the leachate collection pipes.

- If drainage material is stockpiled on-site prior to use, measures will be taken to minimize contamination by fines such as wind-blown particles and surface soil during loading operations.

8.3 SAMPLING REQUIREMENTS AND ACCEPTANCE CRITERIA

Field sampling and laboratory testing frequencies are based on proportionate sampling of construction areas or volumes of material placed as specified by s. NR 516.06. This section describes the required analyses, methods, sampling frequencies, and acceptance limits. The RPR will collect soil samples for laboratory analysis.

8.3.1 Field Testing

No field testing will be required for drainage material, filter material, or pipe bedding material; however, as stated in Section 8.2 above, the RPR will perform visual inspection of this soil for conformance to material specifications and may randomly sample deliveries.

8.3.2 Laboratory Testing

Representative (grab) samples may be obtained from the proposed drainage material, filter material, and pipe bedding material sources prior to delivery of the material. The source sampling frequency will be dependent on the apparent uniformity of the source and must be approved by the CQA officer.

Grab samples of drainage material, filter material, and pipe bedding material placed will be collected and analyzed as follows:

Soil Type	Frequency	Parameter	Test Method
Leachate Drainage Layer Material	1/1,000 CY [(a)]	Grain-size	ASTM D6913[(b)]
Leachate Drainage Layer Material	1/2,500 CY [(c)]	Remolded hydraulic conductivity	ASTM D2434
Filter Material[(e)]	1/1,000 LF of trench[(d)]	Grain-size	ASTM D6913[(b)]
Coarse aggregate bedding (leachate collection lines)	1/1,000 LF of trench[(d)]	Grain-size	ASTM D6913[(b)]
Coarse aggregate bedding sumps)	1/500 CY	Grain-size	ASTM D6913[(b)]
Pipe bedding (leachate conveyance lines)	1/1,000 LF of trench[(d)]	Grain-size	ASTM D6913[(f)]
Coarse aggregate bedding (final cover subsurface drainage lines)	1/1,000 CY	Grain-size	ASTM D6913[(b)]

Notes:

(a) For lesser volumes, a minimum of four samples will be tested.
(b) Testing is required only to the #200 sieve.
(c) For lesser volumes, a minimum of two samples will be tested.
(d) For documentation areas with less than 3,000 feet of pipe trench, a minimum of three samples will be tested.
(e) If a filter analysis confirms that a filter material is required between the leachate drainage layer material and the coarse aggregate bedding.
(f) Testing is required only to the #4 sieve.

Laboratory Testing Acceptance Criteria

The Leachate Drainage Layer material will consist of screened bottom ash, imported sand, or imported gravel and have the following properties:

- Contain no more than 5 percent by weight of fines passing the #200 sieve.
- Have a maximum particle diameter of ¼ inch for bottom ash or sand.
- Have a remolded hydraulic conductivity of at least 1 x 10-2 cm/s or greater at the anticipated field density.
- Have a typical particle diameter of ½ inch or less for gravel.

Coarse aggregate bedding material will consist of washed gravel (such as AASHTO M43 Gradation No. 4 with 100 percent passing the 1 ½ inch sieve), and have the following properties:

- Have a uniformity coefficient less than four.
- Contain no more than 5 percent by weight passing the #4 sieve.
- Have a maximum particle diameter of 1½ inches.
- Have a subrounded particle shape.

Pipe bedding for conveyance piping will consist of sand with a maximum particle diameter of 1½ inches.

Filter calculations will need to be performed to determine whether the leachate collection drainage material is compatible with the coarse aggregate bedding without the use of a filter.

8.4 THICKNESS DOCUMENTATION

The finished elevation of the leachate drainage layer will be surveyed on a 50-foot grid, which coincides with the grid used for the liner system subbase surface. The minimum acceptable thickness will be 1 foot (+0.1 foot tolerance). The contractor may use a GPS dozer and hand held GPS station to document thickness if approved by the owner and CQA officer.

Coarse aggregate bedding material placed along leachate collection pipe alignments will be surveyed for elevation prior to pipe placement and following pipe backfilling at 25-foot intervals, or every 50 feet if a total station or laser equipment is used, to document the thickness of pipe bedding placed below pipe inverts and above the top of pipe. The minimum acceptable pipe bedding thickness for the leachate collection pipe will be 6 inches below and 12 inches above the piping (+0.1 foot tolerance).

9.0 GEOTEXTILE

9.1 GENERAL

This section of the CQA Plan applies to the non-woven geotextile used as a geomembrane cushion in the liner system, as a filter, and as a separator for other construction activities.

Geotextile cushions will be installed in the following locations:

- Leachate collection system trenches and sumps.
- Liner system (for gravel drainage layer).
- Contact water basin between geomembrane and aggregate.

Geotextile filters will be installed in the following location:

- Final cover toe drain.

Geotextile separators will be installed in the following locations:

- Rip rap areas.
- Access road.

9.2 PRE-INSTALLATION

9.2.1 Manufacturing

The geotextile will be supplied to the site in factory rolls. Prior to the delivery of any geotextile rolls, the geotextile manufacturer will provide the CQA officer with the manufacturer's Quality Control Plan used for the production of the geotextile.

The geotextile manufacturer will provide certification, based on tests performed in accordance with the methods listed in Tables 9-1, 9-2, and 9-3, that the geotextile supplied under this plan will meet the material specifications listed in Tables 9-1, 9-2, and 9-3. These tests may be performed by the geotextile manufacturer's laboratory or a laboratory contracted by the manufacturer. Additionally, the manufacturer will provide certification that the manufacturer's Quality Control Plan was fully implemented for the geotextile materials supplied under this plan. The manufacturer shall provide documentation to verify the results of the manufacturer's CQC Plan implementation required by the CQA officer.

The geotextile rolls will be tested and evaluated prior to acceptance. The CQA officer may perform/require additional testing (i.e., conformance testing) as required by detailed specifications or as required in the judgment of the CQA officer to verify that the geotextile meets the specifications.

9.2.2 Delivery, Handling, and Storage of Geotextile Rolls

Each geotextile roll to be used at the landfill facility will be marked by the geotextile manufacturer with the following information (on a durable gummed label, or equivalent, on the inside of the core, and on the outside of the protective wrapping for the roll):

- Name of manufacturer.
- Style and type number.
- Roll length and width.
- Batch (or lot) number.
- Nominal product thickness.
- Date of manufacture.
- Roll number.

The geotextile manufacturer will use the following guidelines in packaging, wrapping, and preparing all geotextile rolls for shipment:

- When cores are required, those that have a crushing strength sufficient to avoid collapse or other damage while in use will be used.

- Each roll will be covered with a wrapping material that will protect the geotextile from damage due to shipment, water, sunlight, or contaminants.

The following practices will be used as minimum in receiving and storing geotextile rolls in the designated storage area at the job site:

- While unloading or transferring the geotextile rolls from one location to another, care will be taken to prevent damage to the wrapping or the geotextile itself. If practicable, the installer/contractor may use forklift trucks fitted with poles that can be inserted into the cores of rolls. The poles will be at least two-thirds the length of the rolls, to prevent breaking the cores and possibly damaging the geotextile. Rolls will not be dragged.

- The geotextile rolls will be stored in such a manner so as to ensure that they are adequately protected from the following:
  - Precipitation.
  - Ultraviolet radiation, including sunlight.
  - Strong oxidizing chemicals, acids, or bases.
  - Flames, including welding sparks.
  - Temperatures in excess of 160°F.
  - Soiling.

The RPR will observe and document, throughout the pre-installation, installation, and post-installation periods, that the installer provides adequate handling equipment used for moving geotextile rolls and that the equipment and handling methods used do not pose unnecessary risk of damage. The installer/contractor is responsible for the means and methods to implement the work.

The installer will be responsible for ensuring that all materials installed meet specifications. The RPR will maintain a log of geotextile roll deliveries. The following information, at a minimum, will be recorded on the log for each shipment received at the job site:

- Date of delivery at the job site.
- For each roll of geotextile, the roll number and batch (or lot) number.

9.3 INSTALLATION

This section describes the quality assurance requirements applicable to the installation, observation, and documentation of geotextile.

9.3.1 Placement

The installer will install all geotextile in such a manner as to ensure that it is not damaged and in a manner that complies with the following requirements:

- In the presence of wind, all geotextile will be secured by suitable methods. The temporary securing material will be left in place until replaced with cover material, if applicable.
- In-place geotextile will be cut with special care to protect other materials from damage that could be caused by the cutting of the geotextile.
- The installer will take necessary precautions to prevent damage to any underlying layers during placement of geotextile.
- During placement of geotextile, care will be taken not to entrap in the geotextile any stones, excessive dust, or moisture that could damage the geotextile.
- A visual examination of the geotextile will be carried out over the entire surface after installation by the installer to ensure that no potentially harmful objects, such as needles, are present.

9.3.2 Seams and Overlaps

The following requirements will be met with regard to seaming and overlapping of geotextile rolls:

- Geotextile seams will be continuously sewn unless heat bonding is approved by the CQA officer and owner. Geotextile will be overlapped 6 inches prior to seaming. The sewing method and stitch type will be per manufacturer's recommendation, but must be approved by the CQA officer. Overlapping of geotextile without sewing may be acceptable for certain applications (e.g., seams under riprap) with approval from the CQA officer and owner.
- Sewing will be performed with thread made from the same base material as the geotextile, or suitable equivalent.
- The installer will pay particular attention to seams to ensure that no materials could be inadvertently trapped beneath the geotextile.

The RPR will be responsible for observing and documenting that the installer performs the above provisions in an acceptable manner.

9.4 POST-INSTALLATION

9.4.1 Final Examination

The RPR will perform a final geotextile examination after the installation of each geotextile layer has been completed. The objectives of the final examination are as follows:

- To examine for the presence of holes, tears, or other deterioration.
- To examine geotextile for excessive tension due to stretching of the fabric during installation.
- To examine for the presence of foreign objects (e.g., stones, soil clods) beneath the geotextile.

If there will be an extended time delay between completion of the geotextile and the start of the installation of any other cover, then the installer will make provisions, by temporarily securing the geotextile by using suitable methods, to protect the geotextile from wind uplift. The RPR will document the placement of the temporary securing methods in the daily report.

9.4.2 Placement of Soil Materials

The construction contractor will place all soil materials located on top of a geotextile in such a manner as to minimize the following:

- Damage to the geotextile and underlying layers.
- Slippage of the geotextile on underlying layers.
- Excessive tensile stresses imposed on the geotextile.

Table 2. (9-1) Geotextile Filter Acceptance Specifications

Property	Units	Type of Criterion	Acceptable Value[1]	Test Method
Apparent Opening Size	mm	Range	0.074-0.180	ASTM D4751
Grab Tensile Properties[2] Tensile Strength Break Elongation	 lb %	 Minimum Minimum	 200 50	ASTM D4632
Permittivity	$gal/min/ft^2$	Minimum	90	ASTM D4491
Mass Per Unit Area	oz/yd^2	Minimum	7.2	ASTM D5261
Puncture Resistance (pin)[4]	lb	Minimum	100	ASTM D4833
Puncture (CBR) Strength[4]	lb	Minimum	500	ASTM D6241
Trapezoidal Tear[2]	lb	Minimum	80	ASTM D4533
UV Resistance[3]	%	Minimum	70	ASTM D7238

Notes:
1. Values are based on discussions with acceptable manufacturers and represent production values at the time this document was prepared. Minimum values are based on -2 standard deviations from the average production values.
2. These tests will be performed and results reported in both the machine and cross directions.
3. Evaluation to be on a 2.0-inch strip tensile specimens after 500 hours exposure.
4. Geotextile to meet puncture resistance (pin) or puncture (CBR) strength.

Table 3. (9-2) Geotextile Cushion Acceptance Criteria

Property	Units	Test Method	12 oz/yd² Acceptable Value	16 oz/yd² Acceptable Value	32 oz/yd² Acceptable Value
Grab tensile properties (1)					
Tensile strength	lb	ASTM D4632	300	370	500
Break elongation	%	ASTM D4632	50	50	50
Mass per unit area	oz/yd²	ASTM D5261	12	16	32
Puncture (CBR) strength	lb	ASTM D6241	800	900	1700
Trapezoidal tear strength	lb	ASTM D4533	115	145	215
UV resistance (2)	%	ASTM D7238	70	70	70

Notes:
1. These tests will be performed and results reported in both the machine and cross directions.
2. Evaluation to be on 2-inch strip tensile specimens after 500 hours exposure.
3. All values are minimum average except UV resistance, which is a minimum value.
4. Direct shear testing requirements for 12 oz/yd² Geotextile Cushion (if installed below a gravel drainage layer and for the contact water basin) are contained in **Table 3-1**.

Table 4. (9-3) Geotextile Separator Acceptance Criteria

Property	Units	Test Method	Value (1)
Grab tensile properties			
Tensile strength	lb	ASTM D4632	305
Break elongation	%	ASTM D4632	15
Puncture Strength (pin)(2)	lb	ASTM D4833	140
Puncture (CBR) Strength(2)	lb	ASTM D6241	800
Apparent Opening Size	mm	ASTM D4751	0.60
Permittivity	s^{-1}	ASTM D4491	0.40

Notes:
1. All numerical values represent minimum average roll values except apparent opening size, which is a maximum average value. Average test results from all rolls in a lot must conform to the tabulated values.
2. Geotextile to meet puncture strength (pin) or puncture (CBR) strength.

10.0 GEOCOMPOSITE

10.1 GENERAL

This section covers the quality assurance requirements for pre-installation, installation, and post installation of geocomposites. The terms pre-installation, installation, and post-installation are applicable only to the geocomposite and do not apply to the overall construction of the landfill facility. Geocomposite will be installed for the drainage layer (geocomposite) within the final cover.

10.2 PRE-INSTALLATION

10.2.1 Manufacturing

The geotextile portion of the geocomposite will be composed of a nonwoven, needle punched, polyester, or polypropylene geotextile. The geocomposite manufacturer will ensure that the geotextile portion of the geocomposite meets the material specifications listed in **Table 10-1**.

The geonet portion of the geocomposite must be fabricated for HDPE resin. The geonet will be manufactured by extruding two sets of strands to form a three-dimensional structure to provide planar flow. The geocomposite manufacturer will ensure that the geonet portion of the geocomposite meets the material specifications listed in **Table 10-1**. The geocomposite manufacturer will ensure that the geocomposite meets the transmissivity specification listed in **Table 3-1**.

The geocomposite rolls will be tested by the manufacturer and evaluated by the CQA officer prior to acceptance. The CQA officer may perform/require additional testing (i.e., conformance testing) as required by detailed specifications or as required in the judgment of the CQA officer to verify that the geocomposite meets the specifications.

10.2.2 Delivery, Handling, and Storage of Geocomposite Rolls

Each geocomposite roll, for use at the landfill facility, will be marked by the geocomposite manufacturer with the following information (on a durable gummed label, or equivalent, on the side core and on the outside protective wrapping for the roll):

- Name of manufacturer.
- Style and type number.
- Roll length and width.
- Batch (or lot) number, if applicable.
- Date manufactured.
- Direction of unrolling.
- Roll number.

The geocomposite manufacturer will use the following guidelines in packing, wrapping, and preparing all geocomposite rolls for shipment:

- When cores are required, those that have a crushing strength sufficient to avoid collapse or other damage while in use will be used.

- Each roll will be covered with a wrapping material that will protect the geotextile from damage due to shipment, water, sunlight, or contaminants.

At a minimum, the following practices will be followed in receiving and storing geocomposite rolls in the covered storage area at the job site:

- While unloading or transferring the geocomposite rolls from one location to another, care will be taken to prevent damage to the geocomposite.

- If practicable, forklift trucks fitted with poles that can be inserted into the cores of the rolls will be used.

- The poles will be at least two-thirds the length of the rolls to avoid breaking the cores and possibly damaging the geocomposite.

- Rolls will not be dragged.

- The geocomposite rolls will be stored in a manner so as to ensure that they are adequately covered to protect the geocomposite from the following:
  - Precipitation.
  - Ultraviolet radiation.
  - Strong oxidizing chemicals, acids, or bases.
  - Flames, including welding sparks.
  - Temperature in excess of 160°F.

The RPR will be responsible throughout the pre-installation, installation, and the post-installation periods for observing and documenting that the installer provides adequate handling equipment used for moving geocomposite rolls and that the equipment used does not damage the geocomposite rolls.

The RPR will maintain a log of geocomposite roll deliveries. The following information, at a minimum, will be recorded on the log for each shipment received at the job site:

- Date of delivery at the job site.

- For each geocomposite roll, the following information: roll number and batch (or lot) number, if applicable.

10.3 TESTING REQUIREMENTS

Refer to **Table 3-1** for transmissivity conformance testing requirements for the geocomposite drainage layer to be in the final cover. Refer to **Table 3-1** for direct shear testing requirements.

10.4 INSTALLATION

10.4.1 Placement

The installer will install all geocomposite in such a manner so as to ensure that it is not damaged in any way, and in a manner that complies with the following:

- The geocomposite will be securely anchored, as shown on the design drawings and specifications, and then rolled down slope in such a manner so as to continually keep the geocomposite in tension. The geocomposite will be positioned by hand after being unrolled to minimize wrinkles, if needed. Horizontal placement of the geocomposite on sideslopes will not be allowed.

- In the presence of wind, all geocomposite will be secured by suitable means. The temporary weighted material will be left in place until replaced with cover material as shown on the design drawings and specifications.

- Cutting will be done according to manufacturer's recommendations.

- The installer will take necessary precautions to prevent damage to any underlying layers during placement of the geocomposite.

- During placement of geocomposite, care will be taken not to entrap any stones, excessive dust, or moisture that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane.

- The geocomposite will not be welded or tack-welded to the geomembrane.

The RPR will observe and document that the installer performs each of the above steps. Any noncompliance with the above requirements will be recorded and reported by the RPR.

10.4.2 Overlaps and Joining

The following requirements will be used with regard to the overlapping and joining of geocomposite rolls:

General

- The installer will pay particular attention to the overlapped areas to ensure that no earthen or foreign materials could be inadvertently trapped beneath the geocomposite.

Geotextile Portion of Geocomposite

- The geotextile portion of the geocomposite will be overlapped 4 to 6 inches.

- Geotextile seams will be continuously sewn unless heat bonding is approved by the CQA officer and owner. The sewing method and stitch type will be per manufacturer's recommendation, but must be approved by the CQA officer. Overlapping of geotextile without sewing may be acceptable for certain applications with approval from the CQA officer and owner.

- Sewing will be performed with thread made from the same base material as the geotextile, or suitable equivalent.

Geonet Portion of Geocomposite

- The geonet portion will be overlapped a minimum of 4 inches.

- Ties will secure geonet overlaps.

- Tying will be performed with pull ties. Ties will be white or brightly colored for easy identification. Metallic devices will not be used under any circumstances.

- Ties will be placed at 5-foot intervals along the length of the panels and at 12-inch intervals at end-to-end connections of panels.

The RPR will observe and document that the installer performs each of the above steps. Any noncompliance with the above requirements will be reported by the RPR to the CQA officer.

10.4.3 Repairs

Any tears or other defects in the geocomposite will be repaired by placing a patch with minimum overlaps described in **Subsection 10.4.2**. The patch will be secured to the original geocomposite by tying every 6 inches. If the tear or other defect width is more than 50 percent of the roll width, the damaged area will be cut out and replaced with new geocomposite. Tying will be as indicated in **Subsection 10.4.2**. These procedures apply to seams and/or patches required for piping penetrations in the final cover.

The RPR will examine and document that the repair of any geocomposite is performed according to the above procedure.

10.5 POST-INSTALLATION PLACEMENT OF SOIL MATERIALS

Final Acceptance

The RPR will perform a final geocomposite examination after installation has been completed. The objectives of this step are as follows:

- To examine the geocomposite for the presence of tears or defects.
- To examine overlaps to make certain that they are in conformance with the requirements of **Subsection 10.4.2**.

If any portion of the geocomposite requires repairs due the above examination, they will then be performed according to the procedures in **Subsection 10.4.3**.

If there will be an extended delay between completion of the geocomposite and the start of the installation of any overlaying cover, the installer will make provisions, by placing temporary securing means, to protect the geocomposite from wind uplift.

Placement of Soil Materials

The contractor will place all soil materials located on top of the geocomposite in such a manner so as to minimize the following:

- Damage to the geocomposite.
- Slippage of the geocomposite on underlying layers.
- Excessive tensile stresses imposed on the geocomposite.

Low ground pressure tracked equipment (< 5 psi) will be used to place the protective cover over the geocomposite. A minimum of 1 foot of cover material is required between the geocomposite and the low ground pressure equipment. A minimum of 2 feet of cover is required between the geocomposite and all other tracked or flotation wheeled equipment. A minimum of 30 inches of cover soil is required between the geocomposite and all rubber-tired vehicles.

Any noncompliance with the above requirements will be recorded and reported by the RPR to the CQA officer.

Table 5. (10-1) Geocomposite Tests, Test Methods, and Acceptance Criteria

Property	Units	Acceptance Value	Test	Criterion
Geocomposite(1)				
Ply Adhesion	lb/in	0.5	ASTM D7005	Min. Average
Transmissivity	m^2/sec	(4)	ASTM D4716	Min. Average
Geonet Core(2)				
Thickness	mils	200	ASTM D5199	Min. Average
Density	g/cu cm	0.94	ASTM D1505	Min. Average
Carbon Black Content	Percent	2	ASTM D1603/4218	Min. Average
Geotextile(2)				
Mass per Unit Area	oz/yd^2	6	ASTM D5261	Min. Average
Grab Tensile	lb	160	ASTM D4632	Min. Average
Puncture Strength (pin)(5)	lb	90	ASTM D4833	Min. Average
Puncture Strength (CBR) (5)	lb	435	ASTM D6241	Min. Average
AOS, US sieve	US Sieve No.	70	ASTM D4751	Min. Average
Permittivity	sec^{-2}	1.5	ASTM D4491	Min. Average
Flow Rate	gpm/ft^2	110	ASTM D4491	Min. Average

Notes:
1. The geocomposite shall be manufactured by heat bonding the geotextile to the geonet on both sides. No burn through geotextiles nor glue or adhesive shall be permitted.
2. Component properties prior to the lamination.
3. Refer to **Table 3-1** for direct shear test requirements.
4. Refer to **Table 3-1** for transmissivity test requirements.
5. Geotextile to meet puncture strength (pin) or puncture strength (CBR) specification.

11.0 GEOSYNTHETIC CLAY LINER

This section covers the quality assurance requirements for Pre-installation (includes GCL manufacturer), Installation, and Post-installation. The terms Pre-installation, Installation, and Post-installation are applicable only to the GCL installation and do not apply to the overall construction of the ash disposal facility.

11.1 GENERAL

This section of the CQA Plan applies to the GCL used in the liner system including sumps.

11.2 PRE-INSTALLATION

Pre-installation activities are designed to help ensure that a high-quality product is being manufactured and that it is properly delivered, handled, and stored to maintain its quality.

11.2.1 Manufacturer's Quality Control Plan

The manufacturer of each component of the GCL and the GCL itself shall have a Manufacturer's Quality Control Plan (MQCP) to ensure their product meets all the stated minimum properties. These manufacturers include the bentonite supplier, the geotextile manufacturer, and the GCL manufacturer.

Bentonite Supplier

The bentonite supplier shall have an MQCP, which is adhered to in the manufacturing process. This plan shall include the following information:

- Documentation that the bentonite is sodium bentonite.
- Testing that demonstrates that the bentonite meets specified gradation requirements.
- Testing that indicates that the bentonite meets specified index test requirements.
- Testing that demonstrates that the bentonite has not been treated with synthetic chemicals or polymers.

Polymer-enhanced bentonite is required for the liner system GCL.

At a minimum, the manufacturer shall perform the tests shown in Table 11-1.

Geotextile Manufacturer

The geotextile manufacturer shall have an MQCP, which is adhered to in their manufacturing process. This plan shall include the following provisions:

- Testing that demonstrates that the product is made of specified polymers.
- Testing that demonstrates that the product meets certain minimum average roll values (for geotextile).

GCL Manufacturer

The GCL manufacturer shall have an MQCP, which describes the procedures for accomplishing quality in the final product. At a minimum, the manufacturer shall perform the tests shown in Table 11-1.

This MQCP shall also dictate the following requirements:

- Overlap alignment lines are to be marked on the edges.
- Completed rolls are to be securely wrapped in plastic.
- Completed rolls are to be stored indoors. Provisions are to be in place to prevent rolls from being stacked too high, to be kept dry, and to prevent damage during handling.
- Quality Control certification is to be provided.

11.2.2 Materials

The GCL shall consist of a layer of pure sodium bentonite clay encapsulated between two geotextiles, and shall comply with all of the manufacturing processes and physical/chemical criteria listed in this section. Polymer-enhanced bentonite shall be used for the liner system GCL.

The bentonite clay utilized in the manufacturing of the GCL, as well as any accessory bentonite clay provided for the seaming and detail work, shall meet the manufacturer's requirements, as specified in their MQCP. The bentonite used in the manufacturing of the GCL shall also meet the requirements of Table 11-1.

The geotextile components of the GCL, and the geosynthetics clay liner itself, shall meet the minimum requirements of their respective MQCP. The GCL shall also meet the requirements of Table 11-1.

11.2.3 GCL Delivery, Handling, and Storage

The GCL panels shall be supplied to the site in factory-produced rolls. The manufacturer shall supply GCL panels to the job site in standard factory roll dimensions.

Each roll of GCL supplied to the site shall be labeled with the following information:

- Name of manufacturer.
- Product type and identification number.
- Batch (or lot) number.
- Date manufactured.
- Roll number.

The GCL manufacturer will ensure that the crushing strength of all GCL roll cores will be sufficient to avoid collapse or other damage while in use.

The rolls of GCL are to be carefully unloaded by the contractor upon delivery to the site. At a minimum, the following practices should be followed in receiving and storing GCL rolls:

- While unloading or transferring the GCL rolls from one location to another, prevent damage to the GCL.

- For standard rolls, a steel support should be inserted through the roll core. The slings or lifting chains should be attached at one end to the support pipe and the other end to the bucket of a front-end loader or lifting device. A spreader bar should be used to support and spread the slings. The bar and support pipe must be long enough to prevent damage to the edges of the GCL during hoisting.

- Alternate methods of unloading or transferring GCL rolls must be approved by the RPR.

- The rolls of GCL will be stored in their original, unopened, wrapped cover in a clean, dry area. The GCL should be stored off the ground on pallets or by other suitable techniques that provide continuous support over the entire length of the roll. The stored GCL shall be covered with a heavy, protective tarpaulin or stored beneath a roof. Care should be used to protect the GCL from the following:

- Precipitation.
- Ultraviolet radiation.
- Strong oxidizing chemicals, acids, and bases.
- Flames, including welding sparks.
- Temperatures in excess of 160°F.

The RPR will be responsible throughout the pre-installation, installation, and post-installation periods, for observing and documenting that the installer provides adequate handling equipment used for moving GCL rolls and that the equipment used does not damage the GCL.

The RPR will be responsible for making certain that the manufacturer, type, and thickness of each roll are correct. The RPR will maintain a log of all GCL delivered to the job site. The following information, at a minimum, will be recorded on the log for each shipment delivered to the job site:

- Date of receipt of delivery at the job site.
- For each GCL roll delivered to the site, the roll number and batch (or lot) number.

11.2.4 Submittals

Prior to GCL installation, the GCL manufacturer and GCL installer will submit the following information to the CQA officer.

GCL Manufacturer/Production Information

- Corporate background and information.
- MQCP for bentonite, geotextile, and GCL manufacturers.
- Project reference list consisting of the principal details of at least 10 projects totaling at least 8,000,000 square feet of GCL installation, if required by the RPR or the CQA officer.
- Results of tests conducted by the bentonite supplier and the geotextile supplier to document the quality of the materials used to manufacture the GCL rolls assigned to the job.
- Copy of Quality Control certifications, signed by the manufacturer. Each quality control certificate shall include roll identification numbers and results of quality control tests.
- Written certification from the manufacturer that the GCL meets the project specifications, that the GCL has been continuously inspected and found to be needle-free through magnetic and metal detection tests, that the bentonite will not shift during transportation or installation, and that the bentonite and geotextile materials meet the manufacturer’s specifications.

GCL Installer Information

- Corporate background information.
- Project reference list of at least five projects totaling 1,000,000 square feet, if required by RPR or CQA officer.

- List of personnel performing field operations along with pertinent experience information, if required by RPR or CQA officer.

The proposed panel placement diagram identifying placement of the GCL panels and seams, as well as additional details that deviate from the engineering drawings, shall be submitted prior to installation if required by the CQA officer. The layout should be drawn to scale, shall include information such as dimensions and details, and shall be adequate for use as a construction plan.

11.3 INSTALLATION

The following installation procedures are designed to ensure the effectiveness of the GCL in meeting its design requirements and to simplify the deployment procedures. These procedures are to be followed by the installer, unless the installer proposes alternate procedures in writing to the CQA Officer and the CQA Officer approves these alternate procedures.

11.3.1 Testing Requirements

This subsection describes the test methods, including sampling procedures and frequencies (if applicable), and the role of the Geosynthetic Testing Laboratory in testing the GCL roll samples. Unless specified otherwise, all sampling procedures will be performed in accordance with the referenced test method defined in this section.

Testing Methods

GCL roll samples will be collected at the Manufacturer's plant by a technician of the Geosynthetic Testing Laboratory or on-site by the RPR and contractor. Sample sizes shall be as required by the Geosynthetic Testing Laboratory. GCL samples will be collected and tested in accordance with the test methods specified in Table 11-1.

The Geosynthetic Testing Laboratory will be responsible for performing the tests on samples submitted to them. Results of tests performed will be reported to the RPR and CQA officer. Retesting of GCL rolls for quality assurance purposes, because of failure to meet any or all of the acceptance specifications in this section, can only be authorized by the CQA Officer or Owner.

Procedures for Determining GCL Roll Test Failures

Table 11-1 lists the specifications that are applicable to the GCL. For any referenced test method that requires the testing of multiple specimens, the criteria in Table 11-1 shall be met based on the average results of the multiple specimen tests.

The following procedure will be used for interpreting results relative to acceptance or rejection of rolls, lots, and shipments of GCL to the site:

- If the test values meet the stated specifications, then the roll and batch will be accepted for use at the job site. If the sample represents all rolls from an entire shipment, then the entire shipment will also be considered accepted.

- If the result does not meet the specification, then the roll and the batch shall be retested at the contractor's expense using specimens either from the original roll sample or from another sample collected by the RPR. For retesting, two additional tests shall be performed for the failed test procedure. (Each additional test shall consist of multiple specimen tests if multiple specimens are called for in the failed test procedure.) If both of the retests are acceptable, then the roll and batch shall be considered to have passed this particular acceptance test; if either of the two additional tests fails, then the roll and batch shall be considered unsuitable without further recourse. RPR may obtain samples from other rolls in the batch. On the basis of testing these samples, the CQA officer may choose to accept a portion of the batch while rejecting the remainder.

If retesting does not result in passing test results as defined in the preceding paragraph, or if there is any other nonconformity with the material specifications, then the contractor shall withdraw the rolls from use in the project at the contractor's sole risk, cost, and expense. Once withdrawn, the same rolls shall not be resubmitted for use. Cost and expense for removing this GCL from the site and replacing it with acceptable GCL shall be the sole risk and responsibility of the contractor.

11.3.2 Required Equipment

The following installation equipment is required on-site:

- Front-end loader, crane, or other similar equipment. The selected piece of equipment shall not cause damage to the subgrade, such as rutting. The installer shall verify in the presence of the RPR that the selected piece of equipment does not damage the subgrade.
- A spreader bar to prevent slings from damaging the ends of the rolls.
- Several steel pipes to be inserted into the roll's core for lifting.
- Wooden pallets for aboveground storage of the GCL rolls.
- Heavy waterproof tarps for protecting all GCL rolls.
- Sandbags for securing the GCL during installation and for the tarps.
- Adhesive or tape for securing patches.
- Granular bentonite for seams, patches, and penetrations.

11.3.3 Surface/Subgrade Preparation

GCL installation will not begin until a proper subgrade has been prepared to accept the GCL. Base material will be select clay fill for the liner. Foreign materials and protrusions should be removed, and all cracks and voids should be filled, and the surface made smooth and uniformly sloping. Unless otherwise required by the contract specification and drawings, the prepared surface should be free from excessive moisture, loose earth, or rocks larger than 2 inches in diameter, rubble, and other foreign matter. The subgrade should be uniformly compacted to ensure against localized settlement and rutting under wheel loads, and should be smoothed with a smooth drum or vibratory roller.

The surface on which the GCL is to be placed should be maintained in a firm, clean, and smooth condition; free of standing water during GCL installation. Vehicle traffic on the subgrade of the GCL shall be restricted to the minimum weight and number of machines needed to deploy the GCL. Vehicles shall be operated to minimize the formation of ruts and surface deformations.

11.3.4 Deployment

As each roll is moved from the storage area, the installer or RPR should remove the labels for storage in the project file.

The rolls of GCL should be brought to the area to be lined with a front-end loader and support pipe set up such that the roll of GCL is fully supported across its length. A spreader bar or similar device should be used to prevent the lifting chains or slings from damaging the edges. Dragging of the GCL should be minimized.

The Contractor shall ensure, and the RPR will verify, that the following criteria are being met:

- The equipment used does not damage the GCL by handling, excessive heat, leakage of hydrocarbons, or by other means.
- The prepared surface underlying the GCL has not deteriorated since previous acceptance, and that it is still acceptable at the time of GCL placement.
- Personnel working on the GCL do not smoke, wear damaging clothing, or engage in other activities that could damage the GCL.
- The method used to unroll the GCL does not cause damage to the GCL and/or the subgrade.
- The method used to place the rolls minimizes wrinkles (especially wrinkles between adjacent panels).

Do not place GCL during precipitation, in the presence of excessive moisture, in any area of ponded water, or during excessive winds. The GCL must be dry when installed and must be dry when covered.

The non-woven side of the GCL should face upwards, and the scrim side of the GCL should face downwards (unless otherwise dictated by project requirements). The GCL will be placed over the prepared surface in such a manner, which minimizes material handling.

The GCL panels should be placed in a manner that ensures sufficient overlap as described in Subsection 11.3.5. Whenever possible, horizontal seams should not occur on slopes steeper the 7H:1V. If horizontal seams are required on slopes, seams should be staggered to provide no end seams within 25 feet up- or downslope on adjacent panels.

The cover material (i.e., geomembrane) should be placed over the GCL during the same day as the placement of the GCL. Only those GCL rolls which can be covered that same day should be unpacked and placed in position.

When wind conditions can affect installation, the GCL installation should be started at the upwind side of the project and proceed downwind. The leading edge of the GCL should be secured at all times with sandbags or other means sufficient to hold it down during high winds.

The GCL should be installed in a relaxed condition and should be free of tension or stress upon completion of the installation. Stretching of the GCL to fit will not be allowed. Deployed rolls (panels) should be straightened by the installation personnel to smooth out creases or irregularities.

The RPR will visually inspect the geotextile quality, bentonite uniformity, and the degree of hydration, if any, of the GCL. Any areas in need of repair shall be marked.

11.3.5 Seaming

Once the first panel has been deployed, adjoining panels should be laid with a 6-inch minimum overlap on longitudinal seams, and 20 inches on the panel end seams, depending on project specifications. Six-inch and 20-inch overlap lines shall be marked on the GCL to assist in obtaining the proper overlap. When connecting GCL panels from a prior construction phase to a new construction phase, a minimum 1-foot overlap should be provided between the previously placed panels and the newly placed panels. All dirt, gravel, or other debris should be removed from the overlap area of the GCL.

Seam overlaps, whenever possible, should be placed such that the direction of flow is from the top panel to the underlying panel to form a shingle effect.

If the GCL requires a granular bentonite seam, then the overlapping panel edge should be pulled back and granular sodium bentonite should be poured continuously along all seams and lap areas for the panel edge to the 6-inch lap line, at a minimum application rate of one-quarter pound per lineal foot.

11.3.6 Patches/Repairs

Irregular shapes, cuts, or tears in the installed GCL should be covered with sufficient GCL to provide a 12-inch overlap in all directions beyond the damaged area. A layer of granular bentonite shall be placed in the overlap zone in accordance with the manufacturer's recommendations. An epoxy-based adhesive, or other approved method, shall be used to secure the patch during backfill operations.

11.3.7 Penetration Seals

The GCL should be sealed around penetrations, pipes, and structures in accordance with the recommendations of the GCL manufacturer.

11.3.8 Covering GCL

Only the amount of GCL that can be inspected, repaired, and covered in the same day should be deployed. The GCL must be covered the same day it is installed.

Geosynthetics

When covering the GCL, precautions shall be taken to prevent damage to the GCL by restricting heavy equipment traffic. Place a slip-sheet over the GCL to allow the textured geomembrane to slide into its proper position. The slip-sheet shall be removed after the geomembrane is in place.

Any leading edge of panels of GCL left unprotected must be covered with heavy, waterproof tarp that is secured and protected with sandbags or other ballast.

GCL Panels at the End of a Phase

This section applies to GCL panels located at the end of a phase of construction that will be connected to GCL panels during construction of a future phase. The edge of the GCL panels shall be protected from excess soil moisture contact by placement of plastic construction film rolled over both the top and bottom sides for at least a 2-foot width along the edge of the GCL panels. The overlying geomembrane shall extend beyond the edge of the GCL. Soil shall be placed over the edges of the geosynthetics to divert water away from the buried edges and to impose overburden pressure to minimize swelling of the GCL.

11.3.9 Submittals

During GCL installation, the GCL installer shall submit the following information to the CQA officer:

- Daily records/logs prepared by the installer documenting work performed, personnel involved, general working conditions, and any problems encountered or anticipated on the project. These records shall be submitted on a weekly basis.
- Copy of subgrade acceptance forms by the installer.
- Quality control documentation.

Table 6. (11-1) GCL Material Tests, Test Methods, and Acceptance Criteria

	Property	Test Method	Units	Criterion	Acceptance Value(1)	Minimum Conformance Testing Frequency(2)(3)
Bentonite properties	Free swell	ASTM D5890	ml/2g	Minimum	24	1/100,000 sf
	Fluid loss	ASTM D5891	ml	Maximum	18	Not required
Physical GCL Properties	Grab strength(6)	ASTM D6768	lb/in	MARV(4)	23	1/100,000 sf
	Bentonite mass per unit area(5)	ASTM D5993	psf	Minimum	0.75	1/40,000 sf
	Peel strength(6)	ASTM D6496	lb/in	Minimum	2.1	1/100,000 sf
	Index flux	ASTM D5887	$m^3/m^2/sec$	Maximum	1×10^{-8}	1/100,000 sf
	Permeability	ASTM D5887	cm/sec	Maximum	5×10^{-9}	Not required
	Hydraulic Conductivity(7)	ASTM D6766	cm/sec	Maximum	5×10^{-9}	Note 8
	Loss on Ignition	ASTM D7626 modified	Percent	Note 9	Note 9	1 test(10)
	Fann Viscosity	API 13A Section 9 modified	Centipose	Note 9	Note 9	1 test(10)

Notes:
1. Values are based on representative manufacturer's product data current acceptable industry standards and practice.
2. CQA officer to coordinate conformance testing at the specified frequencies (minimum) on the GCL rolls supplied to the project.
3. Conformance testing is not required if GCL manufacturer provides testing documentation at the required frequency prior to shipping.
4. MARV = Minimum average roll value.
5. Bentonite mass/unit area reported at zero percent moisture content.
6. Grab and peel strength testing performed in the machine and cross direction. Acceptance value is for the machine direction test.
7. Hydraulic conductivity (compatibility) test for the liner GCL performed using site-generated leachate.
8. One test is required for the liner GCL. The test must be repeated if there is a change in site's coal combustion residuals (CCR) properties, or if the GCL product or the polymer used to enhance the bentonite in the GCL changes.
9. Testing of polymer-enhanced bentonite from liner GCL. Manufacturer's test results will be used to compare with results from conformance testing coordinated by CQA Officer.
10. CQA Officer to coordinate conformance testing of polymer-enhanced liner GCL rolls supplied to the project.
11. Refer to **Section 3.2** for direct shear test requirements.

12.0 GEOMEMBRANE

12.1 GENERAL

This section of the CQA Plan applies to the polyethylene geomembranes used in the liner and final cover systems, and the contact water basin liner.

12.2 PRE-INSTALLATION

This section describes the quality control measures that are applicable to the polyethylene resin manufacturers, geomembrane manufactures, and finished geomembrane roll delivery to the site prior to installation. The geomembrane must be fabricated from polyethylene resin.

In the event that geomembrane materials are obtained from a different manufacturer or are made from different resins, seam samples formed by joining the original and the proposed geomembrane may be tested to confirm the construction compatibility of the two-geomembrane materials. Prior to the use of the new geomembrane material, a minimum of two seamed samples (as described above) may be submitted to the geosynthetics laboratory for destructive seam testing as described in **Subsection 12.4.5.** The CQA officer will review the testing results prior to authorizing the use of the new geomembrane material.

The geomembrane will be supplied to the site in factory rolls. No factory seams will be used to prepare larger panels of geomembrane for delivery to the site.

12.2.1 Manufacturing

Material Specifications

The required geomembrane material for final cover construction is textured 40-mil LLDPE. The approved geomembrane material for the liner system construction is textured 60-mil HDPE.

Quality Control Requirements

Prior to the delivery of any geomembrane rolls to the site, the geomembrane manufacturer will provide the owner and/or the CQA officer with the following information:

- The resin supplier, location of supplier's production plant(s), and resin brand name and product number.
- Any results of tests conducted by the geomembrane manufacturer and/or the resin manufacturer testing laboratories to document the quality of the resin used in fabricating the geomembrane.
- The Quality Control Plan that the geomembrane manufacturer will be using for the geomembrane being supplied.

Every roll of geomembrane for delivery to the site must be manufactured and inspected by the Geomembrane Manufacturer according to the following requirements:

- First quality polyethylene resin must be used.

- The geomembrane must contain no more than a maximum of 1 percent by weight of additives, filler, or extenders, excluding carbon black.

- The geomembrane must have no striations, roughness (except where textured geomembrane is specified), or bubbles on the surface.

- The geomembrane must be free of holes, blisters, undispersed raw materials, or any other sign of contamination by foreign matter.

The geomembrane manufacturer will routinely perform density (ASTM D1505) and melt index (ASTM D1238) tests on the raw resin to document the quality of the HDPE or LLDPE resin used to manufacture the geomembrane rolls assigned to this project.

Manufacturer's Certification

The geomembrane manufacturer will test the geomembrane produced for the site according to the test methods and frequencies listed in Table 12-1. The geomembrane manufacturer will provide certification, based on tests performed by either the geomembrane manufacturer's laboratory or other outside laboratory contracted by the geomembrane manufacturer, that the geomembrane supplied under this plan will meet the specifications presented in Table 12-2, except as noted in Subsection 12.3.1 under Procedures for Determining Geomembrane Roll Test Failures. Additionally, the manufacturer will provide certification that the manufacturer's Quality Control Plan was fully implemented for the geomembrane material supplied under this plan. The manufacturer will provide documentation to verify results of the manufacturer's Quality Control Plan implementation if requested by the CQA officer.

12.2.2 Delivery, Handling, and Storage of Geomembrane Rolls

The geomembrane will be protected during shipment from excessive heat or cold, puncture, cutting, or other damaging or deleterious conditions. The geomembrane rolls will be stored on-site in a designated area and will be protected from long-term ultraviolet exposure prior to actual installation.

Each geomembrane roll will be marked by the geomembrane manufacturer with the following information (on a durable gummed label, or equivalent, on the inside of the core):

- Name of manufacturer.
- Product type and identification number (if any).
- Roll length and width.
- Batch (or lot) number.
- Nominal product thickness.
- Date manufactured.
- Roll (or field panel) number.

When cores are required for preparing geomembrane for shipment, the manufacturer will use cores with sufficient crushing strength to prevent collapse or other damage while in use.

The following practices will be used as a minimum in receiving and storing geomembrane rolls in the designated storage area at the job site:

- While unloading or transferring the geomembrane rolls from one location to another, care will be taken to prevent damage to the geomembrane itself. The preferred method involves using a spreader-bar, straps, and a loader. Rolls will not be dragged.

- Geomembrane rolls will be stored in a manner so as to ensure that they are adequately protected from the following:
  - Equipment damage.
  - Strong oxidizing chemicals, acids, or bases.
  - Flames, including welding sparks.
  - Temperature in excess of 160°F.
  - Dust and dirt.

The RPR will observe and document, throughout the pre-installation, installation, and post-installation periods, that the installer provided adequate handling equipment for moving geomembrane rolls and that the equipment and the handling methods used do not pose unnecessary risk of damage. The installer is responsible for the means and methods to implement the work.

The installer will be responsible for ensuring that all material, installed meet specifications (i.e., that the roll marking label information indicates required specifications and properly represents materials). The RPR will maintain a log of geomembrane roll deliveries. The following information, at a minimum, will be recorded on the log for each shipment received at the job site:

- Date of delivery at job site.
- For each geomembrane roll, the roll number and batch (or lot) number.

12.3 INSTALLATION

This section includes discussion of geomembrane roll testing requirements, earthwork required for geomembrane placement, placement of the geomembrane, defects and repairs of geomembrane, and requirements applicable to other materials in contact with the geomembrane. **Section 12.4** describes the installation and testing requirements for geomembrane seams.

All parties involved in the installation of the geomembranes will be familiar with geomembrane and will focus on protecting the geomembrane from damage during construction activities.

12.3.1 Testing Requirements

This subsection describes the test methods, including sampling procedures and frequencies, and the role of the geosynthetics-testing laboratory in testing the geomembrane roll samples. **Subsection 12.2.1**, under Quality Control Requirements, describes the test methods that are performed on an infrequent basis to demonstrate the uniformity of resin used to fabricate geomembrane shipped to the job site. Seam testing is described in **Subsections 12.4.4** and **14.4.5**.

Testing Methods

A representative of the Geosynthetic Testing Laboratory at the geomembrane manufacturer's plant will collect geomembrane roll samples. The rate of sampling will be one per 100,000 square feet of geomembrane produced for delivery to the site. At least one sample will also be obtained for each geomembrane production batch for each shipment. The installer will not ship to, or receive at the site, geomembrane from more than two production batches in any single shipment without the prior written approval of the CQA officer and/or owner.

Samples collected will be of a size determined by the Geosynthetic Testing Laboratory. The laboratory technician will indicate the machine direction on the sample.

Table 12-1 lists the tests and the test methods to be performed on HDPE or LLDPE geomembrane roll samples. The specifications and methods used in evaluating the results are discussed below under "Procedures for Determining Geomembrane Roll Test Failures." Unless specified otherwise, sample specimens will be prepared in accordance with the referenced test method. The results for tear resistance and each of the tensile property tests will be reported for both the machine and cross direction.

The Geosynthetics Testing Laboratory will be responsible for performing the tests on samples submitted to them as described above under Test Methods. The results of the tests performed will be reported to the CQA officer and the RPR.

Retesting of geomembrane rolls for quality assurance purposes because of failure to meet any or all of the acceptance specifications listed in Table 12-2 can only be authorized by the CQA officer and/or owner.

The geomembrane manufacturer and/or installer may perform their own tests according to the methods and procedures defined in Table 12-1; however, the results will only be applicable to their own quality control needs. The results will not be substituted for the quality assurance testing described herein.

Procedures for Determining Geomembrane Roll Test Failures

Table 12-2 lists the acceptance specifications for HDPE and LLDPE geomembranes. For those tests where results are reported for both machine and cross direction, each result will be compared to the listed specification to determine acceptance.

The following procedure will be used for interpreting results:

- If the test values meet the stated specification in Table 12-2, then the roll and the lot will be accepted for use at the job site. If the sample represents all rolls from an entire shipment, then the entire shipment will also be considered accepted.
- If the result does not meet the specifications, then the roll and the batch may be retested using specimens either from the original roll sample or from another sample collected by the geosynthetic laboratory technician or the RPR. For retesting, two additional tests will be performed for the failed test procedure. (Each additional test will consist of multiple specimen tests if multiple specimens are called for in the test procedure.) If both of the retests are acceptable, then the roll and batch will be considered to have passed this particular acceptance test; if either of the two additional tests fail, then the roll and batch will be considered unsuitable without further recourse. The CQA officer may obtain samples from other rolls in the batch. On the basis of testing these samples, the CQA officer may choose to accept a portion of the batch while rejecting the remainder.

If retesting does not result in passing test results as defined in the preceding paragraph, or if there is any other nonconformity with the material specifications, then the Installer will withdraw the rolls from use in the project at the Installer's sole risk and expense. The installer will be responsible at his/her sole risk, cost, and expense for removing this geomembrane from the site and replacing it with acceptable geomembrane.

12.3.2 Earthwork

The construction contractor will be responsible for preparing the supporting soil according to the plans and specifications. For the installation of any of the geomembrane, the installer will certify in writing that the surface on which the geomembrane will be installed is acceptable. This certification of acceptance will be reported by the Installer prior to the start of geomembrane installation in the area under consideration. Unacceptable areas noted by the Installer will be immediately reported to the RPR.

The installation surface will also be examined by the RPR. The daily observation will be documented in the daily report. The construction contractor or installer will rework areas determined to be unacceptable until acceptable.

12.3.3 Placement

Location and Panel Layout Drawing

The installer will prepare a panel layout drawing for the geomembrane installation covered by this plan prior to the installation and submitted to the CQA officer and owner. The proposed panel layout drawing will show the proposed location and orientation of geomembrane panels to be installed in relation to slope, collection trenches, anchor trench, and phase boundaries. The panel layout drawing will be submitted to the DNR prior to the preconstruction meeting, if required. The owner and CQA officer will review the proposed panel layout drawing and document that it is consistent with accepted practice and the construction plans and specifications.

Installation Techniques

Geomembrane panels will be installed by placing one at a time, and each panel will be seamed by the end of the day on which it was placed. Panels shall be installed such that all seams run perpendicular to the contour lines of the slope.

The RPR will document that the condition of the supporting soil has not changed detrimentally during installation. The RPR will notify the installer and the construction contractor of any damage done (i.e., rutting by equipment used to deploy geomembrane) to the supporting soil prior to panel seaming. It is the responsibility of the Installer to remove the deployed panel to allow the construction contractor to repair the supporting soil. The RPR will observe and document the repair of the supporting soil. The RPR will inform the installer that the method of deployment will be observed during further deployment, and if damage to supporting soil continues, deployment will be stopped and an alternate means of deployment is to be developed. The RPR will document these events and conversations in the daily summary report.

The installer will take the following precautions while installing the geomembrane:

- Ensure the equipment used does not damage the geomembrane by the way it is handled, by excessive heat, by leakage of hydrocarbons, or by other means.

- Ensure the personnel working on the geomembrane do not smoke, wear damaging clothing, or engage in other activities that could damage the geomembrane.

- Ensure that the method used to deploy the geomembrane does not cause scratches or crimps in the geomembrane.

- Ensure that the method used to deploy the rolls minimizes wrinkles.

- Ensure that the geomembrane is adequately loaded to prevent wind uplift.

- Minimize the amount of direct contact with the geomembrane and limit the number of personnel that are allowed on the geomembrane once quality control (QC) and quality assurance (QA) is completed.

- Ensure that only approved equipment is allowed on the surface of the geomembrane (i.e., generators, test equipment). The use of motorized vehicles is not permitted without written approval from the owner and the CQA and/or the RPR.

Weather Conditions

Geomembrane will not be placed in an area of ponded water or during precipitation events. Geomembrane may not be deployed in the presence of excessive winds unless approved by the CQA officer or owner. The installer must receive written approval from the CQA officer or owner to deploy geomembrane in temperatures below 30°F.

Damage

The RPR will examine each panel for damage after placement and will determine which panels, or panel portions, should be rejected, repaired, or accepted. Damaged panels or portions that have been rejected will be marked, removed, and recorded by the RPR.

12.3.4 Defects and Repairs

This section applies to all defects and repairs resulting from examinations, tests, or visual observations performed on the geomembrane material itself and on the seams used in joining rolls in the field.

Identification

All seam and non-seam areas of the geomembrane will be examined and documented by the RPR for identification of defects, holes, blisters, undispersed raw material, and any signs of contamination by any foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane will be clean at the time of examination. The RPR will complete a final examination of the geomembrane in areas in which both the installer and the RPR have completed their QC and QA, respectively. The RPR will document areas in which a final examination has been completed, and the installer will limit personnel access to the completed area. The RPR and the installer will perform a final examination over the entire geomembrane at the completion of the project. The installer and/or the construction contractor will clean any area that is insufficiently clean to complete the final examination.

Evaluation

Each suspect area identified will be nondestructively tested using the vacuum box test method, air test, or spark test method. The RPR will approve the proper test method for each suspect location.

Repair Procedures

Any portion of the geomembrane exhibiting a flaw or failing a destructive or nondestructive test will be repaired. Several procedures exist for the repair of these areas. The procedures available include the following:

- Patching is used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.
- Grinding and rewelding are used to repair small sections of extruded seams.
- Spot welding or seaming is used to repair small tears, pinholes, or other minor, localized flaws.
- Capping is used to repair large lengths of failed seams.
- Other procedures may be used at the recommendation of the Installer if agreed upon by the CQA officer and the RPR.

The repair procedures, materials, and techniques will be approved in advance of the specific repair by the CQA officer, RPR, and installer. At a minimum, the following provisions will be satisfied:

- Patches or caps will extend at least 6 inches beyond the edge of the defect, and all corners of patches will be rounded with a radius of at least 3 inches.
- The type of geomembrane (i.e., smooth or textured) used for repairs will be approved by the RPR prior to completing repairs.

Examination of Repairs

Each repair will be numbered and logged by the RPR. Each repair will be nondestructively tested according to **Subsection 12.4.4.** Repairs that pass the above testing will be considered to be adequate, except that large caps may be of sufficient extent to require destructive seam sampling and testing, at the discretion of the RPR, according to the provisions of **Subsection 12.4.5**.

Failed tests indicate that the repair was inadequate, and the repair will be redone and retested until a passing result is obtained. The RPR will document that all repairs have been subjected to nondestructive testing and will record the number of each repair, the date, and the test outcome.

Large Wrinkles

When seaming of the geomembrane is completed, the RPR will examine the geomembrane for wrinkles. Wrinkles that are higher than they are wide should be smoothed, cut, and seamed by the Installer. The wrinkle repair will be done in accordance with the equipment and procedures described in **Subsections 12.4.2** and **12.4.3** (General Seaming Procedures), respectively, and it will be nondestructively tested using the vacuum box test method described in **Subsection 12.4.4.**

12.4 FIELD SEAMING

This section covers the quality assurance procedures on seams used to join the rolls of geomembrane into a continuous layer. The installation of each of the geomembranes at the landfill will include 100 percent nondestructive testing of all field seams for joining adjacent rolls of geomembranes to document that no openings or gaps exist between geomembrane sheets. In addition, destructive testing will be performed at a routine interval for determining the strength and mode of failure of field seams in both the shear and peel modes.

The allowable field seam methods, equipment, personnel qualifications, and destructive and nondestructive testing methods are described in this section.

12.4.1 Panel/Seam Layout

No horizontal seams will be allowed on slopes greater than 5 horizontal to 1 vertical. In corners and at other odd-shaped geometric intersections, the number of horizontal seams will be minimized. A seam numbering system comparable and compatible with the geomembrane roll numbering system will be agreed upon at the preconstruction meeting (Section 3.3).

12.4.2 Seaming Equipment

The approved process for production field seaming (roll to roll) are the dual hot wedge (fusion-type) seam method and the extrusion fillet welding process. The extrusion fillet weld process will be used for specialty seams and repair seams (nonproduction). No other processes can be used without prior written authorization from the CQA officer and the RPR. Only equipment that has been specifically approved by make and model will be used.

Dual Hot Wedge Process

The installer will meet the following requirements regarding the use, availability, and cleaning of the equipment to be used at the job site:

- An automated self-propelled type of apparatus will be used.
- The welding apparatus will be equipped to continuously monitor applicable temperatures.
- One spare operable seaming device will be maintained on-site at all times.
- Equipment used for seaming will not damage the geomembrane.
- The geomembrane will be protected in areas of heavy traffic to prevent damage discussed in Subsection 12.3.3.
- For cross seams, the edge of the cross seam will be ground to a smooth incline (top and bottom) prior to welding.
- For cross seams, the intersecting dual hot wedge seam will be patched using the extrusion fillet process described below.

- The electric generator for the equipment will be placed on a smooth base in such a way that no damage occurs to the geomembrane. Similarly, a smooth insulating plate or fabric will be placed beneath the hot equipment after use.

The installer will keep records for each seamer performing dual hot wedge seaming, including welding machine I.D. number, ambient temperature, and machine operating temperatures. These data will be recorded at intervals as agreed upon at the preconstruction meeting.

Extrusion Fillet Process

The installer will meet the following requirements regarding the use, availability, and cleaning of the extrusion welding equipment to be used at the job site:

- The welding equipment will be equipped to continuously monitor temperature at the nozzle.
- One spare seaming device will be maintained on-site at all times.
- Equipment used for seaming will not damage the geomembrane.
- The geomembrane will be protected in areas of heavy traffic to prevent damage.
- The extruder will be cleaned and purged prior to beginning seaming, and at any time seaming operations are stopped, until all heat-degraded extrudate has been removed from the barrel. Purged extrudate will not be placed on the geomembrane.
- The electric generator for the equipment will be placed on a smooth base in such a way that no damage occurs to the geomembrane. Similarly, a smooth insulating plate or fabric will be placed beneath the hot equipment after use.
- Grinding geomembrane surfaces for welding preparation will not be performed more than one hour prior to seaming.

The installer and, if applicable, the geomembrane manufacturer will provide documentation to the CQA officer regarding the quality of the extrudate used in the welding apparatus. At a minimum, the extrudate will be compatible with the base material and will contain the same grade and quality of polyethylene resins as used in the base material.

The installer will keep records for each seamer performing extrusion weld seaming, including welding machine I.D. number, extrudate, and ambient temperature. These data will be recorded at intervals as agreed upon at the preconstruction meeting.

12.4.3 Initial Requirements

Personnel Qualifications

All personnel performing seaming operations will be qualified by experience and successfully passing seaming tests for the type of seaming equipment to be used. At least one seamer will have experience in seaming a minimum 1,000,000 square feet of polyethylene geomembrane using the same type of seaming apparatus used at the ash disposal facility. The most experienced seamer, the "master seamer," will have direct supervisory responsibility at the job site.

The installer will provide a list of proposed seaming personnel and their experience records to the CQA officer and the RPR for their review and approval.

Weather Conditions

The weather conditions under which geomembrane seaming can be performed are as follows:

- Unless otherwise authorized in writing by the CQA officer, no seaming will be attempted or performed at an ambient temperature below 32°F (0°C) or above 104°F (40°C).
- Geomembrane will be dry and protected from wind.
- Seaming will not be performed in areas where ponded water has collected below the surface of the geomembrane.

If the installer wishes to use methods that may allow seaming at ambient temperatures below 32°F or above 104°F, the installer will demonstrate and certify that the methods and techniques used to perform the seaming produce seams are entirely equivalent to seams produced at temperatures above 50°F and below 104°F, and that the overall quality of the geomembrane will not be adversely affected.

The RPR will document the following:

- Ambient temperature at which seaming is performed.
- Any precipitation events occurring at the site, including the time of such occurrences, the intensity, and the amount of the event.

The RPR will inform the CQA officer if any of the weather conditions are not being fulfilled. The CQA officer will stop or postpone the geomembrane seaming when weather conditions are unacceptable.

Overlapping and Temporary Bond

The installer will be responsible for ensuring that the following requirements are met:

- Panels of geomembrane will have a finished overlap of a minimum of 3 inches for extrusion welding and 4 inches for fusion welding; but in any event, sufficient overlap will be provided to allow peel tests to be performed on the seam.
- No solvents or adhesives will be used on the geomembrane unless the CQA officer has approved the product in writing. Approval can only be obtained by submitting samples and data sheets to the CQA officer for evaluation.
- Procedures used to temporarily bond adjacent geomembrane panels must not damage the geomembrane; in particular, the temperature of the hot air at the nozzle of any spot welding apparatus will be controlled such that the geomembrane is protected at all times against potential damage.

Trial Seams

Trial seams will be made on fragments of geomembrane to document that seaming conditions are adequate. For each seaming apparatus used and for each seamer, such trial seams will be made at the beginning of each seaming period, following work interruptions, following changes to machine settings for temperature or speed, at changes in weather, and at least once for every 5 hours of seaming activities. Trial seams are to be run using the materials the seaming will be used for (i.e., smooth to smooth, smooth to textured, textured to textured). At a minimum, one trial seam per welding machine will be made at the start of each day by each seaming technician performing welding that day. Also, each seamer will make at least two trial seams each full day of welding.

The trial seams will be examined by the installer and RPR for squeeze-out, foot pressure applied by the seaming equipment, and general appearance. If the seam fails any of these examinations, it will be repeated. If the second trial seam fails these examinations, the welding apparatus and seamer are not allowed to seam until the installer can demonstrate the cause of the failure. Once the installer has made the necessary corrections to the welding equipment, the seamer and apparatus are required to pass two trial seams prior to beginning seaming. The RPR will document the reason for the failure and all subsequent trial seams.

The trial seam samples will be at least 3 feet long by 1 foot wide after seaming, with the seam centered lengthwise. Seam overlap will be as indicated above under Overlapping and Temporary Bond.

Three adjoining specimens, each 1 inch wide, will be cut from each end of the trial seam sample by the installer. The specimens will be tested by the installer in shear and peel, respectively, using a field tensiometer. If a specimen fails, then the entire test will be repeated using two additional specimens cut from each end of the trial seam sample. If the second set of specimens also fails, then the seaming apparatus and seamer will not be accepted and will not be used for seaming until the deficiencies are corrected and two successful trial seams are achieved.

The remainder of the trial seam sample will be identified and marked by the RPR as follows:

- The sample will be assigned a number and marked as to welding apparatus used and the seamers name.
- The date, time, applicable welding equipment operating temperatures, and ambient temperature at the time of seaming will be noted.
- Whether the sample passes or fails will be recorded.

The RPR will observe trial seam procedures and record them on field log forms. The RPR will retain the trial weld sample as an archive sample.

Seam Preparation

The installer will ensure that the following conditions for each of the geomembrane installations covered by this plan are met:

- Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material.
- If seam overlap grinding is required, then the grinding process will be completed according to the geomembrane manufacturer’s instructions within one hour of the seaming operation, and in a way that will not damage the geomembrane or cause excessive striation of the geomembrane surface.

- Seams will be aligned so as to minimize the number of wrinkles and fishmouths.

General Seaming Procedures

Unless otherwise specified, the general seaming procedures to be used by the Installer for each of the geomembrane installations covered by this plan, and observed by the RPR, will be as follows:

- A firm subbase will be provided to achieve proper support for seaming.
- Fishmouths or wrinkles at the seam overlaps will be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles will be seamed, and any portion where the overlap is inadequate will then be patched with the same geomembrane (including thickness) extending a minimum of 6 inches beyond the cut in all directions.
- If seaming operations are to be conducted at night, adequate illumination will be provided.

12.4.4 Nondestructive Testing

Each field seam will be nondestructively tested over its full length using one of the methods described in this section. The purpose of nondestructive testing is to determine the continuity of the seams.

Nondestructive testing, at this stage of development, does not provide any information on the strength of seams. Seam strengths will be determined by destructive testing methods that are described in Subsection 12.4.5. Failure of any of the nondestructive or destructive tests will require the repair of the failed section according to the procedures contained in Subsection 12.3.4.

Nondestructive testing as described in this section will be performed on seams for every geomembrane installation covered by this plan. The recommended test methods for conducting the nondestructive seam testing are the air pressure test for dual hot wedge seams, the vacuum box test for extrusion fillet welds, and leak location testing. These three nondestructive testing methods are described below.

The RPR will perform the following documentation tasks:

- Observe nondestructive seam testing and examine seams for squeeze-out, foot pressure, and general appearance. Failure of these criteria will be considered as failure of the seam, and repair or reconstruction will be required.
- Document location, date, test unit number, name of tester, and outcome of all testing.
- Inform the installer and CQA officer of any required repairs.
- Document that appropriate repairs are made and that the repairs are retested nondestructively with passing results.

Air Pressure Testing

The following test procedures are applicable only to dual hot wedge seams. The equipment for performing the test should meet the following minimum requirements:

- An air compressor or hand pump equipped with a pressure gauge and regulator capable of producing and sustaining a pressure between 25 to 30 pounds per square inch gauge (psig) and mounted on a cushion to protect the geomembrane surface.
- Fittings, rubber hose, valves, etc., to operate the equipment, and a sharp hollow needle or other approved pressure feed device.

Air pressure testing will be performed according to the following procedure (ASTM D5820 and GRI GM 6):

1. Seal both ends of the seam to be tested.
2. Insert needle or other approved pressure feed device into the air space at one end of the dual hot wedge seam.
3. Energize the air compressor or hand pump to the pressure indicated in Table 12-3, based on the material type and thickness. Maintain the indicated pressure during a 2-minute stabilization period. At the end of the stabilization period, record the time and the pressure in the seam.
4. Remove the flexible hose that connects the pressure gauge to the air pump. Observe the pressure gauge for the evaluation period indicated in Table 12-3. Record the time and pressure in the seam at the end of the test period.
5. If the pressure difference between the two recorded readings exceeds the maximum allowable pressure drop indicated in Table 12-3, or if the pressure does not stabilize within the evaluation period, one more pressure-monitoring interval is allowed.
6. If the pressure loss over both evaluation intervals exceeds the allowable pressure drop, or if the pressure does not stabilize, then the seam fails the test.
7. If the pressure loss over either evaluation interval does not exceed the allowable pressure drop, then the seam may be deemed by the installer to have passed the test.
8. The installer must verify that the air channel tested was not obstructed by noting a release of air pressure at the end of the tested seam interval opposite the pressure gauge. If this does not happen, the air channel is blocked and the installer must take the appropriate steps to ensure that the entire seam passes a non-destructive test.

For any seam interval that fails the air pressure nondestructive test, additional nondestructive testing or visual inspection will be used to identify, if possible, the faulty area of the seam. The faulty area will be repaired and retested. If the faulty area cannot be identified, then the entire seam will be repaired and retested.

Vacuum Box Test

Vacuum box testing (ASTM D5641) is to be used on those seams made by the extrusion fillet process, to locate precisely the defects identified from air pressure testing, or to evaluate suspect seam and non-seam areas as discussed in Subsection 12.3.4.

Vacuum box testing equipment must meet the following minimum standards:

- A five-sided vacuum box with an open bottom, a clear viewing panel on top, and a pliable gasket attached to the bottom.
- A vacuum pump and gauge capable of achieving a minimum vacuum of 2 pounds psig [4 inches of mercury (Hg)] and a maximum vacuum of 5 psig.

The following procedure will be used in performing the vacuum box test:

1. Clean the seams to be tested so that they are relatively free from soil or foreign objects that might prohibit a good seal from being formed between the vacuum chamber and the geomembrane.
2. Energize the vacuum pump to a minimum of 4 inches Hg of vacuum (or approximately 2 psig).
3. Wet a strip of geomembrane approximately twice the size of the vacuum box with the soapy solution.
4. Place and center the vacuum box with the gasket in contact with the geomembrane surface over the wetted area of the seam.
5. Applying a normal force to the top of the vacuum box, close the bleed valve, and open the vacuum valve. Check to make certain that a tight seal is created between the geomembrane and the vacuum box.
6. With the vacuum drawn, use the viewing panel to examine the geomembrane seam for bubbles resulting from the flow of air through the seam.
7. Remove the vacuum box by first closing the vacuum valve and then opening the bleed valve. Proceed to Step 8 if bubbles appear in Step 6. If no bubbles appear in Step 6, then proceed directly to Step 9.
8. If bubbles appear through the geomembrane, mark the defective area for repair according to the provisions of Subsection 12.3.4. All repairs will be tested until nondestructive results are passing.
9. Move the vacuum box along the seam to be tested, overlapping the previously tested area by no less than 3 inches.

12.4.5 Destructive Seam Testing

Destructive seam testing will be performed on the geomembrane seams covered by this plan. Destructive seam testing is performed to determine the strength of the seam in both shear and peel failure modes. Destructive seam testing will be performed within 24 hours of sampling either in an on-site laboratory by personnel under the direction of the CQA officer or within 24 hours after it is received at the geosynthetics testing laboratory.

Location and Sampling Frequency

The RPR will select locations where seam samples will be cut out for the destructive testing. Test locations will be determined during seaming at the RPR's discretion. Suspicion of excess crystallinity, contamination, offset welds, or any other potential causes of an imperfect seam may prompt selection of such locations. The installer will not be informed in advance of any location where seam samples will be taken.

The minimum frequency of sample collection will be one test location per every 500 linear feet of seam length per welding apparatus, or every 1,000 linear feet if leak location testing is completed. This minimum frequency will be taken as an average for the entire installation area.

Destructive testing of the geomembrane shall be kept to side slopes when continuous seams are utilized. Patches over geomembrane destructive testing areas shall be checked with nondestructive methods.

Sampling Procedure

Samples will be cut under the direction of the RPR as the seaming progresses. For each sample location, the following information will be documented:

- Assigned sample number.
- Sample location on layout drawing.
- The reason for collecting the sample (e.g., as part of statistical testing program, suspicious seam, etc.). Record this by the sample number.
- For the peel test, which geomembrane is the top and which is the bottom with respect to seams performed using dual hot wedge (fusion) weld techniques.

Two samples for field tensiometer testing shall be at least 6 inches wide by 12 inches long with the seam centered parallel to the width. The distance between the two samples will be 42 inches measured from inside edge to inside edge. If both samples pass the field tensiometer test described below under Field Test Methods, then the sample for laboratory testing will be taken according to the procedure described below.

The sample for laboratory testing will be located between the two samples used for field-testing. Therefore, the laboratory sample will be 12 inches wide by 42 inches long with the seam centered lengthwise. The sample will be cut by the Installer into three parts and distributed as follows:

- A sample, 12 inches by 12 inches, will be kept by the installer for testing, if so desired.
- A sample, 12 inches by 12 inches, will be given to the owner for record storage.
- A sample, 12 inches by 18 inches, will be transmitted to the geosynthetics testing laboratory or on-site testing laboratory by the RPR.

The installer, in accordance with the repair procedures described in **Subsection 12.3.4,** will immediately repair all holes cut into the geomembrane resulting from destructive seam sampling. The repaired area will be nondestructively tested in accordance with the requirements of **Subsection 12.4.4.**

End-of-Seam Sampling

In addition to the 42-inch sample cut for laboratory testing, an additional sample will be cut from each end of each continuous production field seam 100 lineal feet in length or longer for field-testing as described below. These samples, often referred to as bones, need to be only 1 inch wide and can be cut from the portion of the seam that extends into/past the anchor trench so as not to require an additional repair.

Field Test Methods

The three 1-inch-wide samples described above under Sampling Procedure, as well as the end-of-seam samples described above under End-of-Seam Sampling, will be field-tested for peel and two samples tested for shear. Testing will be performed using a field tensiometer or equivalent device to qualitatively determine the mode of failure. The tensile testing machine will be equipped with electrically controlled and smoothly moving jaw separation apparatus, will be capable of adjustments and defined settings for jaw separation rate, and will display jaw separation rates and tensile loadings exerted on the geomembrane samples. Tensile testing machines will be accompanied by documentation for calibration conducted within three months of the start of geomembrane installation. Geomembrane samples will be prepared for field analyses by use of templates and cutting tools that prepare uniformly sized samples.

The seam will be considered passing if the failure in both peel and shear does not occur within the seam. If the samples fail the field tensiometer test, then the repair procedures of **Subsection 12.3.4** for the holes left by the cutout samples, and the seam reconstruction procedures for the repair of the defective seam, discussed later in this subsection, will be implemented.

Laboratory Test Methods

Laboratory testing of the destructive seam samples will be performed by the Geosynthetics Testing Laboratory or on-site testing laboratory under the direction of the CQA officer. All destructive seam tests, whether performed on a trial seam sample (as described above) or on samples cut out from productions seams, will be performed in general accordance with the methodology of ASTM D6392, which stipulates that at least five specimens will be tested in shear and five in peel. Samples will be cut in alternating order (e.g., shear & peel, peel & shear) and will also be tested in the order of cutting, to determine if any trend in seam quality along the length of the sample exists. All specimens will be cut as 1-inch-wide strips to ensure that the seam does not exceed the test gauge length of the specimen.

The following tests will be performed on each seam sample submitted for laboratory testing:

- **Shear and peel maximum tension** is the maximum load per unit width of a 1-inch-wide specimen expressed in pounds per inch of width in both the shear and peel mode, according to ASTM D6392 and GRI GM19a.

- **Shear elongation at break** is the extension at break expressed as a percentage of the initial distance between the edge of the fused track and the nearer grip. This distance should be the same on both sides of the seam and is usually 2 inches. No referenced

ASTM test exists for this procedure as defined; however, the specimen will be elongated to a maximum of 100 percent with any failures of individual specimens noted. For specimens that fail below 100 percent elongation, the value at which failure occurred will be noted on the results.

- **Peel seam separation** estimates the area of seam interface separation expressed as a percentage of the original area.

Also, for both the seam shear and peel tension test, an indication will be given for each specimen tested that defines the locus of the failure. The loci will be defined in accordance with GRI GM19a.

For shear tests, the following values will be reported for each specimen tested:

- Maximum tension in pounds per inch.
- Elongation at break indicating at what percentage the specimen failed (up to a tested maximum of 100).
- The locus of failure using the above designations.

For peel test, the following values will be reported for each specimen tested:

- Maximum tension in pounds per inch.
- Seam separation expressed as percent of original seam area.
- Locus of failure.

For each set of five specimens, the mean and standard deviation will be calculated and reported for the shear maximum tension and peel maximum tension.

Role of Testing Laboratory

The Geosynthetics Testing Laboratory or on-site testing laboratory will be responsible for performing the tests on samples submitted to them as described above. The results of tests performed will be reported to the CQA officer and the RPR. Retesting of seams, because of failure to meet any or all of the specifications listed below, can only be authorized by the CQA officer.

The geomembrane manufacturer and/or the installer may perform their own QC testing in accordance with the methods and procedures defined above under Laboratory Test Methods; however, the results, if substantially different from those obtained by the Geosynthetics Testing Laboratory or on-site laboratory, may only be used to request a retesting by the Geosynthetics Testing Laboratory or on-site testing laboratory. All quality assurance test results from the Geosynthetics Testing Laboratory or on-site laboratory govern over any test results from the geomembrane manufacturer or installer. Only the CQA officer or owner is authorized to approve a retesting request.

Procedures for Determining Destructive Seam Test Failures

The procedures described in this section apply to the destructive testing procedures defined above under Field Test Methods and Laboratory Test Methods. Procedures for repairing failed seams are given in **Subsection 12.3.4** of this plan.

The results from the shear and peel tests for the HDPE and LLDPE geomembrane will be evaluated against the criteria presented in Table 12-4.

All of the tabular criteria for each respective geomembrane type must be met for a given seam to be considered acceptable.

The installer has the following two options in determining the repair boundary whenever a seam has failed either the field tensiometer testing or laboratory destructive testing:

- The seam can be reconstructed between any two previously tested and passed destructive seam test locations.
- The installer can trace the welding path to an intermediate location (at a 10-foot minimum from the point of the failed test in each direction) and request that the field tensiometer tests be performed at these intermediate locations. If the field tensiometer sample results are acceptable, then the seam will be reconstructed between these intermediate locations. If either sample fails, then the process will be repeated until acceptable destructive seam tests have been performed in both directions away from the original failed sample location. All retesting of seams according to this procedure will use the sampling methodology described earlier in this plan under Sampling Procedure.
- The tracing of a failed seam test will continue until the seam boundary is located; tracking will continue into previous day's work, if needed.

For seams reconstructed due to a failing destructive seam sample that are in excess of 50 feet long, an additional sample taken from the reconstructed zone must pass destructive seam testing.

The RPR will be responsible for documenting all actions, including test results submitted by the Geosynthetics Testing Laboratory, taken in conjunction with seam testing. The RPR will also be responsible for keeping the CQA officer informed on seam testing results and the seaming process.

12.5 POST-INSTALLATION

Each component covered by this plan will be examined by the RPR. Any defects, whether due to failed seams, pinholes, or other penetrations, will be repaired.

Placement of the drainage layer material will proceed as soon as practical following the RPR's testing and acceptance of completed geomembrane areas. The drainage material will provide ultraviolet protection, thermal installation, and protection from physical damage.

Low ground pressure tracked equipment (<5 psi) will be used to place the drainage layer material or WisDOT Coarse Aggregate No. 2 over the geomembrane. A minimum of 1 foot of cover material is required between the geomembrane and the low ground pressure equipment. A minimum of 2 feet of cover soil is required between the geomembrane and all other tracked or flotation wheeled equipment. A minimum of 3 feet of cover soil is required between the geomembrane and all rubber-tired vehicles. To prevent movement of the geomembrane and folding of wrinkles, placement of the drainage material shall be performed during cooler temperatures to the extent possible using methods of placement, which minimize wrinkling. Any noncompliance with the above requirements will be reported by the RPR to the CQA Officer.

12.6 ELECTRIC RESISTIVITY LEAK DETECTION SURVEY

Upon completion of construction of the leachate collection system for each phase of development, an electrical resistivity leak detection survey will be performed over the entire surface of the lined area in accordance with ASTM D7007 or an equivalent method approved by the CQA officer and owner.

Leak location testing of the installed geomembrane liner shall be observed by the RPR. Leak location testing shall be conducted after the leachate drainage layer has been placed on the base grades and lower half of the sideslopes. Liner leak location tests shall be completed in accordance with ASTM D7007, "Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials." Documentation of the testing method shall include a description of the procedures and photo documentation.

12.6.1 Electric Resistivity Contractor Requirements

The electrical resistivity testing contractor shall have a minimum of five years of experience in performing electrical leak location surveys, including surveying at least 1,000,000 square feet of geomembrane using this method on at least five different projects, unless otherwise approved by the owner.

12.6.2 Test Procedure

The leak location contractor shall demonstrate in a manner acceptable to the CQA officer and owner that the leak detection equipment and field procedures are capable of detecting a 0.25-inch-diameter leak using an actual or artificial leak. The leak detection capability must be demonstrated when the leak is midway between four measurement grid points; detecting the leak when the measurement is directly over the leak will not be sufficient. The peak-to-peak signal amplitude must be at least three times the peak-to-peak signal obtained under the same conditions with the excitation signal disconnected. The leak location survey must be conducted such that the leak detection measurements are no further apart than the spacing used to demonstrate the leak detection capability.

The contractor will prepare the lined area for the leak location survey, including performing the following tasks:

- Insulating the edges of the geomembrane by leaving a width of dry exposed geomembrane around the perimeter of the geomembrane. This can be accomplished by only partially backfilling the anchor trench, leaving a strip uncovered around the perimeter, or extending the geomembrane outside the anchor trench and leaving its edge exposed.

- Isolating any other electrical paths, if present, that connect the drainage layer on the geomembrane to earth ground.

- Removing any standing water on the surface of the drainage layer covering the primary liner. The survey cannot be done if the ground is frozen or if there is ice or snow on top of the gravel.

- If necessary, wetting the area to be surveyed with water (via water truck, hoses, or other method approved by the CQA officer) in order to maintain good electrical contact with the drainage layer material during the survey.

If any leaks are indicated by the leak location survey, the contractor shall excavate the drainage layer around the area of the leak, open the geotextile, and electrically isolate the leak from the surrounding drainage material. The leak location contractor will then record measurements in the area around the excavation to determine if additional leaks are in the area. The geomembrane installer shall repair the leak, vacuum box test the repair, and repair the geotextile. The contractor will then backfill the area around the repaired leak.

The CQA officer will observe the electrical resistivity testing.

12.6.3 Reports

Upon completion of each leak survey, the electrical resistivity contractor shall submit a report to the CQA officer and the owner documenting the results of the leak location survey. The report shall document the methodology used, the locations and descriptions of the leaks, and a diagram of the facility showing the approximate leak locations.

Table 7. (12-1) Geomembrane Tests and Test Methods

Property	Test Method	Minimum Manufacturer's Testing Frequency (1)	Minimum Conformance Testing Frequency (2)
Asperity height	ASTM D7466	Every 2nd roll(3)	Not required
Carbon black content	ASTM D4218(4)	1/45,000 lb	Not required
Carbon black dispersion	ASTM D5596	1/45,000 lb	Not required
Melt flow index	ASTM D1238	1/batch	1/100,000 sf(5)
Density	ASTM D1505/D792	1/200,000 lb	1/100,000 sf(5)
Tear resistance	ASTM D1004	1/45,000 lb	Not required
Puncture resistance	ASTM D4833	1/45,000 lb	Not required
Tensile properties(6) Break stress Break elongation Yield stress (HDPE) Yield elongation (HDPE)	ASTM D6693 Type IV specimen	1/20,000 lb	1/100,000 sf (7)
Single point notched constant load (SPNCL)(8,9)	ASTM D5397	1 per every 2 resin lots	(11)
Oxidative induction time (OIT) – percent retained after 90 days(10)	ASTM D8117	1/200,000 lb	Not required
Thickness	ASTM D5994 (textured)	10 times/roll	5 places/roll
Thickness for weld edges(12)	ASTM D5199 mod. (textured)	1 per edge per roll	Not required

Notes:

1. Manufacturer to perform quality control testing at the specified frequencies (minimum) on the geomembrane rolls supplied to the project.
2. CQA officer to coordinate conformance testing at the specified frequencies (minimum) on the geomembrane rolls supplied to the project.
3. Alternate the measurement side for double-sided textured sheet.
4. Other methods such as D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.
5. In addition to the minimum frequency noted, a minimum of one test for each batch of resin used to manufacture the rolls delivered on-site must be performed, unless documentation is provided which shows the manufacturer performed testing at the same frequencies.
6. Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of five test specimens each direction.
   Yield elongation is calculated using a gauge length of 1.3 inches.
   Break elongation is calculated using a gauge length of 2.0 inches.
7. In addition to the minimum frequency noted, a minimum of one test for each batch of resin used to manufacture the rolls delivered on-site must be performed.
8. For evaluation of stress crack resistance.
9. Not tested on LLDPE products per GRI GM17.
10. Evaluate samples at 30 and 60 days to compare with 90-day response.
11. A minimum of one test for each batch of HDPE resin used to manufacture rolls delivered on-site unless documentation is provided that shows manufacturer performed testing at the same frequency.
12. For textured geomembrane with a smooth weld edge, one specimen should be taken from each edge within 6" or 150mm of the edge of the geomembrane sheet. These individual specimen values should be reported separately from the textured geomembrane sheet thickness.

Table 8. (12-2) HDPE/LLDPE Textured Geomembrane Acceptance Criteria

Property	Units	Type of Criterion	60-mil HDPE Acceptable Value(1)	40-mil LLDPE Acceptable Value(1)
Asperity height	mils	Minimum average	16	16
Carbon black content	%	Range	2.0-3.0	2.0-3.0
Carbon black dispersion	N/A	Range	Note 2	Note 2
Melt flow index	g/10 min	Maximum	1.0	1.0
Density	g/ml	Maximum (LLDPE)/Minimum average (HDPE)	0.940	0.939
Tear resistance	lb	Minimum average	42	22
Puncture resistance	lb	Minimum average	90	44
Tensile Properties (3)				
Break stress	lb/in	Minimum average	90	60
Break elongation	%	Minimum average	100	250
Yield stress	lb/in	Minimum average	126	Not applicable
Yield elongation	%	Minimum average	12	Not applicable
Thickness	mil	Minimum average	57(4)	38(5)
Thickness for weld edges (textured)	Mil	Minimum individual specimen	54	36

Notes:

1. Values for HDPE are primarily from Table 2(a) of GRI GM13 standards. Values for LLDPE are primarily from Table 2(a) of GRI GM17 standards.
2. Carbon black dispersion (only near spherical agglomerates) for ten different views: nine views in Category 1 or 2, and no more than 1 view in Category 3.
3. MD and XMD average values to be on basis of five test specimens each direction. Break elongation is calculated using gauge length of 2.0 inches. Yield elongation is calculated using a gauge length of 1.3 inches.
4. Lowest allowable individual for eight out of ten values is 54 mil. Lowest allowable individual of 10 values is 51 mil.
5. Lowest allowable individual for eight out of ten values is 36 mil. Lowest allowable individual of 10 values is 34 mil.
6. Refer to **Table 3-1** for direct shear test requirements.

Table 9. (12-3) Geomembrane Air Pressure Testing Standards and Acceptance Values

Geomembrane Type and Thickness(2)	Air Inflation Schedule		Evaluation Time (Minutes)(3)	Maximum Allowable Pressure Drop (psi)
	Minimum Pressure (psi)	Maximum Pressure (psi)		
40-mil LLDPE	20	30	2	4.0
60-mil HDPE	27	30	5	3.0

Notes:
1. All values are based on GRI Test Method GM6, revised 2017.
2. All values apply to both smooth and textured geomembrane for the type and thickness indicated.
3. Evaluation time starts after the initial 2-minute stabilization period.

Table 10. (12-4) Geomembrane Seam Tests, Test Methods, and Acceptance Criteria

Property	Test Method	Units	Type of Criterion	60-mil HDPE Acceptance Values(1)	40-mil LLDPE Acceptance Values(1)
Shear strength (2)	ASTM D6392	ppi	Minimum	120	60
Shear elongation (3)	GRI GM19a	%	Minimum	50	50
Peel strength (2) Fusion	ASTM D6392	ppi	Minimum	91	50
Peel strength (2) Extrusion	ASTM D6392	ppi	Minimum	78	44
Peel separation	GRI GM19a	%	Maximum	25	25

Notes:
1. Values are based on GRI standard specification GM19a, revised March 20, 2021. For double fusion welded seams, both tracks shall be tested for compliance with values listed. The following are unacceptable locus-of-break codes:
   Fusion: AD and AD-BRK >25%
   Extrusion: AD1, AD2 and AD-WLD
   Separation in plane (SIP) is acceptable if strength, shear elongation, and peel separation criteria are met.
2. Five out of the five test specimens must pass the locus-of-break, shear elongation, and peel separation.
3. Five out of five test specimens must meet these requirements.
4. Omit elongation measurements for field testing.

13.0 PIPING

13.1 GENERAL

This section includes quality assurance requirements for piping used throughout the facility. Piping will be used in the construction of the following items:

- Leachate collection system.
- Leachate conveyance system.
- Final cover subsurface drain collection and discharge piping.

This section is divided into three major subheadings, which cover the quality assurance requirements for pre-installation (includes piping manufacturers and fabricators), installation, and post-installation (includes the final observation and documentation of piping installations prior to installation of other materials over and around the pipe). The terms pre-installation, installation, and post-installation are applicable only to the piping installation and do not apply to the overall construction of the landfill facility.

Individual pipe sizes and standard dimension ratios (SDRs) to be used for each individual pipe installation are not detailed in this section; the construction plans and specifications will be used for the determination of correct size and wall thickness.

13.2 LEACHATE DRAINAGE PIPING

Leachate that enters the leachate drainage layer will flow to a lateral pipe in each constructed module. All leachate collection piping will consist of perforated 6-inch SDR 11 HDPE and shall be installed as recommended by the manufacturer. Each module lateral pipe will flow to a pipe placed at the bottom of the east side slope. The leachate collection piping will be sloped as shown on the drawings and will be bedded in coarse aggregate.

13.3 FINAL COVER DRAINAGE PIPING

Surface water that enters the drainage layer will flow to perforated corrugated polyethylene pipe that will be placed at the toe of the slope and at intermediate locations. The surface water collection piping will be sloped at 1 percent, and will be bedded in coarse aggregate at the final cover toe and in drainage material for intermediate drainage pipes.

13.4 PRE-INSTALLATION

13.4.1 Manufacturing

13.4.1.1 High Density Polyethylene

HDPE pipe must be made from extra high molecular weight (EHMW) polyethylene (PE) resin, and must also have a cell classification of 445574C (PE 4710) as defined by ASTM D3350.

13.4.1.2 Polyvinyl Chloride

All polyvinyl chloride (PVC) pipe fittings must be PVC molded fittings. Extruded fittings may not be used unless specifically approved in writing by the CQA officer.

13.4.1.3 Pipe Fabrication

The piping fabricator will be responsible for perforating the pipe delivered by the piping manufacturer according to the plans and specifications.

13.4.1.4 Delivery, Handling, and Storage

Pipe will be protected during shipment from excessive heat or cold, puncture, or other damaging or deleterious conditions. The pipe will be stored on-site in a manner suitable to protect it from long-term ultraviolet exposure prior to actual installation.

The RPR will be responsible throughout the pre-construction, construction, and post-construction periods for observing and documenting that the contractor provides adequate handling equipment for moving pipe and that the equipment and handling methods used do not pose any risk of damage.

The RPR will maintain a log of pipe deliveries throughout the installation. The pipe size and type, at a minimum, will be recorded on the log for each shipment received at the job site.

13.5 INSTALLATION

13.5.1 Connections

13.5.1.1 HDPE Pipe

Unless approved otherwise by the CQA officer, HDPE pipe connections will be made by the butt fusion procedure. The following procedure will be used regarding butt fusion seams:

- Seams will be made at the manufacturer's recommended temperature for fusing pipe and fittings.
- For pipe diameter sizes 4 inches (nominal) and larger, seams will be made using the hydraulic fusion machines. For pipe diameters of less than 4 inches, manual fusion equipment can be used.
- Care will be taken to make certain that adequate pressures are used for fusing pipes and that sufficient cooling periods are allowed prior to testing, bending, or backfilling of pipe sections.

Joints for corrugated pipe must be made with snap couplings.

13.5.1.2 PVC Pipe

Unless approved otherwise by the CQA officer, all PVC pipe connections will be made according to the Standard Practice for the Two-Step (Primer and Solvent Cement) Method of Joining Poly (Vinyl Chloride) (PVC) Pipe and Piping Components with Tapered Sockets with PVC pipe and fittings, ASTM D2855. Particular care will be taken regarding required set and cure times for solvent-cemented joints, which vary for ambient temperature conditions. Joints will not be subjected to stresses by moving or backfilling prior to the specified set times, ASTM D2855. Only original quality solvent cement may be used since expired shelf life and deteriorated cements may cause inadequate connections. The solvent cement shall comply with the requirements of ASTM D2564 and shall be applied in strict accordance with manufacturer's specifications.

13.5.1.3 Placement

Pipe placement will be done in accordance with the following procedure and requirements:

- Piping will be bedded and backfilled according to the plans and specifications.
- Piping placement will not be performed in the presence of excessive moisture. The RPR will document that this condition is fulfilled. Additionally, the RPR will document that the supporting backfill has not been damaged by weather conditions. The RPR will inform the

CQA officer if any of the above conditions are not fulfilled for evaluation of the necessity of corrective action.

- The prepared surface underlying the piping will not show evidence of deterioration since previous acceptance and must be acceptable prior to piping placement.
- The method used to place the piping will not cause damage to the piping and will not disturb the supporting backfill.
- The pipe bedding material will be shovel-sliced, or compacted, to the spring line of the pipe to ensure proper bedding.
- Observations and measurements will be made to ensure that the pipes are of the specified size and dimension ratio and manufactured of the specified material, and that pipe perforations are sized and spaced as specified.
- The RPR will observe and document all pipe installation. Deviations from the plans and specifications will be brought to the attention of the CQA officer for evaluation and the necessity of corrective action.
- Each piping system will be flushed with water. Jet flushing will be used wherever possible. Hydraulic flushing will be performed for other accessible points. The RPR will observe and document that each flushing operation is carried out and will document that the pipes are free flowing. Any system that does not flush properly will be immediately reported to the CQA officer, and corrective action will be taken to remedy the problem.
- All piping will be located as noted in the plans and specifications. Locations, grades, and size requirements are specified on the details of the plan set. Observations and surveying measurements will be made to ensure that the pipes are placed at the specified locations and grades. Deviations from the plans and specifications will be brought to the attention of the CQA officer for evaluation of the necessity of corrective action.
- Non-perforated pipe will be pressure tested. Gravity flow and forcemain leachate pipes shall be pressure tested at 5 psi for 60 minutes. A system pressure of 4.5 or greater after 60 minutes will be considered passing. The RPR will observe and document that this operation is carried out and that the pipes are airtight.
- A video camera inspection will be conducted on all leachate collection pipes after the pipe cleaning. The video camera inspection shall extend a minimum of 300 feet into the base grade of each collection line. The RPR will observe and document the video inspection. Any obstructions, damage, or other concerns will be immediately reported to the CQA officer for evaluation and the necessity for corrective action.

13.5.2 Damage

The RPR will examine each pipe after placement for damage. The RPR will advise the CQA officer as to which pipes will be rejected, repaired, or accepted. Damaged pipes or portions of pipes that have been rejected will be marked and removed from the installation area and documented by the RPR.

13.6 POST INSTALLATION

Pipe invert elevation will be documented every 25 linear feet by survey or every 50 feet if a total station or laser equipment is used, as well as at key points, including changes in grade, intersections, and end points. The minimum allowable tolerance for grade is 0.10 foot at each location. The minimum average slope shall be in accordance with the design drawings.

14.0 ROOTING ZONE MATERIALS

14.1 GENERAL

Rooting zone material will consist of on-site general fill.

All rooting zone material samples and survey measurements will be recorded in the daily summary reports (see **Section 4.2**) as record construction data, including locations (by coordinates) of all laboratory sample points.

14.2 PROCEDURES AND OBSERVATIONS

The RPR will observe rooting zone material placement activities and will document relevant observations to support certification of the following requirements:

- The RPR will periodically observe loads of rooting zone material for general conformance to material specifications and may randomly sample loads.

14.3 SAMPLING REQUIREMENTS AND ACCEPTANCE CRITERIA

Field sampling and laboratory testing frequencies are based on proportionate sampling of construction areas or volumes of material placed as specified by s. NR 516.06. This section describes the required analyses, methods, sampling frequencies, and acceptance limits.

No field testing will be required for rooting zone material; however, as stated in **Section 14.2**, the RPR will perform visual inspection of this material for conformance to material specifications and may randomly sample deliveries.

14.4 THICKNESS DOCUMENTATION

The finished elevation of the rooting zone material layer will be surveyed on a 50-foot grid (or 100-foot grid if more than 4 acres), which coincides with the grid used for the clay cover surface. The minimum acceptable thickness will be 1.0 foot (+0.1 foot tolerance). The contractor may use a GPS dozer and hand held GPS station to document thickness, if approved by the owner and CQA officer.

15.0 TOPSOIL AND SEEDING

This section includes the CQA requirements for placing topsoil and fertilizing, seeding, mulching, and watering topsoil for vegetation. Topsoil will be obtained from on-site topsoil stockpiles.

All survey measurements will be recorded in the daily summary reports (see **Section 4.2**) as record construction data.

15.1 PROCEDURES AND OBSERVATION

The RPR will observe topsoil placement activities and will document relevant observations to support certification of the following requirements:

- The RPR will confirm the source and uniformity of topsoil used. Soil excavation and placement will be monitored for minimization of inorganic soil not compatible for establishment of vegetation.
- Prior to seeding, the topsoil will be worked to prepare a suitable seedbed.
- Fertilizing, seeding, and mulching will be performed in a timely manner.

15.2 ACCEPTANCE CRITERIA

The topsoil will be suitable for establishment and long-term maintenance of the selected vegetation seed mix with appropriate fertilization.

The following seed mix from WisDOT specification Section 630 "Seeding," Right of Way Permanent Seed Mixture No. 20 shall be used:

- Six percent Kentucky Bluegrass.
- Fifteen percent Red Fescue.
- Twenty-four percent Hard Fescue.
- Forty percent Tall Fescue.
- Fifteen percent Perennial Rye Grass.

The seeding rate will be 5 pounds per 1,000 square feet.

15.3 THICKNESS DOCUMENTATION

The thickness of topsoil placement on the final cover will be documented on a 50-foot grid (or 100-foot grid for areas greater than 4 acres). Thickness will be determined by surveying or other acceptable method approved by the owner. The minimum acceptable topsoil thickness for the final cover will be 0.5 foot (+0.1 foot tolerance). The minimum acceptable thickness for all other areas will be 4 inches.

16.0 CONTACT WATER SWALE CONVERSION

16.1 GENERAL

This section includes the testing requirements to evaluate the condition of the existing compacted select clay fill liner below the geomembrane in the existing contact water swale.

16.2 PROCEDURES AND OBSERVATION

The RPR will observe, test, and sample the existing swale liner compacted select clay fill and will document relevant observations to support certification of the following requirements:

- The RPR will select three locations along the swale liner to evaluate the condition of the select clay fill liner. Refer to **Figure 1** for proposed locations.

- The RPR will also select additional locations at a 100-foot spacing along the swale to perform borings as described in Section 5.1 and shown on Figure 1. Each boring will extend to a depth of 9 feet to confirm the soil type to a depth 5 feet below the bottom of the clay liner. An RPR will observe and record the soil type below the clay liner.

- The construction contractor will remove the aggregate at the test and boring locations, and cut a flap through the geotextile and geomembrane at each location. Alternatively, each layer of the geosynthetics will be removed in their entirety dependent on construction schedule.

- The RPR will observe and photograph the surface of the compacted select clay fill liner at three locations and will measure field density and moisture content at the surface of the liner, using methods described in Section 16.3 (Sampling Requirements and Acceptance Criteria), to assess the percent compaction of the existing select clay fill.

- With assistance from the contractor, the RPR will obtain an approximate 2-foot-long Shelby tube sample of the upper select clay fill liner at each of the three locations.

- Voids created by NDG probes, Shelby tubes, and boreholes will be backfilled with granular bentonite.

- The geomembrane will be repaired and tested (if remaining) in accordance with Section 12.

16.3 SAMPLING REQUIREMENTS AND ACCEPTANCE CRITERIA

This section describes the required analyses, methods, sample frequencies, and acceptance limits. The RPR will perform field tests and will collect soil samples for laboratory analysis.

16.3.1 Field Testing

The following field testing methods will be used by the RPR during the existing select clay fill liner evaluation:

Parameter	Method
Moisture content and soil density	ASTM D6938

Field density and moisture content tests will be performed at the select clay fill liner surface at each of three locations along the swale liner.

16.3.2 Field Testing Acceptance Criteria

Acceptance criteria for field density will require soil compaction to a minimum of 90 percent of the Modified Proctor (ASTM D1557) maximum dry density, or a minimum of 95 percent of the Standard Proctor (ASTM D698) maximum dry density. Moisture content requirements will be at least 2 percent wet of optimum if using the Modified Proctor, and at least wet of optimum if using the Standard Proctor, in accordance with s. NR 504.06(2)(f)(3). The acceptable range will be based on Proctor moisture-density relationships and compaction versus permeability relationships previously obtained for the existing select clay fill.

16.3.3 Laboratory Testing

Laboratory testing of the clay liner will be performed on Shelby tube samples collected by the RPR.

16.3.4 Undisturbed Sampling Analysis

One undisturbed Shelby tube sample will be taken at each of three locations and will be submitted to the Soils Testing Laboratory.

The following analyses will be performed on each undisturbed sample obtained at depths of 0 to 1 foot below the liner surface and 1 to 2 feet below the liner surface (two tests per Shelby tube):

Parameter	Test Method[a]
Hydraulic conductivity	ASTM D5084 or SW 846 EPA Method 9100

Notes:
(a) Using effective stresses no greater than 5 psi and hydraulic gradients of 30 or less.

16.3.5 Laboratory Testing Acceptance Criteria

A saturated hydraulic conductivity of 1 x 10^{-7} cm/s or less, when compacted to 90 percent Modified or 95 percent Standard Proctor density or greater at a minimum moisture content 2 percent wet of optimum.

16.4 SELECT CLAY FILL LINER REPAIR

If the field or laboratory test results do not meet the acceptance criteria, the select clay fill liner will be repaired. The repair procedures will include:

16.4.1 Full Liner Repair

- Overexcavate, rework and compact the select clay fill liner to a depth of 4 feet below the base grade.
- Compaction and testing procedures will be in accordance with **Sections 7.2, 7.3.1, 7.3.2, 7.3.4,** and **7.3.6.**
- The liner repair will be acceptable when the field and laboratory test results listed in **Section 16.3** (Sampling Requirements and Acceptance Criteria) meet the acceptance criteria.
- Document select clay fill liner thickness and base grades in accordance with **Section 7.4.** Minimum clay liner thickness will be 4 feet (+0.1 foot tolerance) measured vertically.
- Install, test and document the geomembrane liner in accordance with **Section 12.**

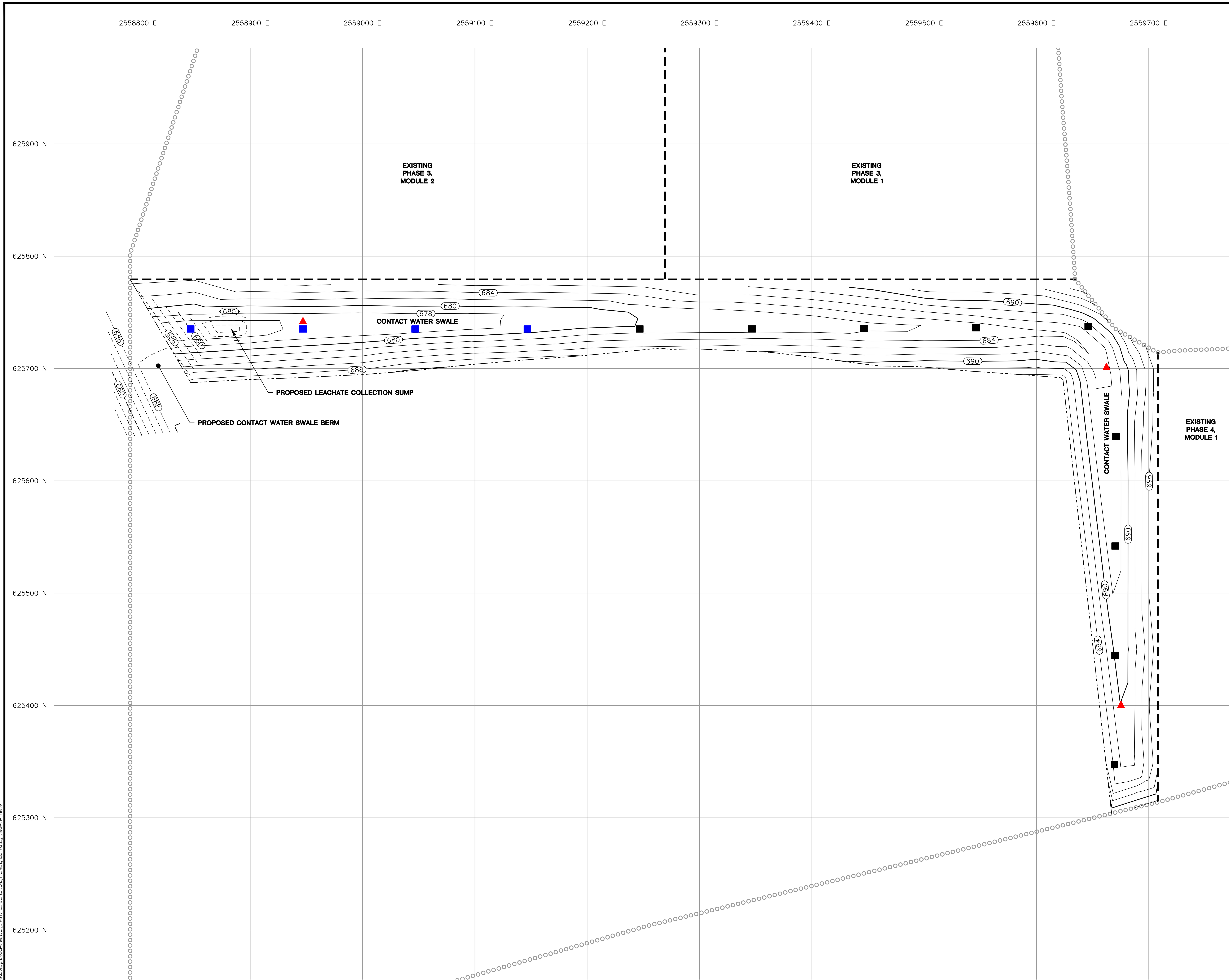
16.4.2 Liner Repair and GCL Installation

- Overexcavate, rework and compact the select clay fill liner to a depth of 2 feet below the base grade.

- Compaction and testing procedures will be in accordance with **Sections 7.2, 7.3.1, 7.3.2, 7.3.4,** and **7.3.6**.
- The liner repair will be acceptable when the field and laboratory test results listed in **Section 16.3** (Sampling Requirements and Acceptance Criteria) meet the acceptance criteria.
- Document select clay fill liner thickness and base grades in accordance with **Section 7.4.**
- Install and document the GCL in accordance with the liner requirements in **Section 11.**
- Install, test and document the geomembrane liner in accordance with **Section 12.**

Figure 1

Existing Clay Liner Testing



LEGEND

- APPROVED LIMITS OF WASTE
- APPROVED MODULE LIMITS
- PROPOSED ASH LIMITS
- PROPOSED GRADE (2' CONTOUR)
- PROPOSED GRADE (10' CONTOUR)
- EXISTING BASE GRADE (2' CONTOUR)
- EXISTING BASE GRADE (10' CONTOUR)
- PROPOSED CLAY LINER SHELBY TUBE TESTING LOCATION
- PROPOSED SUBSOILS TESTING LOCATION
- 2014 SUBSOILS TESTING LOCATION

NOTES:

1. EXISTING BASE GRADES REPRESENT TOP OF EXISTING 4-FOOT CLAY LINER.
2. PROPOSED GRADES REPRESENT TOP OF CLAY FOR CONTACT WATER SWALE SUMP AND BERM (BASE GRADES).

PROJECT NO.	25224280.00	DRAWN BY:	SB/RVG
DRAWN:	02/24/2025	CHECKED BY:	PEG
REVISED:	03/18/2025	APPROVED BY:	

WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

ENGINEER

CONTACT WATER SWALE CONVERSION CONSTRUCTION
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

SITE

CONTACT WATER SWALE MODULE CONSTRUCTION – EXISTING CLAY LINER TESTING

FIGURE
1

Appendix B

Geotechnical Calculations

EVALUATION:

Evaluate the landfill liner side slope drainage layer for static veneer slope stability.

The side slope on the Phase 4, Module 2 base runs at a 3:1 slope for a maximum 64 feet (conservative, longest slope)

The following calculations evaluate the static veneer slope stability of the 3:1 slope.

REFERENCES:

1.) Koerner, Robert M. & Te-Yang Soong, Analysis and Design of Veneer Cover Soils, Geosynthetic Research Institute.

2.) U.S. Department of Transportation - Federal Highway Administration Recycled Materials, Coal Bottom Ash User's Guide

EQUATIONS:

$FS = (-b+(b^2-4*a*c)^{1/2})/(2*a)$

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

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

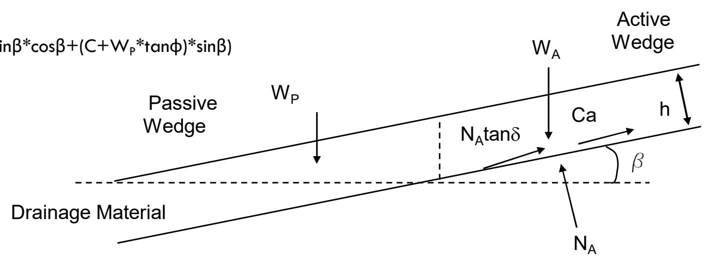
$c = (N_A*\tan\delta+C_a)*(\sin\beta)^2*\tan\phi$

$N_A = W_A*\cos\beta$

$W_A = \gamma*h^2*(L/h-1/\sin\beta-\tan\beta/2)$

$W_P = (\gamma*h^2)/\sin 2\beta$

$C_a = c_a(L-h/\sin\beta)$



DEFINITIONS OF VARIABLES:

FS = Factor of Safety

a, b, & c = intermediate variables (= calculated variable)

N_A = Effective force normal to the failure plane of the active wedge (= calculated variable)

W_A = Total weight of active wedge (= calculated variable)

W_P = Total weight of passive wedge (= calculated variable)

β = Soil slope angle beneath the geomembrane (= 18.42 degrees or 0.322 radians based on liner slope of 3 to 1)

ϕ = Friction angle of the drainage layer material (= 32 degrees, 0.559 radians based on typical values for sand)

δ = Interface friction angle for liner system geosynthetics (to be determined)

c_a = Adhesion for liner system geosynthetics at active wedge (to be determined)

γ = Unit weight of the drainage layer material (= 125 pcf based on conservative wet density of drainage material).

C = Cohesive force along the failure plane of the passive wedge (assumed 0 for drainage layer material)

C_a = Adhesive force of the active wedge for the liner system geosynthetics

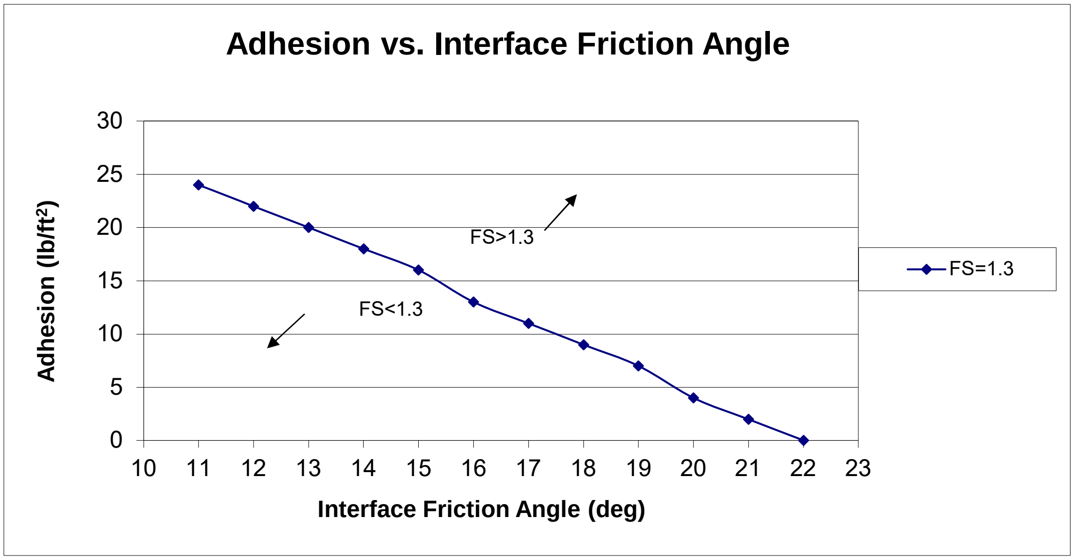
h = Thickness of the drainage layer material(= 1.0 foot based on base design)

L = Length of slope measured along the geomembrane (= 64 feet based on base design)

CALCULATIONS:

To determine the minimum adhesion necessary for a range of interface friction angles to reach a FS of 1.3 or greater.

δ		c_a	W_A	W_P	N_A	C_a	a	b	c	FS
(deg)	(rad)	(lb/ft^2)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	
11	0.192	24	7,584	208	7,195	1,460	718	-1,048	178	**1.3**
12	0.209	22	7,584	208	7,195	1,338	718	-1,050	179	**1.3**
13	0.227	20	7,584	208	7,195	1,217	718	-1,053	180	**1.3**
14	0.244	18	7,584	208	7,195	1,095	718	-1,057	180	**1.3**
15	0.262	16	7,584	208	7,195	973	718	-1,061	181	**1.3**
16	0.279	13	7,584	208	7,195	791	718	-1,046	178	**1.3**
17	0.297	11	7,584	208	7,195	669	718	-1,051	179	**1.3**
18	0.314	9	7,584	208	7,195	548	718	-1,056	180	**1.3**
19	0.332	7	7,584	208	7,195	426	718	-1,061	181	**1.3**
20	0.349	4	7,584	208	7,195	243	718	-1,049	179	**1.3**
21	0.367	2	7,584	208	7,195	122	718	-1,055	180	**1.3**
22	0.384	0	7,584	208	7,195	0	718	-1,062	181	**1.3**



CONCLUSION:

The landfill liner side slope drainage layer was evaluated for static veneer slope stability along its longest slope. Drainage layer material is assumed to be sand; if an alternative material is used this calculation will need to be re-evaluated. Calculations were performed to determine the minimum adhesion necessary for a range of interface friction angles to reach a FS of 1.3 or greater. Each interface friction angle and the coinciding adhesion was graphed in order to easily determine if a material interface is acceptable along the side slope.

Purpose: Determine the maximum shear stress acting on a Geosynthetic Clay Liner (GCL) and the GCL internal shear strength required to provide a minimum slope stability safety factor (FS) of 1.5 for the liner system.

Approach: Use maximum shear stress formula and assumed values.

References: Design of GCL Barrier for Final Cover Side Slope Applications, Gregory N. Richardson, Ph.D., P.E., Geosynthetics '97-541

Calculation: The maximum shear stress acting on the GCL can be calculated as follows:

$$\tau_{act} = W_T \sin\beta$$

$$\beta = 18.4^\circ$$

$$W_T = \gamma \times h$$

Where:

γ	=	Sand Unit Weight	=	125	pcf
h	=	Drainage Layer Thickness	=	1	ft

$$W_T = 125 \text{ psf}$$

$$\tau_{act} = 39.5 \text{ psf}$$

$$FS = \frac{\tau_{resist}}{\tau_{act}} = 1.5$$

$$\tau_{resist} = FS \times \tau_{act} = 1.5 \times 39.5 = 59 \text{ psf}$$

Assumptions: Slope angle, $\beta = 18.4^\circ$ (3:1 horizontal / vertical liner side slope

Sand unit weight, $\gamma = 125$ pcf

Conclusion: For a total weight of the leachate drainage layer of 125 psf and a slope angle of 3:1, the maximum shear stress will be 39.46 psf. A minimum GCL internal shear strength of 59.19 psf is required to provide a slope stability safety factor of 1.5.

SCS ENGINEERS

		Calc. No.	
		Rev. No.	
Job No. 252222259.00	Job: I-43 Plan Modification	By: RAR	Date: 11/21/2024
Client: Wisconsin Power & Light Company	Subject: Geomembrane Puncture Analysis - Drainage Blanket	Chk'd: DLN	Date: 11/22/2024

Purpose: Perform a puncture analysis on the geomembrane to determine the maximum typical particle diameter requirement for a 12 oz geotextile beneath a gravel drainage blanket.

Approach: Use the GRI-Method (Koerner 2008). Evaluate minimum geotextile mass per unit area that will control the design.

References: Modification to the "GRI-Method" for the RF_{CR}-Factor used in the Design of Geotextiles for Puncture Protection of Geomembranes; Robert M. Koerner, Ph.D, P.E., NAE; November 28, 2008, GRI White Paper #14.

Calculation: The following geomembrane puncture analysis was completed to show which factors control the recommended geotextile mass per unit area.

$$FS = \frac{P_{allow}}{P_{act}} \qquad (1)$$

where:

FS = factor of safety

P_{act} = actual pressure due to the applied normal stress, e.g., landfill contents

P_{allow} = allowable pressure using different types of geotextiles and site-specific conditions

$$P_{allow} = \left(50 + 0.00045\frac{M}{H^2}\right)\left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CBD} \times RF_{CR}}\right] \qquad (2)$$

where:

P_{allow} = allowable pressure (kPa)

M = geotextile mass per unit area (g/m^2)

H = protrusion height (m) (assumed to be equal to the typical particle diameter)

MF_S = modification factor for protrusion shape

MF_{PD} = modification factor for packing density

MF_A = modification factor for arching in solids

RF_{CBD} = reduction factor for long-term chemical/biological degradation, and

RF_{CR} = reduction factor for long-term creep

Assumptions:

H =	12 mm (1/2 inch)	= 0.012 m
MF_S =	Subrounded	= 0.5
MF_{PD} =	Dense, 12mm (1/2 inch)	= 0.5
MF_A =	Geostatic, deep	= 0.25
RF_{CBD} =	Mild leachate	= 1.1
RF_{CR} =	12mm (1/2 inch) @ geotextile mass per unit area (gm/m^2) of 406	= 1.8

Estimated for long-term results of 1.3 for 32 oz/SY and 1.6 for 16 oz/SY in white paper #14, Table 3 (See attached graph).

Job No. 25222259.00	Job: I-43 Plan Modification	By: RAR	Date: 11/21/2024
Client: Wisconsin Power & Light Company	Subject: Geomembrane Puncture Analysis - Drainage Blanket	Chk'd: DLN	Date: 11/22/2024

Calculation: Calculate allowable waste fill height using a factor of safety of 3.0 Due to creep effects, a minimum geotextile mass per unit area of 406 g/m^2 will control the design.

$$FS = \frac{P_{allow}}{P_{act}}$$

Assumptions:

Ash Density = 110.0 pcf = 17.3 kN/m^3

Peak Height of Waste = 58.0 ft = 17.7 meters

Calculation:

P_{act} = *solid waste density X peak height of waste*

$$P_{allow} = (FS)(P_{act}) = 3 \times P_{act}$$

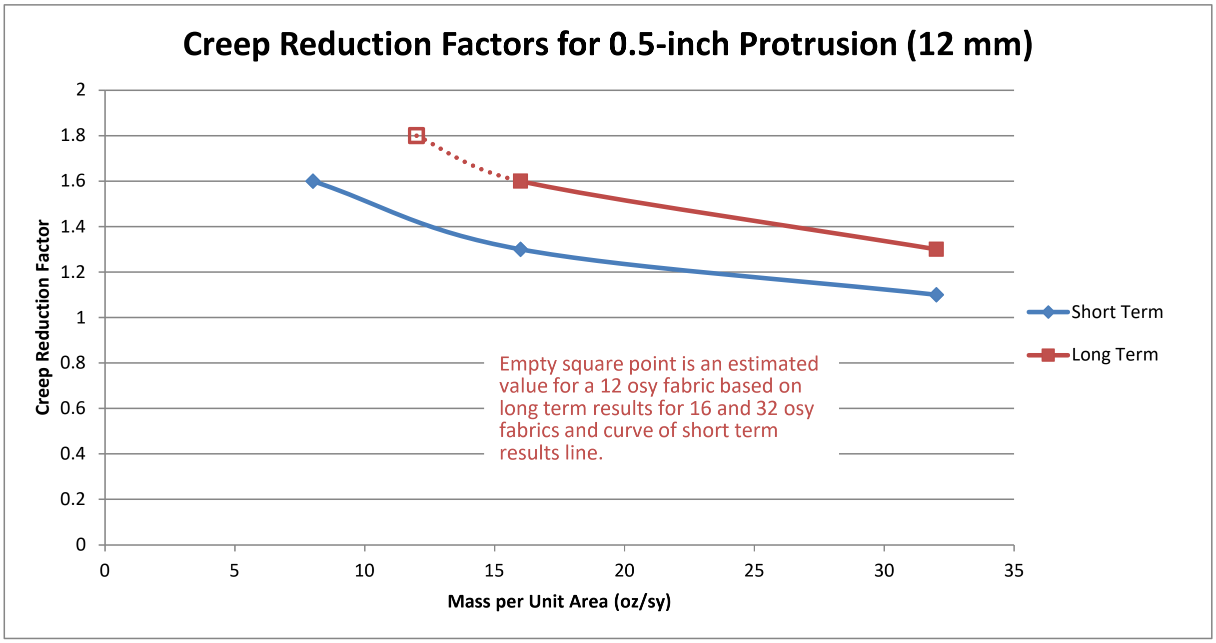
$$P_{allow} = \left(50 + 0.00045 \frac{M}{H^2}\right)\left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CBD} \times RF_{CR}}\right]$$

P_{act} (kPa)	FS	P_{allow} (kPa)	M (g/m2)	Recommendation	Max. Allowable Fill Height (feet)
3552	3	10657	406	See Below	674

Available geotextile cushions include:

M (g/m^2)	M (oz/yd^2)
406	12
542	16
675	20
812	24
950	28
1,080	32

Conclusions: Due to creep effects, a minimum required geotextile mass per unit area of 406 g/m^2 controls the design. Based on the puncture analysis, a 12 oz/yd^2 geotextile will be acceptable for use below a gravel drainage blanket. The maximum allowable fill height is 674 feet which is higher than the maximum design height of 58 feet.



Creep Reduction Factors for 0.5-inch Protrusion (12 mm)
Creep Reduction Factor
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
Mass per Unit Area (oz/sy)
Short Term
Long Term
Empty square point is an estimated value for a 12 osy fabric based on long term results for 16 and 32 osy fabrics and curve of short term results line.

Purpose: Perform a puncture analysis on the geomembrane to determine the geotextile cushion requirements for the geotextile beneath the leachate collection pipe bedding.

Approach: Use the GRI-Method (Koerner 2008). Evaluate minimum geotextile mass per unit area that will control the design.

References: Modification to the "GRI-Method" for the RF_{CR}-Factor used in the Design of Geotextiles for Puncture Protection of Geomembranes; Robert M. Koerner, Ph.D, P.E., NAE; November 28, 2008, GRI White Paper #14.

Calculation: The following geomembrane puncture analysis was completed to show which factors control the recommended geotextile mass per unit area.

$$FS = \frac{P_{allow}}{P_{act}} \qquad (1)$$

where:

FS = factor of safety

P_{act} = actual pressure due to the applied normal stress, e.g., landfill contents

P_{allow} = allowable pressure using different types of geotextiles and site-specific conditions

$$P_{allow} = \left(50 + 0.00045\frac{M}{H^2}\right)\left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CBD} \times RF_{CR}}\right] \qquad (2)$$

where:

P_{allow} = allowable pressure (kPa)

M = geotextile mass per unit area (g/m^2)

H = protrusion height (m) (assumed to be equal to the typical particle diameter)

MF_S = modification factor for protrusion shape

MF_{PD} = modification factor for packing density

MF_A = modification factor for arching in solids

RF_{CBD} = reduction factor for long-term chemical/biological degradation, and

RF_{CR} = reduction factor for long-term creep

Assumptions:

H =	25 mm (1inch)	=	0.025 m
MF_S =	Subrounded	=	0.5
MF_{PD} =	Dense, 25mm (1inch)	=	0.67
MF_A =	Geostatic, deep	=	0.25
RF_{CBD} =	Mild leachate	=	1.1
RF_{CR} =	25mm (1inch) @ geotextile mass per unit area (gm/m^2) of 1100	=	1.5

Calculation: Calculate allowable waste fill height using a factor of safety of 3.0 Due to creep effects, a minimum geotextile mass per unit area of 1,100 g/m^2 will control the design.

$$FS = \frac{P_{allow}}{P_{act}}$$

Assumptions:

Ash Density = 110.0 pcf = 17.3 kN/m^3

Peak Height of Waste = 58.0 ft = 17.7 meters

Calculation:

P_{act} = *solid waste density X peak height of waste*

$$P_{allow} = (FS)(P_{act}) = 3 \times P_{act}$$

$$P_{allow} = \left(50 + 0.00045 \frac{M}{H^2}\right)\left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CBD} \times RF_{CR}}\right]$$

P_{act} (kPa)	FS	P_{allow} (kPa)	M (g/m2)	Recommendation	Max. Allowable Fill Height (feet)
2031	3	6093	1100	See Below	385

Available geotextile cushions include:

M (g/m^2)	M (oz/yd^2)
406	12
542	16
675	20
812	24
950	28
1,080	32

Conclusions: Due to creep effects, the minimum required geotextile mass per unit area of 1,100 g/m^2 controls the design. Based on the puncture analysis, 3 layers of a 12 oz/yd^2 geotextile, 2 layers of a 16 oz/yd^2 geotextile, or a 32 oz/yd^2 geotextile will be acceptable for use below the leachate pipe bedding. The maximum allowable fill height is 385 feet which is higher than the maximum design height of 58 feet.

Purpose: To evaluate the pipe strength of 6-in. dia., SDR 11 HDPE leachate collection piping in the base system of the Edgewater I-43 Dry Ash Disposal Facility Phase 4, Module 2 using designed properties and parameters.

Approach: Use referenced formulas to determine the maximum height waste can be placed above the leachate piping and the specific physical pipe properties necessary to perform adequately.

References:

1. Plastics Pipe Institute, 2nd Edition Handbook of PE Pipe, Buried PE Pipe Design (Attachment 1)
2. ISCO Industries, Typical Physical Properties and Dimension Charts, www.isco-pipe.com (Attachment 2)
3. "Soil Reaction for Buried Flexible Pipe", Amster K. Howard, U.S. Bureau of Reclamation
4. Plan of Operation, Metro Landfill Western Expansion, Appendix F - "Report on Metro Landfill - Pipe Design", Watkins, 1989
5. U.S. Department of Transportation, Federal Highway Administration, Recycled Materials, Coal Ash User's Guide
6. "HDPE Leachate Collection Pipe Design by Fundamentals of Mechanics", Harrison and Watkins, 1996, Nineteenth International Madison Waste Conference.
7. SCS Engineers, Plan Modification Addendum No. 2, Edgewater Generating Station, "Revised Phase 4, Module 2 -- Base Grades and Leachate Collection System" and "Revised Phase 4, Module 2 -- Final Cover Grades" Plan Sheets, November 2024.

Assumptions:

1. Waste above the piping is assumed to be wet.
2. Wet waste unit weight is a conservative 110 pcf from research and typical project experience values.
3. Live loads are negligible above the piping. The maximum fill height over an 6-in SDR 11 HDPE pipe will be 58 feet for the current design.
4. Leachate collection pipes will be 6-in., SDR 11 HDPE in Module 2.
5. Allowable compressive stress for HDPE pipe is 1,000 psi (Plastic Pipe Institute, Attachment 1).

Calculations: **Pipe Loading, P_y**

$$P_y = DL + LL$$

where,
P_y = Pipe Load, lb/in²
DL = Dead Load, lb/in²
LL = Live Load, lb/in²

Dead Load, *DL*

$$DL = \frac{\gamma \cdot H}{144}$$

where,				
γ	= Fill Unit Weight, lb/ft³	=	**110**	(waste unit weight)
H	= Height of cover, ft	=	**58**	(max. waste height)
DL	= Dead Load, lb/in²	=	**44**	

In our case the live load = 0, due to limited live loads above the piping after placement.

So, P_y = DL = **44** lb/in²

Assuming 6 inch SDR 11 HDPE for leachate collection piping

Outer Diameter of Pipe (OD) = **6.625** **in.** (From Attachment 2)
Min. Pipe wall thickness (t) = **0.602** **in.** (From Attachment 2)

Calculations: **Deflection**

(cont.) A deflection of 5 to 7.5% has become the standard for limiting deflection in flexible pipes. Based on Figure 7.16 in Uni-Bell (1991) and Watkins (1989) a vertical strain of greater than 5% will never be reached for flexible pipe bedded in compacted gravel, independent of vertical soil pressure. At 90% compaction the vertical strain will always be less than 2%. The height of fill over the pipe is not a factor when the pipe is well bedded in gravel. These findings are consistent for HDPE piping with the Harrison and Watkins (1996) paper.

Wall Crushing

where,
σ = Compressive Stress, lb/in²
T = Wall Thrust, lb/in
A = Area of Pipe Wall, in²/in

$$\sigma = \frac{T}{A}$$

Wall Thrust, T

$$T = \frac{P_y \cdot D_o}{2}$$

SDR 11 HDPE Piping

where,	P_y	=	Vertical Fill Pressure lb/in^2	=	**44**	(Previously Calculated)
	D_0	=	Outside Diameter, in	=	**6.625**	(SDR 11, 6-inch)
	T	=	Wall Thrust, lb/in	=	**147**	
	A	=	Area of Pipe Wall, in^2/in	=	**0.602**	(Solid=Thickness)

So, σ = Compressive Stress, lb/in² = **244**

Result: The allowable compressive strength of HDPE pipe is approximately 1,000 psi, so the calculated compressive stress values are acceptable and wall crushing of the pipe will be avoided when the pipe is at least SDR 11, 6-inch diameter for the leachate collection pipe.

Leachate Collection Piping Maximum Height - SDR 11 HDPE

For	P_y	=	Vertical Fill Pressure lb/in^2	=	**182**	
	D_0	=	Outside Diameter, in	=	**6.625**	(SDR 11, 6-inch)
	T	=	Wall Thrust, lb/in	=	**602**	
	A	=	Area of Pipe Wall, in^2/in	=	**0.602**	(Solid=Thickness)

So, σ = Compressive Stress, lb/in² = **1,000**

Maximum Height (feet) = Py*(144)/ɣ = **238**

Result: The maximum height of fill above the 6-inch SDR 11 HDPE piping is 238 feet for a fill unit weight of 110 lb/ft^3 to maintain the required minimum factor of safety against wall crushing. Wall crushing controls the maximum fill height that can be placed above the leachate collection pipes. The maximum fill height above the 6-inch diameter piping when Module 2 is filled will be approximately 58 feet, which is lower than the maximum allowable fill height.

Attachment 1

From the Handbook of PE Pipe 2008, Second Edition by the Plastics Pipe Institute

TABLE C.1

Allowable Compressive Stress for 73°F (23°C)

	Pe Pipe Material Designation Code (1)					
	PE 2406		PE3408		PE 4710	
	PE 2708		PE 3608			
			PE 3708			
			PE 3710			
			PE 4708			
	psi	MPa	psi	MPa	psi	MPa
Allowable Compressive Stress	800	5.52	1000	6.90	1150	7.93

(1) See Chapter 5 for an explanation of the PE Pipe Material Designation Code.

Attachment 2

From the ISCO Technical Library (Nov. 21, 2024)

PE4710 HDPE IPS Pipe Sizes

IPS and Large Diameter Metric HDPE Pipe Size Chart

DR		7			7.3			9			11			13.5			15.5		
PE4710 Pressure Rating		333 psi			317 psi			250 psi			200 psi			160 psi			138 psi		
Nom. OD	Actual OD(in)	Min Wall(in)	Avg ID (in)	Weight (lb/ft)	Min Wall(in)	Avg ID (in)	Weight (lb/ft)	Min Wall(in)	Avg ID (in)	Weight (lb/ft)	Min Wall(in)	Avg ID (in)	Weight (lb/ft)	Min Wall(in)	Avg ID (in)	Weight (lb/ft)	Min Wall(in)	Avg ID (in)	Weight (lb/ft)
3/4"	1.05	0.150	0.732	0.186	0.144	0.745	0.180	0.117	0.803	0.150	0.095	0.848	0.126	--	--	--	--	--	--
1"	1.315	0.188	0.917	0.292	0.180	0.933	0.282	0.146	1.005	0.235	0.120	1.062	0.197	--	--	--	--	--	--
1-1/4"	1.66	0.237	1.157	0.465	0.227	1.178	0.449	0.184	1.269	0.375	0.151	1.340	0.314	--	--	--	--	--	--
1-1/2"	1.9	0.271	1.325	0.609	0.260	1.348	0.588	0.211	1.452	0.492	0.173	1.534	0.411	--	--	--	--	--	--
2"	2.375	0.339	1.656	0.952	0.325	1.685	0.919	0.264	1.816	0.768	0.216	1.917	0.643	0.176	2.002	0.533	0.153	2.050	0.469
3"	3.5	0.500	2.440	2.068	0.479	2.484	1.997	0.389	2.676	1.668	0.318	2.825	1.396	0.259	2.950	1.158	0.226	3.021	1.019
4"	4.5	0.643	3.137	3.419	0.616	3.193	3.301	0.500	3.440	2.757	0.409	3.633	2.307	0.333	3.793	1.915	0.290	3.885	1.685
5"	5.563	0.795	3.878	5.225	0.762	3.947	5.044	0.618	4.253	4.214	0.506	4.491	3.526	0.412	4.689	2.926	0.359	4.802	2.575
6"	6.625	0.946	4.619	7.410	0.908	4.701	7.154	0.736	5.064	5.977	0.602	5.348	5.001	0.491	5.585	4.150	0.427	5.719	3.652
8"	8.625	1.232	6.013	12.559	1.182	6.120	12.125	0.958	6.593	10.130	0.784	6.963	8.476	0.639	7.271	7.035	0.556	7.445	6.190
10"	10.75	1.536	7.494	19.509	1.473	7.628	18.836	1.194	8.218	15.736	0.977	8.678	13.168	0.796	9.062	10.928	0.694	9.280	9.616
12"	12.75	1.821	8.889	27.444	1.747	9.047	26.497	1.417	9.747	22.136	1.159	10.293	18.523	0.944	10.748	15.372	0.823	11.006	13.527
14"	14	2.000	9.760	33.089	1.918	9.934	31.947	1.556	10.702	26.689	1.273	11.302	22.333	1.037	11.801	18.534	0.903	12.085	16.309
16"	16	2.286	11.154	43.218	2.192	11.353	41.726	1.778	12.231	34.859	1.455	12.916	29.169	1.185	13.487	24.208	1.032	13.812	21.302
18"	18	2.571	12.549	54.698	2.466	12.773	52.810	2.000	13.760	44.119	1.636	14.531	36.918	1.333	15.173	30.638	1.161	15.538	26.960
20"	20	2.857	13.943	67.529	2.740	14.192	65.197	2.222	15.289	54.468	1.818	16.145	45.577	1.481	16.859	37.825	1.290	17.265	33.284
22"	22	3.143	15.337	81.710	3.014	15.611	78.889	2.444	16.818	65.906	2.000	17.760	55.148	1.630	18.545	45.768	1.419	18.991	40.274
24"	24	3.429	16.731	97.241	3.288	17.030	93.884	2.667	18.347	78.433	2.182	19.375	65.631	1.778	20.231	54.468	1.548	20.717	47.929
26"	26	3.714	18.126	114.124	3.562	18.449	110.183	2.889	19.876	92.050	2.364	20.989	77.026	1.926	21.917	63.924	1.677	22.444	56.250
28"	28	4.000	19.520	132.356	3.836	19.868	127.786	3.111	21.404	106.757	2.545	22.604	89.331	2.074	23.603	74.137	1.806	24.170	65.237
30"	30	--	--	--	--	--	--	3.333	22.933	122.552	2.727	24.218	102.549	2.222	25.289	85.106	1.935	25.897	74.889
32"	32	--	--	--	--	--	--	3.556	24.462	139.437	2.909	25.833	116.678	2.370	26.975	96.831	2.065	27.623	85.208
34"	34	--	--	--	--	--	--	3.778	25.991	157.411	3.091	27.447	131.718	2.519	28.661	109.314	2.194	29.350	96.191
36"	36	--	--	--	--	--	--	4.000	27.520	176.475	3.273	29.062	147.670	2.667	30.347	122.552	2.323	31.076	107.841
42"	42	--	--	--	--	--	--	--	--	--	3.818	33.905	200.996	3.111	35.404	166.807	2.710	36.255	146.783
48"	48	--	--	--	--	--	--	--	--	--	4.364	38.749	262.525	3.556	40.462	217.871	3.097	41.435	191.717
54"	54	--	--	--	--	--	--	--	--	--	4.909	43.593	332.258	4.000	45.520	275.742	3.484	46.614	242.642
1600mm/63"	62.990	--	--	--	--	--	--	--	--	--	--	--	--	4.667	53.107	390.580	4.065	54.383	340.150
65"	65.000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Purpose: To evaluate the pipe strength of 18-in. dia., SDR 17 HDPE sump riser piping in the base system of the Edgewater I-43 Dry Ash Disposal Facility Phase 4, Module 2 using designed properties and parameters.

Approach: Use referenced formulas to determine the maximum height waste can be placed above the sump riser piping and the specific physical pipe properties necessary to perform adequately.

References:

1. Plastics Pipe Institute, 2nd Edition Handbook of PE Pipe, Buried PE Pipe Design (Attachment 1)
2. ISCO Industries, Typical Physical Properties and Dimension Charts, www.isco-pipe.com (Attachment 2)
3. "Soil Reaction for Buried Flexible Pipe", Amster K. Howard, U.S. Bureau of Reclamation
4. Plan of Operation, Metro Landfill Western Expansion, Appendix F - "Report on Metro Landfill - Pipe Design", Watkins, 1989
5. U.S. Department of Transportation, Federal Highway Administration, Recycled Materials, Coal Ash User's Guide
6. "HDPE Leachate Collection Pipe Design by Fundamentals of Mechanics", Harrison and Watkins, 1996, Nineteenth International Madison Waste Conference.
7. SCS Engineers, Plan Modification Addendum No. 2, Edgewater Generating Station, "Revised Phase 4, Module 2 -- Base Grades and Leachate Collection System" and "Revised Phase 4, Module 2 -- Final Cover Grades" Plan Sheets, November 2024.

Assumptions:

1. Waste above the piping is assumed to be wet.
2. Wet waste unit weight is a conservative 110 pcf from research and typical project experience values.
3. Live loads are negligible above the piping. The maximum fill height over an 18-in SDR 17 HDPE pipe will be 44 feet for the current design.
4. Sump riser pipes will be 18-in., SDR 17 HDPE in Phase 4, Module 2
5. Allowable compressive stress for HDPE pipe is 1,000 psi (Plastic Pipe Institute, Attachment 1).

Calculations: **Pipe Loading, P_y**

$$P_y = DL + LL$$

where,
P_y = Pipe Load, lb/in^2
DL = Dead Load, lb/in^2
LL = Live Load, lb/in^2

Dead Load, *DL*

$$DL = \frac{\gamma \cdot H}{144}$$

where,					
γ	=	Fill Unit Weight, lb/ft^3	=	**110**	(waste unit weight)
H	=	Height of cover, ft	=	**44**	(max. waste height)
DL	=	Dead Load, lb/in^2	=	**34**	

In our case the live load = 0, due to limited live loads above the piping after placement.

So, P_y = DL = **34** lb/in^2

Assuming 18 inch SDR 17 HDPE for leachate sump riser piping

Outer Diameter of Pipe (OD) = **18** **in.** (From Attachment 2)
Min. Pipe wall thickness (t) = **1.059** **in.** (From Attachment 2)

Calculations: **Deflection**

(cont.) A deflection of 5 to 7.5% has become the standard for limiting deflection in flexible pipes. Based on Figure 7.16 in Uni-Bell (1991) and Watkins (1989) a vertical strain of greater than 5% will never be reached for flexible pipe bedded in compacted gravel, independent of vertical soil pressure. At 90% compaction the vertical strain will always be less than 2%. The height of fill over the pipe is not a factor when the pipe is well bedded in gravel. These findings are consistent for HDPE piping with the Harrison and Watkins (1996) paper.

Wall Crushing

where, σ = Compressive Stress, lb/in²
T = Wall Thrust, lb/in
A = Area of Pipe Wall, in²/in

$$\sigma = \frac{T}{A}$$

Wall Thrust, T

$$T = \frac{P_y \cdot D_o}{2}$$

SDR 17 HDPE Piping

where,	P_y =	Vertical Fill Pressure lb/in²	=	**34**	(Previously Calculated)
	D_0 =	Outside Diameter, in	=	**18.000**	(SDR 17, 18-inch)
	T =	Wall Thrust, lb/in	=	**303**	
	A =	Area of Pipe Wall, in²/in	=	**1.059**	(Solid=Thickness)

So, σ = Compressive Stress, lb/in² = **286**

Result: The allowable compressive strength of HDPE pipe is approximately 1,000 psi, so the calculated compressive stress values are acceptable and wall crushing of the pipe will be avoided when the pipe is at least SDR 17, 18-inch diameter for the sump riser pipe.

Sump Riser Piping Maximum Height - SDR 17 HDPE

For	P_y =	Vertical Fill Pressure lb/in²	=	**118**	
	D_0 =	Outside Diameter, in	=	**18.000**	(SDR 17, 18-inch)
	T =	Wall Thrust, lb/in	=	**1,059**	
	A =	Area of Pipe Wall, in²/in	=	**1.059**	(Solid=Thickness)

So, σ = Compressive Stress, lb/in² = **1,000**

Maximum Height (feet) = Py*(144)/ɣ = **154**

Result: The maximum height of fill above the 18-inch SDR 17 HDPE piping is 154 feet for a fill unit weight of 110 lb/ft³ to maintain the required minimum factor of safety against wall crushing. Wall crushing controls the maximum fill height that can be placed above the sump riser pipes. The maximum fill height above the 18-inch diameter piping when Phase 2 is filled will be approximately 44 feet, which is lower than the maximum allowable fill height.

Attachment 1

From the Handbook of PE Pipe 2008, Second Edition by the Plastics Pipe Institute

TABLE C.1

Allowable Compressive Stress for 73°F (23°C)

	Pe Pipe Material Designation Code [1]					
	PE 2406		PE3408		PE 4710	
	PE 2708		PE 3608			
			PE 3708			
			PE 3710			
			PE 4708			
	psi	MPa	psi	MPa	psi	MPa
Allowable Compressive Stress	800	5.52	1000	6.90	1150	7.93

(1) See Chapter 5 for an explanation of the PE Pipe Material Designation Code.

Attachment 2

From the ISCO Technical Library (Nov. 21, 2024)

DR		17			19			21			26			32.5		
PE4710 Pressure Rating		125 psi			111 psi			100 psi			80 psi			64 psi		
Nom. OD	"Actual OD	Min Wall (in)	Avg ID (in)	Weight (lb/ft)	Min Wall (in)	Avg ID (in)	Weight (lb/ft)	Min Wall (in)	Avg ID (in)	Weight (lb/ft)	Min Wall (in)	Avg ID (in)	Weight (lb/ft)	Min Wall (in)	Avg ID (in)	Weight (lb/ft)
3/4"	1.05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1"	1.315	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1-1/4"	1.66	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1-1/2"	1.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2"	2.375	0.140	2.079	0.431	--	--	--	--	--	--	--	--	--	--	--	--
3"	3.5	0.206	3.064	0.935	--	--	--	0.167	3.147	0.766	--	--	--	--	--	--
4"	4.5	0.265	3.939	1.546	0.237	3.998	1.392	0.214	4.046	1.266	0.173	4.133	1.033	0.138	4.206	0.833
5"	5.563	0.327	4.869	2.362	0.293	4.942	2.127	0.265	5.001	1.935	0.214	5.109	1.578	0.171	5.200	1.272
6"	6.625	0.390	5.799	3.350	0.349	5.886	3.017	0.315	5.956	2.744	0.255	6.085	2.238	0.204	6.193	1.805
8"	8.625	0.507	7.549	5.678	0.454	7.663	5.114	0.411	7.754	4.651	0.332	7.922	3.793	0.265	8.062	3.059
10"	10.75	0.632	9.409	8.821	0.566	9.551	7.944	0.512	9.665	7.226	0.413	9.873	5.892	0.331	10.049	4.752
12"	12.75	0.750	11.160	12.408	0.671	11.327	11.175	0.607	11.463	10.164	0.490	11.710	8.289	0.392	11.918	6.684
14"	14	0.824	12.254	14.961	0.737	12.438	13.474	0.667	12.587	12.255	0.538	12.858	9.994	0.431	13.087	8.059
16"	16	0.941	14.005	19.541	0.842	14.215	17.599	0.762	14.385	16.007	0.615	14.695	13.053	0.492	14.956	10.526
18"	18	1.059	15.755	24.731	0.947	15.992	22.273	0.857	16.183	20.259	0.692	16.532	16.520	0.554	16.826	13.322
20"	20	1.176	17.506	30.532	1.053	17.768	27.498	0.952	17.981	25.011	0.769	18.369	20.395	0.615	18.695	16.447
22"	22	1.294	19.256	36.944	1.158	19.545	33.272	1.048	19.779	30.263	0.846	20.206	24.678	0.677	20.565	19.900
24"	24	1.412	21.007	43.966	1.263	21.322	39.597	1.143	21.577	36.015	0.923	22.043	29.369	0.738	22.434	23.683
26"	26	1.529	22.758	51.599	1.368	23.099	46.471	1.238	23.375	42.268	1.000	23.880	34.468	0.800	24.304	27.795
28"	28	1.647	24.508	59.843	1.474	24.876	53.896	1.333	25.173	49.021	1.077	25.717	39.974	0.862	26.174	32.235
30"	30	1.765	26.259	68.697	1.579	26.653	61.870	1.429	26.971	56.274	1.154	27.554	45.889	0.923	28.043	37.005
32"	32	1.882	28.009	78.162	1.684	28.429	70.395	1.524	28.770	64.027	1.231	29.391	52.212	0.985	29.913	42.103
34"	34	2.000	29.760	88.238	1.789	30.206	79.469	1.619	30.568	72.281	1.308	31.228	58.942	1.046	31.782	47.531
36"	36	2.118	31.511	98.924	1.895	31.983	89.093	1.714	32.366	81.035	1.385	33.065	66.080	1.108	33.652	53.287
42"	42	2.471	36.762	134.646	2.211	37.314	121.266	2.000	37.760	110.297	1.615	38.575	89.943	1.292	39.260	72.530
48"	48	2.824	42.014	175.865	2.526	42.644	158.388	2.286	43.154	144.061	1.846	44.086	117.476	1.477	44.869	94.733
54"	54	3.176	47.266	222.579	2.842	47.975	200.459	2.571	48.549	182.328	2.077	49.597	148.681	1.662	50.478	119.896
1600/63"	62.990	3.706	55.143	303.398	3.315	55.970	273.362	3.000	56.631	249.570	2.423	57.854	203.630	1.938	58.881	164.280
65"	65.000	3.824	56.893	322.667	--	--	--	3.095	58.439	264.466	2.5000	59.700	215.806	2.000	60.760	174.112
1800mm	70.870	4.169	62.029	Call	--	--	--	3.375	63.712	Call	2.726	65.088	Call	2.147*	66.314*	Call
2000mm	78.740	4.632	68.921	Call	--	--	--	3.750	70.791	Call	3.028	72.320	Call	2.386*	73.682*	Call
2250mm	88.580	5.211	77.536	Call	--	--	--	4.218	79.640	Call	3.407	81.360	Call	2.684*	82.892*	Call
2500mm	98.430	5.790	86.151	Call	--	--	--	4.687	88.489	Call	3.786	90.400	Call	2.983*	92.102*	Call
2720mm	107.100	--	--	--	--	--	--	5.100	96.600	Call	4.100	98.700	Call	3.3*	100.3*	Call

SCS ENGINEERS

Calc. No.

Rev. No.

Job No. 25222259.00	Job: Edgewater I43 Ash Disposal Facility	By: MJT	Date: 01/19/2024
Client: WPL	Subject: Unit Gradient Calculation (4:1)	Chk'd: DLN	Date: 03/12/2024

Purpose: To determine the maximum length of 4H:1V slope that the final cover drainage layer (geocomposite) can carry infiltrating water and remain stable, and the recommended minimum interface friction angle for final cover stability.

Approach: Use the unit gradient method to determine the maximum slope length.

References:

1. Landfilldesign.com

2. "GRI-GC8, Determination of the Allowable Flow Rate of a Drainage Geocomposite". Geosynthetics Research Institute, 2001

3. "Beyond a factor-of-safety value, i.e., the probability of failure". GRI Newsletter/Report, Vol. 15, no. 3

4. "Designing with Geosynthetics". R.M. Koerner, Prentice Hall Publishing Co., Englewood Cliffs, NJ, 1998

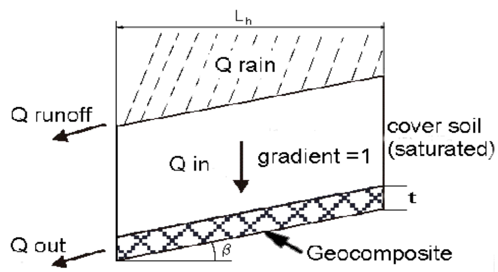
5. "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers". J. P. Giroud, J. G. Zornberg and A. Zhao, Geosynthetics International, Vol. 7, Nos 4-5

6. "Lateral Drainage Design update - part 2". G. N. Richardson, J. P. Giroud and A. Zhao, Geotechnical Fabrics Report, March 2002

7. HELP Model "User's Guide", Table 4: Default Soil, Waste, and Geosynthetic Characteristics

8. Soong, T.Y. and Koerner, R.M. (1997), "The Design of Drainage Systems over Geosynthetically Lined Slopes", Geosynthetics Research Institute, Report #19.

8. SCS Engineers, Plan Modification Addendum No. 1, Edgewater I43 Ash Disposal Facility, Final Cover Grades Plan Sheet, March 2024



With Darcy's Law:

$Q = k \times i \times A$

Inflow of water in the Drainage Material

$Q_{in} = k_{veg} \times i \times A = k_{veg} \times 1 \times L_h \times 1$

Outflow of water from the geocomposite at the toe of the slope

$Q_{out} = k_{comp} \times i \times A = k_{comp} \times i \times t \times 1 = \theta_{required} \times \sin\beta = \theta \times i \times 1$

where $\theta = k_{comp} \times t$

(minimum allowable outflow to keep head within geocomposite)

Inflow equals Outflow (Factor of Safety = 1)

$Q_{in} = Q_{out}$

This results in a required transmissivity of the geocomposite of:

$$\theta_{required} = \frac{k_{veg} \times L_h}{\sin\beta}$$

Which results in the ultimate transmissivity after multiplying by the Total Servicability Factor (TSF)

$$\theta_{ultimate} = \theta_{required} \times FS_d \times RF_{in} \times RF_{cr} \times RF_{cc} \times RF_{bc}$$

Assumptions: 1. Soil hydraulic gradient j = 1.

2. Typical topsoil in the site area is assumed to be silty clay based on the Preliminary Site Feasibility Report prepared by Mead and Hunt, Inc. in December 1977. Estimated permeability of 1.90E-05 cm/sec is from the HELP Model User's Guide.
3. Geocomposite hydraulic gradient = sinβ where β=14˚ (4:1 horizontal/vertical final cover slope).
4. Factor of safety and transmissivity reduction factors are from recommended values in GRI report #19 (Leachate collection system example) and HELP model "Users Guide"
5. Maximum 4:1 horizontal final cover slope length from crest to toe drain is 167 feet as shown in the Plan Modification Addendum final cover drawings.

Calculation: Constants

L_h	=	Drainage pipe spacing or length of slope measured horizontally	=	See Below	
k_{veg}	=	Permeability of the vegetative supporting soil	=	1.90E-05	cm/sec
S	=	The liner's slope, **S** = tan **β**	=	25%	β = 14 ˚
FS_{slope}	=	Minimum factor of safety against sliding, for soil/geocomposite or geocomposite/geomembrane interfaces	=	1.5	
$\delta_{req'd}$	=	Minimum interface friction angle = $\tan^{-1}(FS_{slope}*\tan(b))$	=	20.6	degrees
FS_d	=	Overall factor of safety for drainage	=	2.0	
RF_{in}	=	Intrusion Reduction Factor	=	1.1	
RF_{cr}	=	Creep Reduction Factor	=	1.2	
RF_{cc}	=	Chemical Clogging Reduction Factor	=	1.1	
RF_{bc}	=	Biological Clogging Reduction Factor	=	1.4	

Determine the ultimate transmissivity based on a given slope length

L_h (feet)	L_h (meter)	Θ_{ult} (m^2/sec)	
167	51	1.57E-04	~ Total slope length (4H:1V slope only)

Conclusions: For the proposed design with a toe-of-slope drainage outlet and the assumed vegetative layer hydraulic conductivity, a minimum transmissivity of 1.57E-04 m^2/sec is required for the final cover sideslopes For ease of construction, the same drainage geocomposite required for the 3% final cover plateau could also be used on the final cover sideslopes.

A minimum interface friction angle of 20.6 degrees is required to achieve a minimum recommended final cover slope stability safety factor of 1.5.

Purpose: To size the collection piping and space the outlet piping to accommodate the final cover 4:1 slope subsurface drainage.

Approach: Use the Darcy equation to determine the worst case flow rate to the pipe. Use Manning's equation to determine if the designed pipe size (4 inches) for the given flow rate is acceptable. Also determine what hole / perforation size would be acceptable based on the available bedding material.

References:

1. SCS Engineers, Plan Modification Addendum No. 1, Edgewater I43 Ash Disposal Facility, Final Cover Grades Plan Sheet, March 2024

2. NAVFAC DM 7, Design Criteria for Protective Filters

3. Advanced Drainage Systems (ADS), Inc. Drainage Handbook, Section 3-0 Hydraulics, July 2010

4. Advanced Drainage Systems (ADS), Inc. Technical Note (TN 1.01) Dual Wall HDPE Perforation Patterns, January 2015

Calculation: __Infiltration Flow / Collection Pipe Flow Capacity__

Darcy's Equation: $Q_{in} = K_{veg} \times i \times A = K_{veg} \times 1 \times L_h \times 1 \times FS$

Inflow of water into geocomposite from surface = Inflow of water into collection pipe

K_{veg} = 1.90E-05 = Permeability of topsoil (cm/s)

L_h = 167 ft = 51 m = Longest horizontal length between collection pipes

FS (drainage) = 2.0 = Factor of safety, to account for variation in cover soil

Q_{in} = 5.90 cm^3/s = 0.0002 cfs = Required collection pipe capacity, per linear foot of pipe

so, Required geocomposite transmissivity (from Cover Unit Gradient Calculation)

$\Theta_{req} = (K_{veg} \times L_h) / i * FS$ where, i = 0.25

Θ_{req} = 7.74E-05 m^2/sec

__Geocomposite Flow Capacity / Outlet Pipe Flow Capacity__

Darcy's Equation: $Q = k \times i \times A$ — Q = flow rate

$A = L \times t$ — t = thickness

$\Theta = k \times t$ — k = permeability

so, $Q = \Theta \times i \times L$ — Θ = transmissivity

i = 0.25 = hydraulic gradient, for 4:1 slope

L_{out} = 200 = length of collection pipe (i.e. spacing between outlet pipe) (ft)

Θ_{req} = 8.32E-04 = Required transmissivity of geocomposite (ft^2/s)

Q_{out} = **0.042** = Required collection pipe capacity, per linear foot of pipe (cfs)

__Design Pipe Flow__

Manning's Equation: $$Q = \frac{1.49}{n} \times 3.14 \times r^2 \times \left(\frac{r}{2}\right)^{2/3} \times slope^{1/2}$$

Where: n = 0.012 = Manning's Number for corrugated HDPE pipe with smooth interior

r = 2.0 = Radius of 4" pipe (in)

r = 0.1667 = Radius of 4" pipe (ft)

slope = 0.01 (Collection pipe) and 0.01 (Outlet pipe)

So, Q = **0.207** = Collection Pipe at 1% slope (cfs)

Q = **0.207** = Outlet Pipe at 1% slope, 'min. design slope' (cfs)

__Result:__ 0.207 cfs is greater than 0.0002 cfs and 0.042 cfs, so a 4-inch outlet pipe at the toe is acceptable.

Bedding Stone Diameter Sizing

Perforation design of 4" pipe (from ADS)

Maximum slot length = 0.875 inch

Maximum slot width = 0.125 inch

*Slot width will control the size of bedding stone

D_{85F} / Slot Width > (1.2 to 1.4) , [From the NAVFAC DM 7 Manual]

D_{85F} = (0.125 inch) * 1.2 = 0.150 inch

D_{85F} = (0.125 inch) * 1.4 = 0.175 inch

So, a bedding stone with a D_{85F} between 0.150 and 0.175 inch or larger would be acceptable.

Conclusion: Based on the outlet pipe estimated flow, one 4" outlet pipe spaced at 200 ft or less would be adequate.

A 4-inch diameter collection pipe at a 1% slope is suitable to collect the expected drainage layer flow.

For a 0.125 inch perforated pipe slot width, bedding stone diameter should be between 0.150 and 0.175 inch (equivalent to a No. 4 sieve) or larger.

A 4-inch diameter outlet pipe at a 1% slope is suitable to discharge the expected drainage layer flow.

April 5, 2024
File No. 25222259.00

TECHNICAL MEMORANDUM

ANALYSIS BY: Niko Villaneuva
Brandon Suchomel

REVIEWED BY: Deb Nelson
Phil Gearing

SUBJECT: Slope Stability Analysis
Plan of Operation Modification
Edgewater I-43 Ash Disposal Facility, License #2853

PURPOSE

The purpose of the slope stability analyses was to evaluate the most critical future slope:

- The final cover 4H:1V slope in Phase 3 at the highest final cover grade

CONCLUSION

The attached results confirm that the final cover slope will be stable during the construction and operation of the disposal facility modules.

APPROACH

SCS Engineers (SCS) evaluated the slope stability of the southern slope of Phase 3 final cover slope at the most critical/highest final cover grade cross-section (i.e., at the time of final cover placement) after the filling of the proposed converted contact water swale liner. The 4H:1V final cover slope analyzed at the south side has a maximum final cover fill height of approximately 50 feet above base grades, and a peak elevation of approximately 731 feet above mean sea level. A piezometric surface was assumed just below the landfill clay liner. The final cover slope was evaluated for block and optimized circular failure.

RESULTS

The calculated safety factors for each slope section and failure type are shown in the summary table.

SCS recommends a minimum safety factor of 1.5 for the final grade slopes. The results indicate that the final grade slopes have acceptable minimum safety factors.

Table 1. Factor of Safety Results Summary

Scenario Analyzed	Calculated Safety Factor	Recommended Minimum Safety Factor
Critical Future Final Grades (See Figure 1)		
Optimized Circular (Rotational Failure)	1.548	1.500
Block (Translational Failure) Left of Intercell Berm	1.877	1.500
Block (Translational Failure) Contact Water Swale	1.896	1.500

REFERENCES

1. SCS Engineers, Edgewater I-43 Ash Disposal Facility, Plan Modification Request Addendum No. 1, 2024.

2. SCS Engineers, Edgewater I-43 Ash Disposal Facility, Phase 3, Module 2 Liner and Area 1 Final Cover Construction – Construction Documentation Report, 2016, existing as-built composite liner grades, material properties for subbase, clay liner, drainage layer, and geosynthetics.

3. TRI/Environmental, Interface Friction Test Results, 2015, for 2015 Phase 3 Module 2 Liner Construction.

4. TRI/Environmental, Consolidated-Undrained Triaxial Compression Test Results for FGD Material, 2015, material properties for CCR.

5. U.S. Department of Transportation, Federal Highway Administration, Recycled Materials, Coal Ash User's Guide.

6. Stabilization of FGD By-Products by Using Fly Ash, Cement, and Sialite, 2009 WOCA Conference.

7. Geo-Slope International, Ltd., GeoStudio 2023.1.1, Slope/W slope stability software.

8. U.S. Army Corps of Engineers, Slope Stability Engineer Manual EM 1110-2-1902, October 2003.

9. SCS Engineers, Edgewater I-43 Ash Disposal Facility, Unstable Areas Compliance Demonstration Phase 3 Modules 1 and 2, Phase 4 Module 1, 2018.

ASSUMPTIONS

- The critical final grades are the worst-case scenario (shown on Figure 1) for the longest/highest final grade slope. This includes the full buildout of approved and proposed module construction.

- Drainage layers in each of the existing and future modules and leachate drainage materials in the contact water swale area have the same properties.

- Geosynthetics installed for each of the module composite liners have the same properties.

- Clay material for each of the existing and future module composite liners have the same properties.

- Coal combustion residual (CCR) waste material will be the same in each of the existing and future modules.

- A final grade slope of 4H:1V is representative of the design final cover grades.

- The groundwater elevation will remain below the elevation at the base of the landfill liner system.

- The disposal facility will be operated to prevent development of liquid pressures, or seepage forces, within the waste, and there will be no buildup of leachate above the top of the drainage layer.

- The disposal facility will be operated to prevent placement of weak layers of waste within the overall waste mass.

- Optimized circular and sliding block failure stability analyses are appropriate to evaluate the final cover slope stability.

- Material properties are as shown in the table below, based on the indicated references and assumed values based on experience. Friction angles for soils are conservative assumed values based on soil type, published typical values, and SCS experience. The CCR friction angle is a conservative assumed value based on published values and 2015 triaxial compression test results by TRI/Environmental for CCR.

Table 2. Material Properties Summary Table

Material	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)	Reference
Final Cover	125	28	0	2
CCR	86	20	0	4, 5, 6, and 9
Drainage Layer	115	30	0	2 and 9
Geosynthetics	58	19.5	0	3 and 9
Clay Liner	130	28	0	2 and 9
Subbase	135	28	0	2 and 9

Attachments: Calculations organized as follows:

- Figure 1. Slope Stability Cross Section Location
- Slope/W Outputs

BSS/NV/REO_LMH/DLN/PEG

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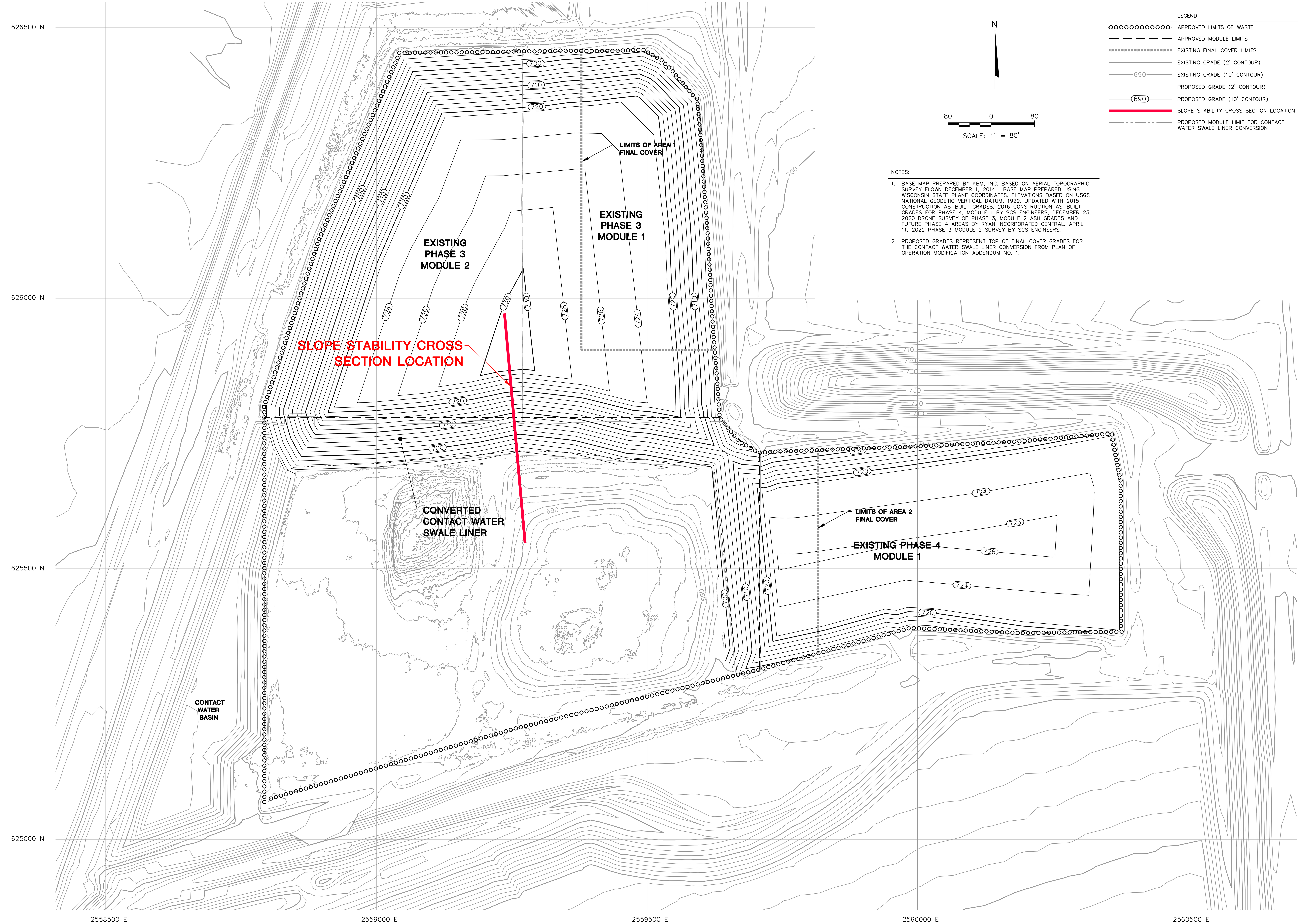


LEGEND

- APPROVED LIMITS OF WASTE
- APPROVED MODULE LIMITS
- EXISTING FINAL COVER LIMITS
- EXISTING GRADE (2' CONTOUR)
- 690 EXISTING GRADE (10' CONTOUR)
- PROPOSED GRADE (2' CONTOUR)
- 690 PROPOSED GRADE (10' CONTOUR)
- SLOPE STABILITY CROSS SECTION LOCATION
- PROPOSED MODULE LIMIT FOR CONTACT WATER SWALE LINER CONVERSION

NOTES:

1. BASE MAP PREPARED BY KBM, INC. BASED ON AERIAL TOPOGRAPHIC SURVEY FLOWN DECEMBER 1, 2014. BASE MAP PREPARED USING WISCONSIN STATE PLANE COORDINATES. ELEVATIONS BASED ON USGS NATIONAL GEODETIC VERTICAL DATUM, 1929. UPDATED WITH 2015 CONSTRUCTION AS-BUILT GRADES, 2016 CONSTRUCTION AS-BUILT GRADES FOR PHASE 4, MODULE 1 BY SCS ENGINEERS, DECEMBER 23, 2020 DRONE SURVEY OF PHASE 3, MODULE 2 ASH GRADES AND FUTURE PHASE 4 AREAS BY RYAN INCORPORATED CENTRAL, APRIL 11, 2022 PHASE 3 MODULE 2 SURVEY BY SCS ENGINEERS.

2. PROPOSED GRADES REPRESENT TOP OF FINAL COVER GRADES FOR THE CONTACT WATER SWALE LINER CONVERSION FROM PLAN OF OPERATION MODIFICATION ADDENDUM NO. 1.

PROJECT NO.	25222259.00	DRAWN BY:	BSS
DRAWN:	03/22/2024	CHECKED BY:	PEG
REVISED:	03/22/2024	APPROVED BY:	PEG 6/13/24

WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

ENGINEER

PLAN MODIFICATION ADDENDUM NO. 1
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

SITE

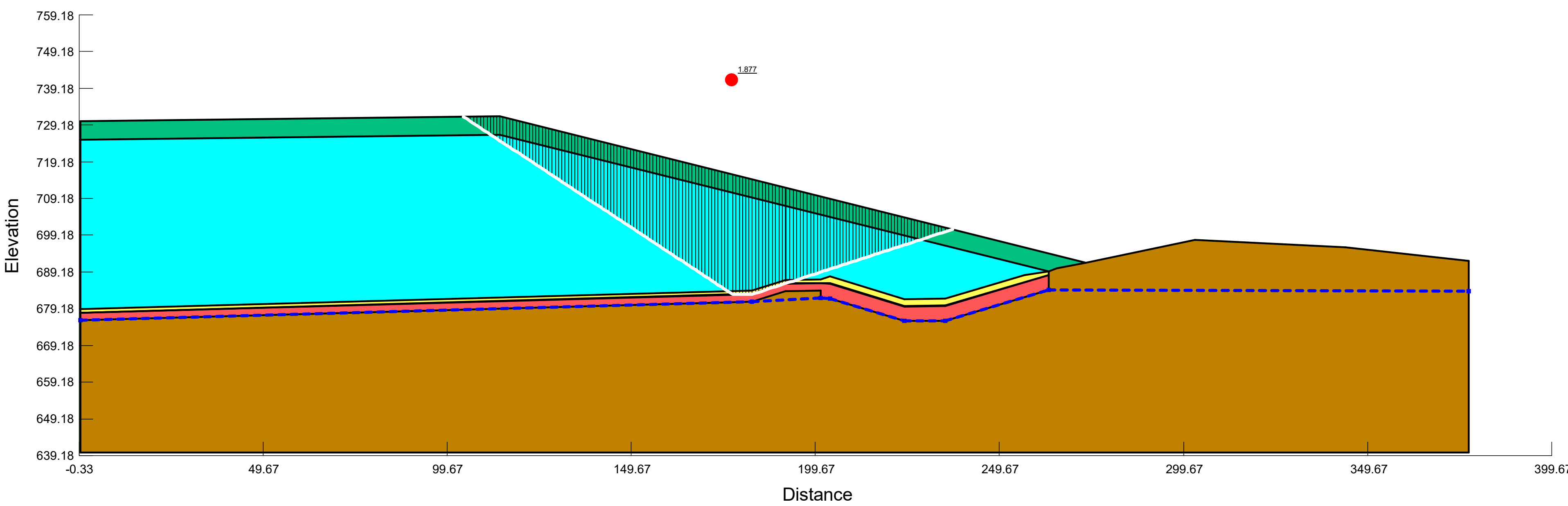
SLOPE STABILITY
CROSS SECTION LOCATION

FIGURE
1 OF 1

I-43 Plan of Operation Modification - Final Grade Stability Analysis
Block Failure-Intercell Berm
Analysis Type: Janbu
Last Solved Date: 03/27/2024, 04:20:20 PM

Factor of Safety: 1.877

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Piezometric Surface
	CCR	86	0	20	
	Clay Liner	130	0	28	
	Drainage Layer	115	0	30	
	Final Cover	125	0	28	
	Geosynthetics	58	0	19.5	
	Subbase	135	0	28	1



Block Failure-Intercell Berm

File Information

- File Version: 11.05
- Title: I-43 Plan of Operation Modification - Final Grade Stability Analysis
- Created By: Villanueva, Niko
- Last Edited By: Villanueva, Niko
- Revision Number: 52
- Date: 03/27/2024
- Time: 04:16:14 PM
- Tool Version: 23.1.1.829
- File Name: I-43 Proposed Final Grades_Section A_240327.gsz
- Directory: I:\25222259.00\Data and Calculations\Geotechnical\Slope Stability\SlopeW Analysis\
- Last Solved Date: 03/27/2024
- Last Solved Time: 04:20:20 PM

Project Settings

- Unit System: U.S. Customary Units

Analysis Settings

Block Failure-Intercell Berm

- Kind: SLOPE/W
- Analysis Type: Janbu
- Settings
  - PWP Conditions from: Piezometric Surfaces
  - Apply Phreatic Correction: No
  - Use Staged Rapid Drawdown: No
  - Unit Weight of Water: 62.430189 pcf
- Slip Surface
  - Direction of movement: Left to Right
  - Use Passive Mode: No
  - Slip Surface Option: Block
  - Critical slip surfaces saved: 10
  - Restrict Block Crossing: No
  - Optimize Critical Slip Surface Location: No
  - Tension Crack Option: (none)
- Distribution
  - F of S Calculation Option: Constant
- Convergence
  - Geometry Settings
    - Minimum Slip Surface Depth: 0.1 ft
    - Minimum Slip Surface Volume: 35.314667 ft^3
    - Number of Columns: 150
  - Factor of Safety Convergence Settings
    - Maximum Number of Iterations: 100
    - Tolerable difference in F of S: 0.001

Under-Relaxation Criteria
Initial Rate: 1
Minimum Rate: 0.1
Rate Reduction Factor: 0.65
Reduction Frequency (iterations): 50

Materials

CCR
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 86 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 20 °
Phi-B: 0 °

Clay Liner
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 130 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °

Drainage Layer
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 30 °
Phi-B: 0 °

Geosynthetics
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 58 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 19.5 °
Phi-B: 0 °

Subbase
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 135 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Surface: 1

Final Cover
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 125 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (0, 730.2) ft
Right Coordinate: (377.2, 692.2) ft

Slip Surface Block

Left Grid
- Upper Left: (167.74, 682.79) ft
- Lower Left: (167.74, 682.69) ft
- Lower Right: (177.24, 682.96) ft
- X Increments: 10
- Y Increments: 4
- Starting Angle: 115 °
- Ending Angle: 160 °
- Angle Increments: 10

Right Grid
- Upper Left: (177.94, 683.07) ft
- Lower Left: (177.94, 682.97) ft
- Lower Right: (182.5, 683.1) ft
- X Increments: 10
- Y Increments: 4
- Angle Increments: 10

Piezometric Surfaces

Piezometric Surface 1

Coordinates

	X	Y
Coordinate 1	0 ft	676 ft
Coordinate 2	182.5 ft	681.1 ft
Coordinate 3	201.2 ft	682.1 ft
Coordinate 4	203.7 ft	682 ft
Coordinate 5	223.8 ft	675.8 ft
Coordinate 6	234.9 ft	675.9 ft
Coordinate 7	263 ft	684.3 ft
Coordinate 8	377.2 ft	684 ft

Geometry

Name: 2D Geometry

Settings

View: 2D
Element Thickness: 1 ft

Points

	X	Y
Point 1	0 ft	640 ft

Point 2	377.2 ft	640 ft
Point 3	377.2 ft	692.2 ft
Point 4	343.6 ft	695.9 ft
Point 5	302.7 ft	697.9 ft
Point 6	265.2 ft	690.1 ft
Point 7	263.1 ft	689.3 ft
Point 8	263.1 ft	688.4 ft
Point 9	263.1 ft	688.3 ft
Point 10	263.1 ft	684.3 ft
Point 11	234.9 ft	675.9 ft
Point 12	223.8 ft	675.8 ft
Point 13	203.7 ft	682 ft
Point 14	201.2 ft	682.1 ft
Point 15	201.2 ft	684.1 ft
Point 16	191.6 ft	684 ft
Point 17	182.5 ft	681.1 ft
Point 18	0 ft	676 ft
Point 19	0 ft	678 ft
Point 20	182.5 ft	683.1 ft
Point 21	191.6 ft	686 ft
Point 22	201.2 ft	686.1 ft
Point 23	203.7 ft	686 ft
Point 24	223.8 ft	679.8 ft
Point 25	234.9 ft	679.9 ft
Point 26	0 ft	678.1 ft
Point 27	182.5 ft	683.2 ft
Point 28	191.6 ft	686.1 ft
Point 29	201.2 ft	686.2 ft
Point 30	203.7 ft	686.1 ft
Point 31	223.8 ft	679.9 ft
Point 32	234.9 ft	680 ft
Point 33	0 ft	679 ft
Point 34	182.5 ft	684.1 ft
Point 35	191.6 ft	687 ft
Point 36	201.2 ft	687.1 ft
Point 37	203.7 ft	688 ft
Point 38	0 ft	725.2 ft
Point 39	113.97399 ft	726.5815 ft
Point 40	256.51003 ft	688.33703 ft
Point 41	234.9 ft	681.9 ft
Point 42	223.8 ft	681.8 ft
Point 43	0 ft	730.2 ft
Point 44	113.97399 ft	731.5815 ft
Point 45	273.22402 ft	691.769 ft

Regions

	Material	Points	Area
Region 1	Subbase	1,2,3,4,5,45,6,7,8,9,10,11,12,13,14,15,16,17,18	16,534 ft^2
Region 2	Clay Liner	18,19,20,21,22,23,24,25,9,10,11,12,13,14,15,16,17	650 ft^2

Region 3	Geosynthetics	19,26,27,28,29,30,31,32,8,9,25,24,23,22,21,20	26.31 ft²
Region 4	Drainage Layer	26,33,34,35,36,37,30,29,28,27	184.58 ft²
Region 5	CCR	33,38,39,7,40,41,42,37,36,35,34	8,689.4 ft²
Region 6	Final Cover	38,39,7,6,45,44,43	1,339.4 ft²
Region 7	Drainage Layer	37,42,41,40,7,8,32,31,30	109.57 ft²

Slip Results

Slip Surfaces Analysed: 302676 of 366025 converged

Current Slip Surface

Slip Surface: 290,515
Factor of Safety: 1.877
Volume: 2,302.6823 ft³
Weight: 222,792.19 lbf
Resisting Moment: 3,771,783.9 lbf·ft
Activating Moment: 1,699,412.1 lbf·ft
Resisting Force: 80,759.502 lbf
Activating Force: 43,014.985 lbf
Slip Rank: 1 of 366,025 slip surfaces
Exit: (237.02936, 700.81766) ft
Entry: (104.07551, 731.46152) ft
Radius: 65.431871 ft
Center: (175.84965, 739.12248) ft

Slip Columns

	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength	Suction Strength	Base Material
Column 1	104.53916 ft	731.15464 ft	0 psf	32.895362 psf	17.490774 psf	0 psf	0 psf	Final Cover
Column 2	105.46645 ft	730.54088 ft	0 psf	98.686086 psf	52.472323 psf	0 psf	0 psf	Final Cover
Column 3	106.39374 ft	729.92712 ft	0 psf	164.47681 psf	87.453871 psf	0 psf	0 psf	Final Cover
Column 4	107.32103 ft	729.31336 ft	0 psf	230.26753 psf	122.43542 psf	0 psf	0 psf	Final Cover
Column 5	108.24832 ft	728.69960 ft	0 psf	296.05826 psf	157.41697 psf	0 psf	0 psf	Final Cover
Column 6	109.17561 ft	728.08584 ft	0 psf	361.84898 psf	192.39852 psf	0 psf	0 psf	Final Cover
Column 7	110.10290 ft	727.47208 ft	0 psf	427.63971 psf	227.38006 psf	0 psf	0 psf	Final Cover
Column 8	111.03019 ft	726.85832 ft	0 psf	493.43043 psf	262.36161 psf	0 psf	0 psf	Final Cover
Column 9	111.90719 ft	726.27784 ft	0 psf	575.1492 psf	209.33719 psf	0 psf	0 psf	CCR
Column 10	112.73391 ft	725.73065 ft	0 psf	617.61926 psf	224.79503 psf	0 psf	0 psf	CCR
Column 11	113.56063 ft	725.18346 ft	0 psf	660.08931 psf	240.25286 psf	0 psf	0 psf	CCR

Column 12	114.41638 ft	724.61704 ft	0 psf	695.21258 psf	253.03669 psf	0 psf	0 psf	CCR
Column 13	115.30117 ft	724.03141 ft	0 psf	722.98907 psf	263.1465 psf	0 psf	0 psf	CCR
Column 14	116.18596 ft	723.44579 ft	0 psf	750.76555 psf	273.25631 psf	0 psf	0 psf	CCR
Column 15	117.07075 ft	722.86016 ft	0 psf	778.54204 psf	283.36613 psf	0 psf	0 psf	CCR
Column 16	117.95554 ft	722.27453 ft	0 psf	806.31852 psf	293.47594 psf	0 psf	0 psf	CCR
Column 17	118.84033 ft	721.68890 ft	0 psf	834.09501 psf	303.58576 psf	0 psf	0 psf	CCR
Column 18	119.72512 ft	721.10327 ft	0 psf	861.8715 psf	313.69557 psf	0 psf	0 psf	CCR
Column 19	120.60991 ft	720.51764 ft	0 psf	889.64798 psf	323.80539 psf	0 psf	0 psf	CCR
Column 20	121.49470 ft	719.93201 ft	0 psf	917.42447 psf	333.9152 psf	0 psf	0 psf	CCR
Column 21	122.37949 ft	719.34638 ft	0 psf	945.20096 psf	344.02501 psf	0 psf	0 psf	CCR
Column 22	123.26428 ft	718.76075 ft	0 psf	972.97744 psf	354.13483 psf	0 psf	0 psf	CCR
Column 23	124.14906 ft	718.17512 ft	0 psf	1,000.7539 psf	364.24464 psf	0 psf	0 psf	CCR
Column 24	125.03385 ft	717.58949 ft	0 psf	1,028.5304 psf	374.35446 psf	0 psf	0 psf	CCR
Column 25	125.91864 ft	717.00387 ft	0 psf	1,056.3069 psf	384.46427 psf	0 psf	0 psf	CCR
Column 26	126.80343 ft	716.41824 ft	0 psf	1,084.0834 psf	394.57409 psf	0 psf	0 psf	CCR
Column 27	127.68822 ft	715.83261 ft	0 psf	1,111.8599 psf	404.6839 psf	0 psf	0 psf	CCR
Column 28	128.57301 ft	715.24698 ft	0 psf	1,139.6364 psf	414.79371 psf	0 psf	0 psf	CCR
Column 29	129.45780 ft	714.66135 ft	0 psf	1,167.4128 psf	424.90353 psf	0 psf	0 psf	CCR
Column 30	130.34259 ft	714.07572 ft	0 psf	1,195.1893 psf	435.01334 psf	0 psf	0 psf	CCR
Column 31	131.22738 ft	713.49009 ft	0 psf	1,222.9658 psf	445.12316 psf	0 psf	0 psf	CCR
Column 32	132.11217 ft	712.90446 ft	0 psf	1,250.7423 psf	455.23297 psf	0 psf	0 psf	CCR
Column 33	132.99696 ft	712.31883 ft	0 psf	1,278.5188 psf	465.34279 psf	0 psf	0 psf	CCR
Column 34	133.88174 ft	711.73320 ft	0 psf	1,306.2953 psf	475.4526 psf	0 psf	0 psf	CCR
Column 35	134.76653 ft	711.14757 ft	0 psf	1,334.0718 psf	485.56241 psf	0 psf	0 psf	CCR
Column 36	135.65132 ft	710.56194 ft	0 psf	1,361.8483 psf	495.67223 psf	0 psf	0 psf	CCR
Column 37	136.53611 ft	709.97632 ft	0 psf	1,389.6247 psf	505.78204 psf	0 psf	0 psf	CCR

Column 38	137.42090 ft	709.39069 ft	0 psf	1,417.4012 psf	515.89186 psf	0 psf	0 psf	CCR
Column 39	138.30569 ft	708.80506 ft	0 psf	1,445.1777 psf	526.00167 psf	0 psf	0 psf	CCR
Column 40	139.19048 ft	708.21943 ft	0 psf	1,472.9542 psf	536.11149 psf	0 psf	0 psf	CCR
Column 41	140.07527 ft	707.63380 ft	0 psf	1,500.7307 psf	546.2213 psf	0 psf	0 psf	CCR
Column 42	140.96006 ft	707.04817 ft	0 psf	1,528.5072 psf	556.33111 psf	0 psf	0 psf	CCR
Column 43	141.84485 ft	706.46254 ft	0 psf	1,556.2837 psf	566.44093 psf	0 psf	0 psf	CCR
Column 44	142.72964 ft	705.87691 ft	0 psf	1,584.0601 psf	576.55074 psf	0 psf	0 psf	CCR
Column 45	143.61442 ft	705.29128 ft	0 psf	1,611.8366 psf	586.66056 psf	0 psf	0 psf	CCR
Column 46	144.49921 ft	704.70565 ft	0 psf	1,639.6131 psf	596.77037 psf	0 psf	0 psf	CCR
Column 47	145.38400 ft	704.12002 ft	0 psf	1,667.3896 psf	606.88019 psf	0 psf	0 psf	CCR
Column 48	146.26879 ft	703.53440 ft	0 psf	1,695.1661 psf	616.99 psf	0 psf	0 psf	CCR
Column 49	147.15358 ft	702.94877 ft	0 psf	1,722.9426 psf	627.09981 psf	0 psf	0 psf	CCR
Column 50	148.03837 ft	702.36314 ft	0 psf	1,750.7191 psf	637.20963 psf	0 psf	0 psf	CCR
Column 51	148.92316 ft	701.77751 ft	0 psf	1,778.4956 psf	647.31944 psf	0 psf	0 psf	CCR
Column 52	149.80795 ft	701.19188 ft	0 psf	1,806.272 psf	657.42926 psf	0 psf	0 psf	CCR
Column 53	150.69274 ft	700.60625 ft	0 psf	1,834.0485 psf	667.53907 psf	0 psf	0 psf	CCR
Column 54	151.57753 ft	700.02062 ft	0 psf	1,861.825 psf	677.64889 psf	0 psf	0 psf	CCR
Column 55	152.46232 ft	699.43499 ft	0 psf	1,889.6015 psf	687.7587 psf	0 psf	0 psf	CCR
Column 56	153.34710 ft	698.84936 ft	0 psf	1,917.378 psf	697.86851 psf	0 psf	0 psf	CCR
Column 57	154.23189 ft	698.26373 ft	0 psf	1,945.1545 psf	707.97833 psf	0 psf	0 psf	CCR
Column 58	155.11668 ft	697.67810 ft	0 psf	1,972.931 psf	718.08814 psf	0 psf	0 psf	CCR
Column 59	156.00147 ft	697.09247 ft	0 psf	2,000.7074 psf	728.19796 psf	0 psf	0 psf	CCR
Column 60	156.88626 ft	696.50685 ft	0 psf	2,028.4839 psf	738.30777 psf	0 psf	0 psf	CCR
Column 61	157.77105 ft	695.92122 ft	0 psf	2,056.2604 psf	748.41759 psf	0 psf	0 psf	CCR
Column 62	158.65584 ft	695.33559 ft	0 psf	2,084.0369 psf	758.5274 psf	0 psf	0 psf	CCR
Column 63	159.54063 ft	694.74996 ft	0 psf	2,111.8134 psf	768.63722 psf	0 psf	0 psf	CCR

Column 64	160.42542 ft	694.16433 ft	0 psf	2,139.5899 psf	778.74703 psf	0 psf	0 psf	CCR
Column 65	161.31021 ft	693.57870 ft	0 psf	2,167.3664 psf	788.85684 psf	0 psf	0 psf	CCR
Column 66	162.19500 ft	692.99307 ft	0 psf	2,195.1429 psf	798.96666 psf	0 psf	0 psf	CCR
Column 67	163.07978 ft	692.40744 ft	0 psf	2,222.9193 psf	809.07647 psf	0 psf	0 psf	CCR
Column 68	163.96457 ft	691.82181 ft	0 psf	2,250.6958 psf	819.18629 psf	0 psf	0 psf	CCR
Column 69	164.84936 ft	691.23618 ft	0 psf	2,278.4723 psf	829.2961 psf	0 psf	0 psf	CCR
Column 70	165.73415 ft	690.65055 ft	0 psf	2,306.2488 psf	839.40592 psf	0 psf	0 psf	CCR
Column 71	166.61894 ft	690.06493 ft	0 psf	2,334.0253 psf	849.51573 psf	0 psf	0 psf	CCR
Column 72	167.50373 ft	689.47930 ft	0 psf	2,361.8018 psf	859.62554 psf	0 psf	0 psf	CCR
Column 73	168.38852 ft	688.89367 ft	0 psf	2,389.5783 psf	869.73536 psf	0 psf	0 psf	CCR
Column 74	169.27331 ft	688.30804 ft	0 psf	2,417.3547 psf	879.84517 psf	0 psf	0 psf	CCR
Column 75	170.15810 ft	687.72241 ft	0 psf	2,445.1312 psf	889.95499 psf	0 psf	0 psf	CCR
Column 76	171.04289 ft	687.13678 ft	0 psf	2,472.9077 psf	900.0648 psf	0 psf	0 psf	CCR
Column 77	171.92768 ft	686.55115 ft	0 psf	2,500.6842 psf	910.17462 psf	0 psf	0 psf	CCR
Column 78	172.81247 ft	685.96552 ft	0 psf	2,528.4607 psf	920.28443 psf	0 psf	0 psf	CCR
Column 79	173.69725 ft	685.37989 ft	0 psf	2,556.2372 psf	930.39424 psf	0 psf	0 psf	CCR
Column 80	174.58204 ft	684.79426 ft	0 psf	2,584.0137 psf	940.50406 psf	0 psf	0 psf	CCR
Column 81	175.46683 ft	684.20863 ft	0 psf	2,611.7902 psf	950.61387 psf	0 psf	0 psf	CCR
Column 82	176.56156 ft	683.48405 ft	0 psf	2,491.5859 psf	1,438.5178 psf	0 psf	0 psf	Drainage Layer
Column 83	177.66528 ft	683.04906 ft	0 psf	3,021.1325 psf	1,069.8391 psf	0 psf	0 psf	Geosynthetics
Column 84	178.55500 ft	683.05125 ft	0 psf	3,012.1537 psf	1,066.6596 psf	0 psf	0 psf	Geosynthetics
Column 85	179.43167 ft	683.06208 ft	0 psf	2,991.944 psf	1,059.5029 psf	0 psf	0 psf	Geosynthetics
Column 86	180.30833 ft	683.07292 ft	0 psf	2,971.7342 psf	1,052.3463 psf	0 psf	0 psf	Geosynthetics
Column 87	181.18500 ft	683.08375 ft	0 psf	2,951.5245 psf	1,045.1896 psf	0 psf	0 psf	Geosynthetics
Column 88	182.06167 ft	683.09458 ft	0 psf	2,931.3148 psf	1,038.033 psf	0 psf	0 psf	Geosynthetics
Column 89	182.95500 ft	683.24784 ft	0 psf	3,080.818 psf	1,090.9749 psf	0 psf	0 psf	Geosynthetics

Column 90	183.86500 ft	683.54352 ft	0 psf	3,033.0563 psf	1,074.0616 psf	0 psf	0 psf	Geosynthetics
Column 91	184.77500 ft	683.83919 ft	0 psf	2,985.2945 psf	1,057.1482 psf	0 psf	0 psf	Geosynthetics
Column 92	185.68500 ft	684.13487 ft	0 psf	2,937.5328 psf	1,040.2349 psf	0 psf	0 psf	Geosynthetics
Column 93	186.59500 ft	684.43055 ft	0 psf	2,889.771 psf	1,023.3216 psf	0 psf	0 psf	Geosynthetics
Column 94	187.50500 ft	684.72622 ft	0 psf	2,842.0092 psf	1,006.4083 psf	0 psf	0 psf	Geosynthetics
Column 95	188.41500 ft	685.02190 ft	0 psf	2,794.2475 psf	989.49493 psf	0 psf	0 psf	Geosynthetics
Column 96	189.32500 ft	685.31758 ft	0 psf	2,746.4857 psf	972.58161 psf	0 psf	0 psf	Geosynthetics
Column 97	190.23500 ft	685.61325 ft	0 psf	2,698.724 psf	955.66828 psf	0 psf	0 psf	Geosynthetics
Column 98	191.14500 ft	685.90893 ft	0 psf	2,650.9622 psf	938.75496 psf	0 psf	0 psf	Geosynthetics
Column 99	191.66873 ft	686.07910 ft	0 psf	2,624.1061 psf	929.24469 psf	0 psf	0 psf	Geosynthetics
Column 100	192.21440 ft	686.25640 ft	0 psf	2,702.62 psf	1,560.3584 psf	0 psf	0 psf	Drainage Layer
Column 101	193.16829 ft	686.56634 ft	0 psf	2,640.5546 psf	1,524.5249 psf	0 psf	0 psf	Drainage Layer
Column 102	194.12217 ft	686.87627 ft	0 psf	2,578.4892 psf	1,488.6914 psf	0 psf	0 psf	Drainage Layer
Column 103	195.07061 ft	687.18444 ft	0 psf	2,422.1644 psf	881.59576 psf	0 psf	0 psf	CCR
Column 104	196.01359 ft	687.49083 ft	0 psf	2,372.4057 psf	863.48505 psf	0 psf	0 psf	CCR
Column 105	196.95657 ft	687.79723 ft	0 psf	2,322.6469 psf	845.37434 psf	0 psf	0 psf	CCR
Column 106	197.89956 ft	688.10362 ft	0 psf	2,272.8881 psf	827.26362 psf	0 psf	0 psf	CCR
Column 107	198.84254 ft	688.41001 ft	0 psf	2,223.1294 psf	809.15291 psf	0 psf	0 psf	CCR
Column 108	199.78552 ft	688.71641 ft	0 psf	2,173.3706 psf	791.0422 psf	0 psf	0 psf	CCR
Column 109	200.72851 ft	689.02280 ft	0 psf	2,123.6118 psf	772.93149 psf	0 psf	0 psf	CCR
Column 110	201.61667 ft	689.31138 ft	0 psf	2,076.746 psf	755.87373 psf	0 psf	0 psf	CCR
Column 111	202.45000 ft	689.58215 ft	0 psf	2,032.7732 psf	739.86894 psf	0 psf	0 psf	CCR
Column 112	203.28333 ft	689.85291 ft	0 psf	1,988.8004 psf	723.86414 psf	0 psf	0 psf	CCR
Column 113	204.13696 ft	690.13027 ft	0 psf	1,943.7569 psf	707.46966 psf	0 psf	0 psf	CCR
Column 114	205.01087 ft	690.41422 ft	0 psf	1,897.6428 psf	690.6855 psf	0 psf	0 psf	CCR
Column 115	205.88478 ft	690.69818 ft	0 psf	1,851.5287 psf	673.90134 psf	0 psf	0 psf	CCR

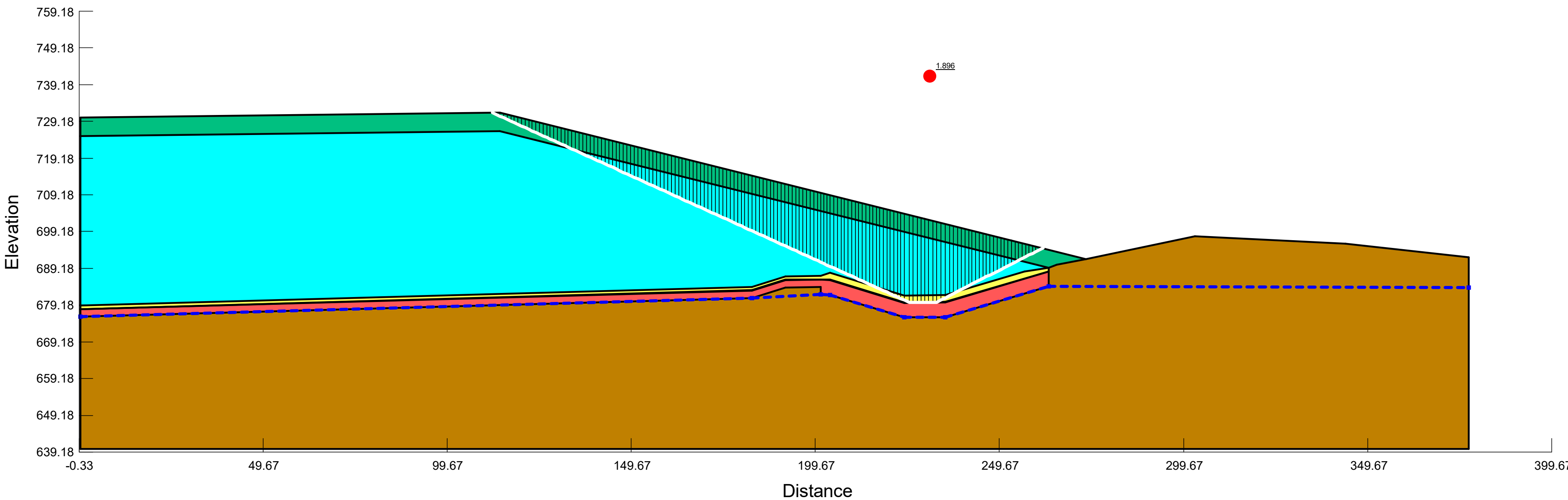
Column 116	206.75870 ft	690.98213 ft	0 psf	1,805.4146 psf	657.11718 psf	0 psf	0 psf	CCR
Column 117	207.63261 ft	691.26608 ft	0 psf	1,759.3005 psf	640.33302 psf	0 psf	0 psf	CCR
Column 118	208.50652 ft	691.55003 ft	0 psf	1,713.1864 psf	623.54886 psf	0 psf	0 psf	CCR
Column 119	209.38043 ft	691.83398 ft	0 psf	1,667.0723 psf	606.7647 psf	0 psf	0 psf	CCR
Column 120	210.25435 ft	692.11793 ft	0 psf	1,620.9582 psf	589.98054 psf	0 psf	0 psf	CCR
Column 121	211.12826 ft	692.40189 ft	0 psf	1,574.8441 psf	573.19638 psf	0 psf	0 psf	CCR
Column 122	212.00217 ft	692.68584 ft	0 psf	1,528.73 psf	556.41222 psf	0 psf	0 psf	CCR
Column 123	212.87609 ft	692.96979 ft	0 psf	1,482.6159 psf	539.62806 psf	0 psf	0 psf	CCR
Column 124	213.75000 ft	693.25374 ft	0 psf	1,436.5018 psf	522.8439 psf	0 psf	0 psf	CCR
Column 125	214.62391 ft	693.53769 ft	0 psf	1,390.3877 psf	506.05973 psf	0 psf	0 psf	CCR
Column 126	215.49783 ft	693.82164 ft	0 psf	1,344.2736 psf	489.27557 psf	0 psf	0 psf	CCR
Column 127	216.37174 ft	694.10560 ft	0 psf	1,298.1595 psf	472.49141 psf	0 psf	0 psf	CCR
Column 128	217.24565 ft	694.38955 ft	0 psf	1,252.0454 psf	455.70725 psf	0 psf	0 psf	CCR
Column 129	218.11957 ft	694.67350 ft	0 psf	1,205.9313 psf	438.92309 psf	0 psf	0 psf	CCR
Column 130	218.99348 ft	694.95745 ft	0 psf	1,159.8172 psf	422.13893 psf	0 psf	0 psf	CCR
Column 131	219.86739 ft	695.24140 ft	0 psf	1,113.7031 psf	405.35477 psf	0 psf	0 psf	CCR
Column 132	220.74130 ft	695.52535 ft	0 psf	1,067.589 psf	388.57061 psf	0 psf	0 psf	CCR
Column 133	221.61522 ft	695.80930 ft	0 psf	1,021.4749 psf	371.78645 psf	0 psf	0 psf	CCR
Column 134	222.48913 ft	696.09326 ft	0 psf	975.36077 psf	355.00229 psf	0 psf	0 psf	CCR
Column 135	223.36304 ft	696.37721 ft	0 psf	929.24667 psf	338.21813 psf	0 psf	0 psf	CCR
Column 136	224.25325 ft	696.66645 ft	0 psf	882.27287 psf	321.12106 psf	0 psf	0 psf	CCR
Column 137	225.15975 ft	696.96099 ft	0 psf	834.43938 psf	303.7111 psf	0 psf	0 psf	CCR
Column 138	226.06624 ft	697.25553 ft	0 psf	786.60589 psf	286.30113 psf	0 psf	0 psf	CCR
Column 139	226.97274 ft	697.55007 ft	0 psf	738.7724 psf	268.89116 psf	0 psf	0 psf	CCR
Column 140	227.87924 ft	697.84461 ft	0 psf	690.93891 psf	251.4812 psf	0 psf	0 psf	CCR
Column 141	228.80159 ft	698.14430 ft	0 psf	651.22169 psf	346.26071 psf	0 psf	0 psf	Final Cover

Column 142	229.73981 ft	698.44915 ft	0 psf	576.96256 psf	306.77643 psf	0 psf	0 psf	Final Cover
Column 143	230.67803 ft	698.75399 ft	0 psf	502.70343 psf	267.29215 psf	0 psf	0 psf	Final Cover
Column 144	231.61624 ft	699.05883 ft	0 psf	428.44429 psf	227.80787 psf	0 psf	0 psf	Final Cover
Column 145	232.55446 ft	699.36368 ft	0 psf	354.18516 psf	188.32359 psf	0 psf	0 psf	Final Cover
Column 146	233.49268 ft	699.66852 ft	0 psf	279.92603 psf	148.83931 psf	0 psf	0 psf	Final Cover
Column 147	234.43089 ft	699.97337 ft	0 psf	205.6669 psf	109.35503 psf	0 psf	0 psf	Final Cover
Column 148	235.43234 ft	700.29876 ft	0 psf	126.403 psf	67.209668 psf	0 psf	0 psf	Final Cover
Column 149	236.49702 ft	700.64470 ft	0 psf	42.134333 psf	22.403223 psf	0 psf	0 psf	Final Cover

I-43 Plan of Operation Modification - Final Grade Stability Analysis
Block Failure-Contact Water Swale
Analysis Type: Janbu
Last Solved Date: 03/27/2024, 04:18:15 PM

Factor of Safety: 1.896

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Piezometric Surface
	CCR	86	0	20	
	Clay Liner	130	0	28	
	Drainage Layer	115	0	30	
	Final Cover	125	0	28	
	Geosynthetics	58	0	19.5	
	Subbase	135	0	28	1



Block Failure-Contact Water Swale

File Information

File Version: 11.05
Title: I-43 Plan of Operation Modification - Final Grade Stability Analysis
Created By: Villanueva, Niko
Last Edited By: Villanueva, Niko
Revision Number: 52
Date: 03/27/2024
Time: 04:16:14 PM
Tool Version: 23.1.1.829
File Name: I-43 Proposed Final Grades_Section A_240327.gsz
Directory: I:\25222259.00\Data and Calculations\Geotechnical\Slope Stability\SlopeW Analysis\
Last Solved Date: 03/27/2024
Last Solved Time: 04:18:15 PM

Project Settings

Unit System: U.S. Customary Units

Analysis Settings

Block Failure-Contact Water Swale

- Kind: SLOPE/W
- Analysis Type: Janbu
- Settings
  - PWP Conditions from: Piezometric Surfaces
  - Apply Phreatic Correction: No
  - Use Staged Rapid Drawdown: No
  - Unit Weight of Water: 62.430189 pcf
- Slip Surface
  - Direction of movement: Left to Right
  - Use Passive Mode: No
  - Slip Surface Option: Block
  - Critical slip surfaces saved: 10
  - Restrict Block Crossing: No
  - Optimize Critical Slip Surface Location: No
  - Tension Crack Option: (none)
- Distribution
  - F of S Calculation Option: Constant
- Convergence
  - Geometry Settings
    - Minimum Slip Surface Depth: 0.1 ft
    - Minimum Slip Surface Volume: 35.314667 ft³
    - Number of Columns: 150
  - Factor of Safety Convergence Settings
    - Maximum Number of Iterations: 100
    - Tolerable difference in F of S: 0.001

Under-Relaxation Criteria
Initial Rate: 1
Minimum Rate: 0.1
Rate Reduction Factor: 0.65
Reduction Frequency (iterations): 50

Materials

CCR

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 86 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 20 °
Phi-B: 0 °

Clay Liner

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 130 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °

Drainage Layer

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 30 °
Phi-B: 0 °

Geosynthetics

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 58 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 19.5 °
Phi-B: 0 °

Subbase

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 135 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Surface: 1

Final Cover

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 125 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (0, 730.2) ft
Right Coordinate: (377.2, 692.2) ft

Slip Surface Block

Left Grid
- Upper Left: (223.8, 679.9) ft
- Lower Left: (223.8, 679.8) ft
- Lower Right: (225.2, 679.81) ft
- X Increments: 10
- Y Increments: 4
- Starting Angle: 115 °
- Ending Angle: 160 °
- Angle Increments: 10

Right Grid
- Upper Left: (232.55, 679.97) ft
- Lower Left: (232.55, 679.88) ft
- Lower Right: (234.9, 679.9) ft
- X Increments: 10
- Y Increments: 4
- Angle Increments: 10

Piezometric Surfaces

Piezometric Surface 1

Coordinates

	X	Y
Coordinate 1	0 ft	676 ft
Coordinate 2	182.5 ft	681.1 ft
Coordinate 3	201.2 ft	682.1 ft
Coordinate 4	203.7 ft	682 ft
Coordinate 5	223.8 ft	675.8 ft
Coordinate 6	234.9 ft	675.9 ft
Coordinate 7	263 ft	684.3 ft
Coordinate 8	377.2 ft	684 ft

Geometry

Name: 2D Geometry

Settings

View: 2D
Element Thickness: 1 ft

Points

	X	Y
Point 1	0 ft	640 ft

Point 2	377.2 ft	640 ft
Point 3	377.2 ft	692.2 ft
Point 4	343.6 ft	695.9 ft
Point 5	302.7 ft	697.9 ft
Point 6	265.2 ft	690.1 ft
Point 7	263.1 ft	689.3 ft
Point 8	263.1 ft	688.4 ft
Point 9	263.1 ft	688.3 ft
Point 10	263.1 ft	684.3 ft
Point 11	234.9 ft	675.9 ft
Point 12	223.8 ft	675.8 ft
Point 13	203.7 ft	682 ft
Point 14	201.2 ft	682.1 ft
Point 15	201.2 ft	684.1 ft
Point 16	191.6 ft	684 ft
Point 17	182.5 ft	681.1 ft
Point 18	0 ft	676 ft
Point 19	0 ft	678 ft
Point 20	182.5 ft	683.1 ft
Point 21	191.6 ft	686 ft
Point 22	201.2 ft	686.1 ft
Point 23	203.7 ft	686 ft
Point 24	223.8 ft	679.8 ft
Point 25	234.9 ft	679.9 ft
Point 26	0 ft	678.1 ft
Point 27	182.5 ft	683.2 ft
Point 28	191.6 ft	686.1 ft
Point 29	201.2 ft	686.2 ft
Point 30	203.7 ft	686.1 ft
Point 31	223.8 ft	679.9 ft
Point 32	234.9 ft	680 ft
Point 33	0 ft	679 ft
Point 34	182.5 ft	684.1 ft
Point 35	191.6 ft	687 ft
Point 36	201.2 ft	687.1 ft
Point 37	203.7 ft	688 ft
Point 38	0 ft	725.2 ft
Point 39	113.97399 ft	726.5815 ft
Point 40	256.51003 ft	688.33703 ft
Point 41	234.9 ft	681.9 ft
Point 42	223.8 ft	681.8 ft
Point 43	0 ft	730.2 ft
Point 44	113.97399 ft	731.5815 ft
Point 45	273.22402 ft	691.769 ft

Regions

	Material	Points	Area
Region 1	Subbase	1,2,3,4,5,45,6,7,8,9,10,11,12,13,14,15,16,17,18	16,534 ft^2
Region 2	Clay Liner	18,19,20,21,22,23,24,25,9,10,11,12,13,14,15,16,17	650 ft^2

Region 3	Geosynthetics	19,26,27,28,29,30,31,32,8,9,25,24,23,22,21,20	26.31 ft²
Region 4	Drainage Layer	26,33,34,35,36,37,30,29,28,27	184.58 ft²
Region 5	CCR	33,38,39,7,40,41,42,37,36,35,34	8,689.4 ft²
Region 6	Final Cover	38,39,7,6,45,44,43	1,339.4 ft²
Region 7	Drainage Layer	37,42,41,40,7,8,32,31,30	109.57 ft²

Slip Results

Slip Surfaces Analysed: 278762 of 366025 converged

Current Slip Surface

Slip Surface: 365,306
Factor of Safety: 1.896
Volume: 1,869.0061 ft³
Weight: 188,114.67 lbf
Resisting Moment: 3,457,558.8 lbf·ft
Activating Moment: 1,372,842.6 lbf·ft
Resisting Force: 73,805.371 lbf
Activating Force: 38,935.764 lbf
Slip Rank: 1 of 366,025 slip surfaces
Exit: (261.47267, 694.70684) ft
Entry: (111.87312, 731.55603) ft
Radius: 69.361184 ft
Center: (193.48039, 740.76833) ft

Slip Columns

	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength	Suction Strength	Base Material
Column 1	112.39834 ft	731.31668 ft	0 psf	27.23483 psf	14.481016 psf	0 psf	0 psf	Final Cover
Column 2	113.44877 ft	730.83797 ft	0 psf	81.704491 psf	43.443048 psf	0 psf	0 psf	Final Cover
Column 3	114.46215 ft	730.37614 ft	0 psf	120.07035 psf	63.842537 psf	0 psf	0 psf	Final Cover
Column 4	115.43848 ft	729.93121 ft	0 psf	142.3324 psf	75.67948 psf	0 psf	0 psf	Final Cover
Column 5	116.41480 ft	729.48627 ft	0 psf	164.59445 psf	87.516424 psf	0 psf	0 psf	Final Cover
Column 6	117.39113 ft	729.04133 ft	0 psf	186.85651 psf	99.353368 psf	0 psf	0 psf	Final Cover
Column 7	118.36745 ft	728.59640 ft	0 psf	209.11856 psf	111.19031 psf	0 psf	0 psf	Final Cover
Column 8	119.34378 ft	728.15146 ft	0 psf	231.38062 psf	123.02726 psf	0 psf	0 psf	Final Cover
Column 9	120.32010 ft	727.70652 ft	0 psf	253.64267 psf	134.8642 psf	0 psf	0 psf	Final Cover
Column 10	121.29643 ft	727.26159 ft	0 psf	275.90472 psf	146.70114 psf	0 psf	0 psf	Final Cover
Column 11	122.27275 ft	726.81665 ft	0 psf	298.16678 psf	158.53809 psf	0 psf	0 psf	Final Cover

Column 12	123.24908 ft	726.37171 ft	0 psf	320.42883 psf	170.37503 psf	0 psf	0 psf	Final Cover
Column 13	124.22540 ft	725.92678 ft	0 psf	342.69088 psf	182.21197 psf	0 psf	0 psf	Final Cover
Column 14	125.20172 ft	725.48184 ft	0 psf	364.95294 psf	194.04892 psf	0 psf	0 psf	Final Cover
Column 15	126.17805 ft	725.03690 ft	0 psf	387.21499 psf	205.88586 psf	0 psf	0 psf	Final Cover
Column 16	127.15437 ft	724.59197 ft	0 psf	409.47704 psf	217.72281 psf	0 psf	0 psf	Final Cover
Column 17	128.13070 ft	724.14703 ft	0 psf	431.7391 psf	229.55975 psf	0 psf	0 psf	Final Cover
Column 18	129.10702 ft	723.70209 ft	0 psf	454.00115 psf	241.39669 psf	0 psf	0 psf	Final Cover
Column 19	130.08335 ft	723.25716 ft	0 psf	476.2632 psf	253.23364 psf	0 psf	0 psf	Final Cover
Column 20	131.05967 ft	722.81222 ft	0 psf	498.52526 psf	265.07058 psf	0 psf	0 psf	Final Cover
Column 21	132.03600 ft	722.36728 ft	0 psf	520.78731 psf	276.90752 psf	0 psf	0 psf	Final Cover
Column 22	133.01232 ft	721.92234 ft	0 psf	543.04936 psf	288.74447 psf	0 psf	0 psf	Final Cover
Column 23	134.00048 ft	721.47202 ft	0 psf	582.85938 psf	212.14346 psf	0 psf	0 psf	CCR
Column 24	135.00047 ft	721.01629 ft	0 psf	599.12849 psf	218.06494 psf	0 psf	0 psf	CCR
Column 25	136.00046 ft	720.56057 ft	0 psf	615.3976 psf	223.98641 psf	0 psf	0 psf	CCR
Column 26	137.00045 ft	720.10485 ft	0 psf	631.66672 psf	229.90788 psf	0 psf	0 psf	CCR
Column 27	138.00044 ft	719.64913 ft	0 psf	647.93583 psf	235.82936 psf	0 psf	0 psf	CCR
Column 28	139.00043 ft	719.19341 ft	0 psf	664.20494 psf	241.75083 psf	0 psf	0 psf	CCR
Column 29	140.00042 ft	718.73769 ft	0 psf	680.47406 psf	247.6723 psf	0 psf	0 psf	CCR
Column 30	141.00041 ft	718.28196 ft	0 psf	696.74317 psf	253.59377 psf	0 psf	0 psf	CCR
Column 31	142.00040 ft	717.82624 ft	0 psf	713.01228 psf	259.51525 psf	0 psf	0 psf	CCR
Column 32	143.00039 ft	717.37052 ft	0 psf	729.2814 psf	265.43672 psf	0 psf	0 psf	CCR
Column 33	144.00038 ft	716.91480 ft	0 psf	745.55051 psf	271.35819 psf	0 psf	0 psf	CCR
Column 34	145.00037 ft	716.45908 ft	0 psf	761.81962 psf	277.27967 psf	0 psf	0 psf	CCR
Column 35	146.00036 ft	716.00335 ft	0 psf	778.08874 psf	283.20114 psf	0 psf	0 psf	CCR
Column 36	147.00035 ft	715.54763 ft	0 psf	794.35785 psf	289.12261 psf	0 psf	0 psf	CCR
Column 37	148.00034 ft	715.09191 ft	0 psf	810.62696 psf	295.04409 psf	0 psf	0 psf	CCR

Column 38	149.00033 ft	714.63619 ft	0 psf	826.89608 psf	300.96556 psf	0 psf	0 psf	CCR
Column 39	150.00032 ft	714.18047 ft	0 psf	843.16519 psf	306.88703 psf	0 psf	0 psf	CCR
Column 40	151.00031 ft	713.72475 ft	0 psf	859.4343 psf	312.8085 psf	0 psf	0 psf	CCR
Column 41	152.00030 ft	713.26902 ft	0 psf	875.70342 psf	318.72998 psf	0 psf	0 psf	CCR
Column 42	153.00029 ft	712.81330 ft	0 psf	891.97253 psf	324.65145 psf	0 psf	0 psf	CCR
Column 43	154.00028 ft	712.35758 ft	0 psf	908.24164 psf	330.57292 psf	0 psf	0 psf	CCR
Column 44	155.00027 ft	711.90186 ft	0 psf	924.51076 psf	336.4944 psf	0 psf	0 psf	CCR
Column 45	156.00026 ft	711.44614 ft	0 psf	940.77987 psf	342.41587 psf	0 psf	0 psf	CCR
Column 46	157.00025 ft	710.99042 ft	0 psf	957.04898 psf	348.33734 psf	0 psf	0 psf	CCR
Column 47	158.00024 ft	710.53469 ft	0 psf	973.3181 psf	354.25882 psf	0 psf	0 psf	CCR
Column 48	159.00023 ft	710.07897 ft	0 psf	989.58721 psf	360.18029 psf	0 psf	0 psf	CCR
Column 49	160.00022 ft	709.62325 ft	0 psf	1,005.8563 psf	366.10176 psf	0 psf	0 psf	CCR
Column 50	161.00021 ft	709.16753 ft	0 psf	1,022.1254 psf	372.02323 psf	0 psf	0 psf	CCR
Column 51	162.00020 ft	708.71181 ft	0 psf	1,038.3945 psf	377.94471 psf	0 psf	0 psf	CCR
Column 52	163.00019 ft	708.25609 ft	0 psf	1,054.6637 psf	383.86618 psf	0 psf	0 psf	CCR
Column 53	164.00018 ft	707.80036 ft	0 psf	1,070.9328 psf	389.78765 psf	0 psf	0 psf	CCR
Column 54	165.00017 ft	707.34464 ft	0 psf	1,087.2019 psf	395.70913 psf	0 psf	0 psf	CCR
Column 55	166.00016 ft	706.88892 ft	0 psf	1,103.471 psf	401.6306 psf	0 psf	0 psf	CCR
Column 56	167.00015 ft	706.43320 ft	0 psf	1,119.7401 psf	407.55207 psf	0 psf	0 psf	CCR
Column 57	168.00014 ft	705.97748 ft	0 psf	1,136.0092 psf	413.47355 psf	0 psf	0 psf	CCR
Column 58	169.00013 ft	705.52175 ft	0 psf	1,152.2783 psf	419.39502 psf	0 psf	0 psf	CCR
Column 59	170.00012 ft	705.06603 ft	0 psf	1,168.5475 psf	425.31649 psf	0 psf	0 psf	CCR
Column 60	171.00011 ft	704.61031 ft	0 psf	1,184.8166 psf	431.23796 psf	0 psf	0 psf	CCR
Column 61	172.00010 ft	704.15459 ft	0 psf	1,201.0857 psf	437.15944 psf	0 psf	0 psf	CCR
Column 62	173.00009 ft	703.69887 ft	0 psf	1,217.3548 psf	443.08091 psf	0 psf	0 psf	CCR
Column 63	174.00008 ft	703.24315 ft	0 psf	1,233.6239 psf	449.00238 psf	0 psf	0 psf	CCR

Column 64	175.00007 ft	702.78742 ft	0 psf	1,249.893 psf	454.92386 psf	0 psf	0 psf	CCR
Column 65	176.00006 ft	702.33170 ft	0 psf	1,266.1621 psf	460.84533 psf	0 psf	0 psf	CCR
Column 66	177.00005 ft	701.87598 ft	0 psf	1,282.4312 psf	466.7668 psf	0 psf	0 psf	CCR
Column 67	178.00004 ft	701.42026 ft	0 psf	1,298.7004 psf	472.68828 psf	0 psf	0 psf	CCR
Column 68	179.00003 ft	700.96454 ft	0 psf	1,314.9695 psf	478.60975 psf	0 psf	0 psf	CCR
Column 69	180.00002 ft	700.50882 ft	0 psf	1,331.2386 psf	484.53122 psf	0 psf	0 psf	CCR
Column 70	181.00001 ft	700.05309 ft	0 psf	1,347.5077 psf	490.45269 psf	0 psf	0 psf	CCR
Column 71	182.00000 ft	699.59737 ft	0 psf	1,363.7768 psf	496.37417 psf	0 psf	0 psf	CCR
Column 72	182.99211 ft	699.14525 ft	0 psf	1,379.9176 psf	502.24892 psf	0 psf	0 psf	CCR
Column 73	183.97632 ft	698.69672 ft	0 psf	1,395.93 psf	508.07695 psf	0 psf	0 psf	CCR
Column 74	184.96053 ft	698.24818 ft	0 psf	1,411.9424 psf	513.90499 psf	0 psf	0 psf	CCR
Column 75	185.94474 ft	697.79965 ft	0 psf	1,427.9547 psf	519.73302 psf	0 psf	0 psf	CCR
Column 76	186.92895 ft	697.35112 ft	0 psf	1,443.9671 psf	525.56106 psf	0 psf	0 psf	CCR
Column 77	187.91316 ft	696.90259 ft	0 psf	1,459.9795 psf	531.38909 psf	0 psf	0 psf	CCR
Column 78	188.89737 ft	696.45406 ft	0 psf	1,475.9919 psf	537.21712 psf	0 psf	0 psf	CCR
Column 79	189.88158 ft	696.00553 ft	0 psf	1,492.0043 psf	543.04516 psf	0 psf	0 psf	CCR
Column 80	190.86579 ft	695.55700 ft	0 psf	1,508.0167 psf	548.87319 psf	0 psf	0 psf	CCR
Column 81	191.85000 ft	695.10847 ft	0 psf	1,524.0291 psf	554.70122 psf	0 psf	0 psf	CCR
Column 82	192.83421 ft	694.65994 ft	0 psf	1,540.0415 psf	560.52926 psf	0 psf	0 psf	CCR
Column 83	193.81842 ft	694.21141 ft	0 psf	1,556.0539 psf	566.35729 psf	0 psf	0 psf	CCR
Column 84	194.80263 ft	693.76288 ft	0 psf	1,572.0663 psf	572.18533 psf	0 psf	0 psf	CCR
Column 85	195.78684 ft	693.31435 ft	0 psf	1,588.0787 psf	578.01336 psf	0 psf	0 psf	CCR
Column 86	196.77105 ft	692.86582 ft	0 psf	1,604.091 psf	583.84139 psf	0 psf	0 psf	CCR
Column 87	197.75526 ft	692.41729 ft	0 psf	1,620.1034 psf	589.66943 psf	0 psf	0 psf	CCR
Column 88	198.73947 ft	691.96876 ft	0 psf	1,636.1158 psf	595.49746 psf	0 psf	0 psf	CCR
Column 89	199.72368 ft	691.52023 ft	0 psf	1,652.1282 psf	601.32549 psf	0 psf	0 psf	CCR

Column 90	200.70789 ft	691.07170 ft	0 psf	1,668.1406 psf	607.15353 psf	0 psf	0 psf	CCR
Column 91	201.61667 ft	690.65754 ft	0 psf	1,682.9257 psf	612.53485 psf	0 psf	0 psf	CCR
Column 92	202.45000 ft	690.27777 ft	0 psf	1,696.4834 psf	617.46946 psf	0 psf	0 psf	CCR
Column 93	203.28333 ft	689.89800 ft	0 psf	1,710.0411 psf	622.40407 psf	0 psf	0 psf	CCR
Column 94	204.18328 ft	689.48787 ft	0 psf	1,724.6825 psf	627.73311 psf	0 psf	0 psf	CCR
Column 95	205.14983 ft	689.04739 ft	0 psf	1,740.4077 psf	633.45659 psf	0 psf	0 psf	CCR
Column 96	206.11638 ft	688.60691 ft	0 psf	1,756.1328 psf	639.18006 psf	0 psf	0 psf	CCR
Column 97	207.08294 ft	688.16642 ft	0 psf	1,771.8579 psf	644.90354 psf	0 psf	0 psf	CCR
Column 98	208.04949 ft	687.72594 ft	0 psf	1,787.583 psf	650.62701 psf	0 psf	0 psf	CCR
Column 99	209.01604 ft	687.28545 ft	0 psf	1,803.3081 psf	656.35049 psf	0 psf	0 psf	CCR
Column 100	209.98260 ft	686.84497 ft	0 psf	1,819.0333 psf	662.07396 psf	0 psf	0 psf	CCR
Column 101	210.94915 ft	686.40449 ft	0 psf	1,834.7584 psf	667.79744 psf	0 psf	0 psf	CCR
Column 102	211.91570 ft	685.96400 ft	0 psf	1,850.4835 psf	673.52091 psf	0 psf	0 psf	CCR
Column 103	212.88225 ft	685.52352 ft	0 psf	1,866.2086 psf	679.24439 psf	0 psf	0 psf	CCR
Column 104	213.84881 ft	685.08304 ft	0 psf	1,881.9337 psf	684.96786 psf	0 psf	0 psf	CCR
Column 105	214.81536 ft	684.64255 ft	0 psf	1,897.6589 psf	690.69134 psf	0 psf	0 psf	CCR
Column 106	215.77094 ft	684.20707 ft	0 psf	1,828.8156 psf	1,055.8672 psf	0 psf	0 psf	Drainage Layer
Column 107	216.71553 ft	683.77660 ft	0 psf	1,847.0339 psf	1,066.3855 psf	0 psf	0 psf	Drainage Layer
Column 108	217.66013 ft	683.34612 ft	0 psf	1,865.2523 psf	1,076.9039 psf	0 psf	0 psf	Drainage Layer
Column 109	218.60472 ft	682.91564 ft	0 psf	1,883.4707 psf	1,087.4223 psf	0 psf	0 psf	Drainage Layer
Column 110	219.54932 ft	682.48516 ft	0 psf	1,901.6891 psf	1,097.9407 psf	0 psf	0 psf	Drainage Layer
Column 111	220.49391 ft	682.05469 ft	0 psf	1,919.9075 psf	1,108.4591 psf	0 psf	0 psf	Drainage Layer
Column 112	221.43851 ft	681.62421 ft	0 psf	1,938.1259 psf	1,118.9775 psf	0 psf	0 psf	Drainage Layer
Column 113	222.38311 ft	681.19373 ft	0 psf	1,956.3443 psf	1,129.4959 psf	0 psf	0 psf	Drainage Layer
Column 114	223.32770 ft	680.76326 ft	0 psf	1,974.5627 psf	1,140.0143 psf	0 psf	0 psf	Drainage Layer
Column 115	224.49719 ft	680.23029 ft	0 psf	2,002.7551 psf	1,156.2912 psf	0 psf	0 psf	Drainage Layer

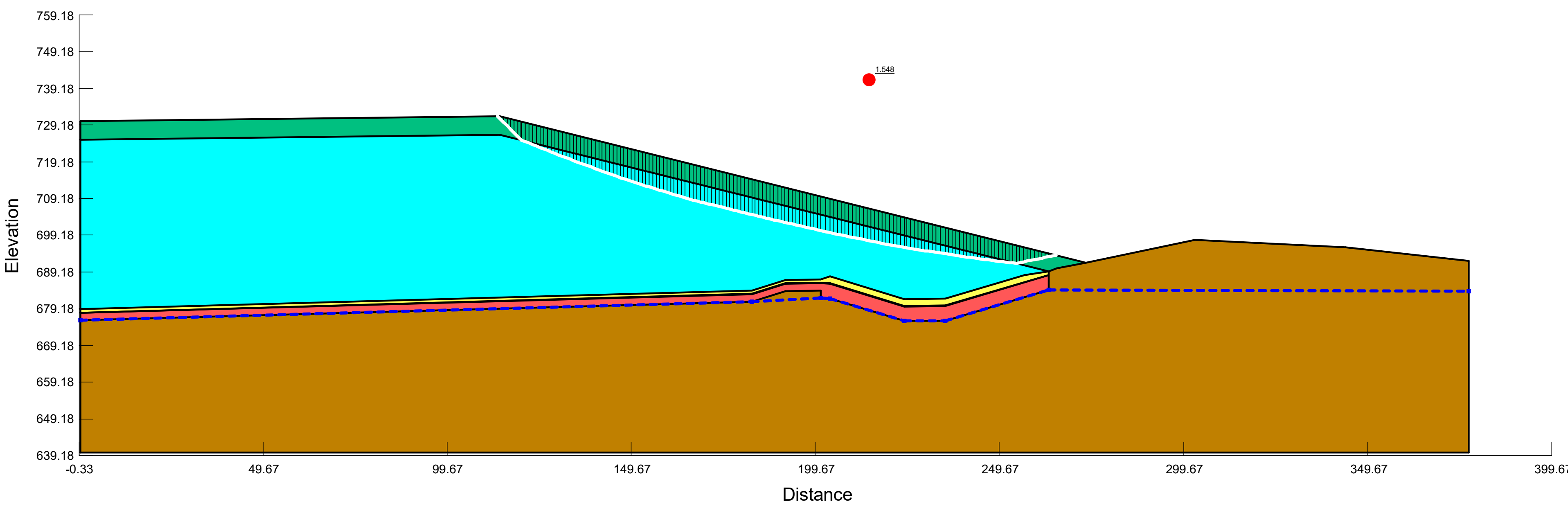
Column 116	225.72219 ft	679.91557 ft	0 psf	2,293.2003 psf	812.06482 psf	0 psf	0 psf	Geosynthetics
Column 117	226.77500 ft	679.92286 ft	0 psf	2,270.8737 psf	804.15857 psf	0 psf	0 psf	Geosynthetics
Column 118	227.82500 ft	679.93143 ft	0 psf	2,247.5011 psf	795.88188 psf	0 psf	0 psf	Geosynthetics
Column 119	228.87500 ft	679.94000 ft	0 psf	2,224.1285 psf	787.6052 psf	0 psf	0 psf	Geosynthetics
Column 120	229.92500 ft	679.94857 ft	0 psf	2,200.7558 psf	779.32851 psf	0 psf	0 psf	Geosynthetics
Column 121	230.97500 ft	679.95714 ft	0 psf	2,177.3832 psf	771.05183 psf	0 psf	0 psf	Geosynthetics
Column 122	232.03382 ft	679.97021 ft	0 psf	2,156.8106 psf	763.76669 psf	0 psf	0 psf	Geosynthetics
Column 123	233.15073 ft	680.27609 ft	0 psf	2,475.6858 psf	1,429.3379 psf	0 psf	0 psf	Drainage Layer
Column 124	234.31691 ft	680.87029 ft	0 psf	2,365.4885 psf	1,365.7154 psf	0 psf	0 psf	Drainage Layer
Column 125	235.47690 ft	681.46133 ft	0 psf	2,261.5964 psf	1,305.7333 psf	0 psf	0 psf	Drainage Layer
Column 126	236.63070 ft	682.04922 ft	0 psf	2,164.0094 psf	1,249.3914 psf	0 psf	0 psf	Drainage Layer
Column 127	237.78450 ft	682.63711 ft	0 psf	2,066.4225 psf	1,193.0496 psf	0 psf	0 psf	Drainage Layer
Column 128	238.84752 ft	683.17875 ft	0 psf	1,854.2051 psf	674.87545 psf	0 psf	0 psf	CCR
Column 129	239.81977 ft	683.67413 ft	0 psf	1,783.8141 psf	649.25524 psf	0 psf	0 psf	CCR
Column 130	240.79201 ft	684.16952 ft	0 psf	1,713.4232 psf	623.63504 psf	0 psf	0 psf	CCR
Column 131	241.76426 ft	684.66490 ft	0 psf	1,643.0322 psf	598.01483 psf	0 psf	0 psf	CCR
Column 132	242.73651 ft	685.16029 ft	0 psf	1,572.6413 psf	572.39463 psf	0 psf	0 psf	CCR
Column 133	243.70876 ft	685.65567 ft	0 psf	1,502.2504 psf	546.77442 psf	0 psf	0 psf	CCR
Column 134	244.68101 ft	686.15106 ft	0 psf	1,431.8594 psf	521.15422 psf	0 psf	0 psf	CCR
Column 135	245.65325 ft	686.64644 ft	0 psf	1,361.4685 psf	495.53401 psf	0 psf	0 psf	CCR
Column 136	246.62550 ft	687.14183 ft	0 psf	1,291.0776 psf	469.91381 psf	0 psf	0 psf	CCR
Column 137	247.59775 ft	687.63721 ft	0 psf	1,220.6866 psf	444.2936 psf	0 psf	0 psf	CCR
Column 138	248.57000 ft	688.13260 ft	0 psf	1,150.2957 psf	418.6734 psf	0 psf	0 psf	CCR
Column 139	249.54224 ft	688.62798 ft	0 psf	1,079.9048 psf	393.05319 psf	0 psf	0 psf	CCR
Column 140	250.51449 ft	689.12337 ft	0 psf	1,009.5138 psf	367.43299 psf	0 psf	0 psf	CCR
Column 141	251.48674 ft	689.61875 ft	0 psf	939.12291 psf	341.81278 psf	0 psf	0 psf	CCR

Column 142	252.45899 ft	690.11414 ft	0 psf	868.73197 psf	316.19258 psf	0 psf	0 psf	CCR
Column 143	253.43124 ft	690.60952 ft	0 psf	798.34104 psf	290.57238 psf	0 psf	0 psf	CCR
Column 144	254.40348 ft	691.10491 ft	0 psf	727.9501 psf	264.95217 psf	0 psf	0 psf	CCR
Column 145	255.35983 ft	691.59219 ft	0 psf	677.10021 psf	360.02057 psf	0 psf	0 psf	Final Cover
Column 146	256.30026 ft	692.07136 ft	0 psf	572.93094 psf	304.63279 psf	0 psf	0 psf	Final Cover
Column 147	257.24070 ft	692.55054 ft	0 psf	468.76168 psf	249.24501 psf	0 psf	0 psf	Final Cover
Column 148	258.18114 ft	693.02972 ft	0 psf	364.59242 psf	193.85723 psf	0 psf	0 psf	Final Cover
Column 149	259.12158 ft	693.50889 ft	0 psf	260.42316 psf	138.46945 psf	0 psf	0 psf	Final Cover
Column 150	260.06201 ft	693.98807 ft	0 psf	156.25389 psf	83.081669 psf	0 psf	0 psf	Final Cover
Column 151	261.00245 ft	694.46725 ft	0 psf	52.084631 psf	27.69389 psf	0 psf	0 psf	Final Cover

I-43 Plan of Operation Modification - Final Grade Stability Analysis
Optimized Circular Failure
Analysis Type: Bishop
Last Solved Date: 03/27/2024, 12:28:42 PM

Factor of Safety: 1.548

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Piezometric Surface
	CCR	86	0	20	
	Clay Liner	130	0	28	
	Drainage Layer	115	0	30	
	Final Cover	125	0	28	
	Geosynthetics	58	0	19.5	
	Subbase	135	0	28	1



Optimized Circular Failure

File Information

File Version: 11.05
Title: I-43 Plan of Operation Modification - Final Grade Stability Analysis
Created By: Villanueva, Niko
Last Edited By: Villanueva, Niko
Revision Number: 50
Date: 03/27/2024
Time: 12:27:25 PM
Tool Version: 23.1.1.829
File Name: I-43 Proposed Final Grades_Section A_240327.gsz
Directory: I:\25222259.00\Data and Calculations\Geotechnical\Slope Stability\SlopeW Analysis\
Last Solved Date: 03/27/2024
Last Solved Time: 12:28:42 PM

Project Settings

Unit System: U.S. Customary Units

Analysis Settings

Optimized Circular Failure

Kind: SLOPE/W
Analysis Type: Bishop
Settings
- PWP Conditions from: Piezometric Surfaces
- Apply Phreatic Correction: No
- Use Staged Rapid Drawdown: No
- Unit Weight of Water: 62.430189 pcf

Slip Surface
- Direction of movement: Left to Right
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 10
- Optimize Critical Slip Surface Location: Yes
- Optimizations Settings
  - Maximum Iterations: 2,000
  - Starting Points: 8
  - Ending Points: 16
  - Driving Side Maximum Convex Angle: 5 °
  - Resisting Side Maximum Convex Angle: 1 °
- Tension Crack Option: (none)

Distribution
- F of S Calculation Option: Constant

Convergence
- Geometry Settings
  - Minimum Slip Surface Depth: 0.1 ft

Minimum Slip Surface Volume: 35.314667 ft^3
Number of Columns: 150
Factor of Safety Convergence Settings
Maximum Number of Iterations: 100
Tolerable difference in F of S: 0.001
Under-Relaxation Criteria
Initial Rate: 1
Minimum Rate: 0.1
Rate Reduction Factor: 0.65
Reduction Frequency (iterations): 50

Materials

CCR

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 86 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 20 °
Phi-B: 0 °

Clay Liner

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 130 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °

Drainage Layer

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 30 °
Phi-B: 0 °

Geosynthetics

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 58 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 19.5 °
Phi-B: 0 °

Subbase

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 135 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Surface: 1

Final Cover

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 125 pcf

Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Type: Range
Left-Zone Left Coordinate: (83.06545, 731.20685) ft
Left-Zone Right Coordinate: (147, 723.325) ft
Left-Zone Increment: 100
Right Type: Range
Right-Zone Left Coordinate: (246.03204, 698.56699) ft
Right-Zone Right Coordinate: (293, 695.8824) ft
Right-Zone Increment: 100
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 730.2) ft
Right Coordinate: (377.2, 692.2) ft

Piezometric Surfaces

Piezometric Surface 1

Coordinates

	X	Y
Coordinate 1	0 ft	676 ft
Coordinate 2	182.5 ft	681.1 ft
Coordinate 3	201.2 ft	682.1 ft
Coordinate 4	203.7 ft	682 ft
Coordinate 5	223.8 ft	675.8 ft
Coordinate 6	234.9 ft	675.9 ft
Coordinate 7	263.1 ft	684.3 ft
Coordinate 8	377.2 ft	684 ft

Geometry

Name: 2D Geometry

Settings

View: 2D
Element Thickness: 1 ft

Points

	X	Y
Point 1	0 ft	640 ft
Point 2	377.2 ft	640 ft
Point 3	377.2 ft	692.2 ft

Point 4	343.6 ft	695.9 ft
Point 5	302.7 ft	697.9 ft
Point 6	265.2 ft	690.1 ft
Point 7	263.1 ft	689.3 ft
Point 8	263.1 ft	688.4 ft
Point 9	263.1 ft	688.3 ft
Point 10	263.1 ft	684.3 ft
Point 11	234.9 ft	675.9 ft
Point 12	223.8 ft	675.8 ft
Point 13	203.7 ft	682 ft
Point 14	201.2 ft	682.1 ft
Point 15	201.2 ft	684.1 ft
Point 16	191.6 ft	684 ft
Point 17	182.5 ft	681.1 ft
Point 18	0 ft	676 ft
Point 19	0 ft	678 ft
Point 20	182.5 ft	683.1 ft
Point 21	191.6 ft	686 ft
Point 22	201.2 ft	686.1 ft
Point 23	203.7 ft	686 ft
Point 24	223.8 ft	679.8 ft
Point 25	234.9 ft	679.9 ft
Point 26	0 ft	678.1 ft
Point 27	182.5 ft	683.2 ft
Point 28	191.6 ft	686.1 ft
Point 29	201.2 ft	686.2 ft
Point 30	203.7 ft	686.1 ft
Point 31	223.8 ft	679.9 ft
Point 32	234.9 ft	680 ft
Point 33	0 ft	679 ft
Point 34	182.5 ft	684.1 ft
Point 35	191.6 ft	687 ft
Point 36	201.2 ft	687.1 ft
Point 37	203.7 ft	688 ft
Point 38	0 ft	725.2 ft
Point 39	113.97399 ft	726.5815 ft
Point 40	256.51003 ft	688.33703 ft
Point 41	234.9 ft	681.9 ft
Point 42	223.8 ft	681.8 ft
Point 43	0 ft	730.2 ft
Point 44	113.97399 ft	731.5815 ft
Point 45	273.22402 ft	691.769 ft

Regions

	Material	Points	Area
Region 1	Subbase	1,2,3,4,5,45,6,7,8,9,10,11,12,13,14,15,16,17,18	16,534 ft^2
Region 2	Clay Liner	18,19,20,21,22,23,24,25,9,10,11,12,13,14,15,16,17	650 ft^2
Region 3	Geosynthetics	19,26,27,28,29,30,31,32,8,9,25,24,23,22,21,20	26.31 ft^2
Region 4	Drainage Layer	26,33,34,35,36,37,30,29,28,27	184.58 ft^2

Region 5	CCR	33,38,39,7,40,41,42,37,36,35,34	8,689.4 ft²
Region 6	Final Cover	38,39,7,6,45,44,43	1,339.4 ft²
Region 7	Drainage Layer	37,42,41,40,7,8,32,31,30	109.57 ft²

Slip Results

Slip Surfaces Analysed: 109477 of 112212 converged

Current Slip Surface

Slip Surface: 112,212
Factor of Safety: 1.548
Volume: 1,151.4271 ft³
Weight: 126,959.35 lbf
Resisting Moment: 11,504,102 lbf·ft
Activating Moment: 7,429,425.5 lbf·ft
Resisting Force: 44,501.749 lbf
Activating Force: 29,268.743 lbf
Slip Rank: 1 of 112,212 slip surfaces
Exit: (265.15225, 693.78694) ft
Entry: (113.32553, 731.57364) ft
Radius: 68.499226 ft
Center: (248.51788, 943.53514) ft

Slip Columns

	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength	Suction Strength	Base Material
Column 1	113.64976 ft	731.24798 ft	0 psf	30.636178 psf	16.289545 psf	0 psf	0 psf	Final Cover
Column 2	114.45348 ft	730.44071 ft	0 psf	94.896169 psf	50.457188 psf	0 psf	0 psf	Final Cover
Column 3	115.41246 ft	729.47749 ft	0 psf	162.14379 psf	86.213384 psf	0 psf	0 psf	Final Cover
Column 4	116.37145 ft	728.51428 ft	0 psf	229.39142 psf	121.96958 psf	0 psf	0 psf	Final Cover
Column 5	117.33043 ft	727.55106 ft	0 psf	296.63904 psf	157.72578 psf	0 psf	0 psf	Final Cover
Column 6	118.28941 ft	726.58785 ft	0 psf	363.88667 psf	193.48197 psf	0 psf	0 psf	Final Cover
Column 7	119.24840 ft	725.62463 ft	0 psf	431.13429 psf	229.23817 psf	0 psf	0 psf	Final Cover
Column 8	119.75223 ft	725.11858 ft	0 psf	506.93471 psf	184.50915 psf	0 psf	0 psf	CCR
Column 9	120.28447 ft	724.89090 ft	0 psf	580.16643 psf	211.16331 psf	0 psf	0 psf	CCR
Column 10	121.30028 ft	724.48443 ft	0 psf	592.15551 psf	215.52698 psf	0 psf	0 psf	CCR
Column 11	122.31609 ft	724.07796 ft	0 psf	604.14459 psf	219.89065 psf	0 psf	0 psf	CCR
Column 12	123.33189 ft	723.67149 ft	0 psf	616.13367 psf	224.25432 psf	0 psf	0 psf	CCR

Column 13	124.34770 ft	723.26503 ft	0 psf	628.12276 psf	228.61799 psf	0 psf	0 psf	CCR
Column 14	125.36351 ft	722.85856 ft	0 psf	640.11184 psf	232.98166 psf	0 psf	0 psf	CCR
Column 15	126.37931 ft	722.45209 ft	0 psf	652.10092 psf	237.34532 psf	0 psf	0 psf	CCR
Column 16	127.39512 ft	722.04563 ft	0 psf	664.09 psf	241.70899 psf	0 psf	0 psf	CCR
Column 17	128.41092 ft	721.63916 ft	0 psf	676.07908 psf	246.07266 psf	0 psf	0 psf	CCR
Column 18	129.42673 ft	721.23269 ft	0 psf	688.06816 psf	250.43633 psf	0 psf	0 psf	CCR
Column 19	130.44254 ft	720.82622 ft	0 psf	700.05724 psf	254.8 psf	0 psf	0 psf	CCR
Column 20	131.44273 ft	720.44124 ft	0 psf	715.41991 psf	260.39155 psf	0 psf	0 psf	CCR
Column 21	132.42731 ft	720.07774 ft	0 psf	724.70691 psf	263.77174 psf	0 psf	0 psf	CCR
Column 22	133.41189 ft	719.71424 ft	0 psf	733.99391 psf	267.15193 psf	0 psf	0 psf	CCR
Column 23	134.39647 ft	719.35073 ft	0 psf	743.2809 psf	270.53212 psf	0 psf	0 psf	CCR
Column 24	135.38106 ft	718.98723 ft	0 psf	752.5679 psf	273.91231 psf	0 psf	0 psf	CCR
Column 25	136.36564 ft	718.62373 ft	0 psf	761.8549 psf	277.2925 psf	0 psf	0 psf	CCR
Column 26	137.35022 ft	718.26023 ft	0 psf	771.14189 psf	280.6727 psf	0 psf	0 psf	CCR
Column 27	138.33480 ft	717.89673 ft	0 psf	780.42889 psf	284.05289 psf	0 psf	0 psf	CCR
Column 28	139.31938 ft	717.53322 ft	0 psf	789.71589 psf	287.43308 psf	0 psf	0 psf	CCR
Column 29	140.30396 ft	717.16972 ft	0 psf	799.00288 psf	290.81327 psf	0 psf	0 psf	CCR
Column 30	141.28854 ft	716.80622 ft	0 psf	808.28988 psf	294.19346 psf	0 psf	0 psf	CCR
Column 31	142.27312 ft	716.44272 ft	0 psf	817.57687 psf	297.57365 psf	0 psf	0 psf	CCR
Column 32	143.25771 ft	716.07922 ft	0 psf	826.86387 psf	300.95384 psf	0 psf	0 psf	CCR
Column 33	144.24229 ft	715.71571 ft	0 psf	836.15087 psf	304.33403 psf	0 psf	0 psf	CCR
Column 34	145.22687 ft	715.35221 ft	0 psf	845.43786 psf	307.71422 psf	0 psf	0 psf	CCR
Column 35	146.21145 ft	714.98871 ft	0 psf	854.72486 psf	311.09441 psf	0 psf	0 psf	CCR
Column 36	147.19203 ft	714.65207 ft	0 psf	871.76299 psf	317.29578 psf	0 psf	0 psf	CCR
Column 37	148.16861 ft	714.34228 ft	0 psf	877.01669 psf	319.20797 psf	0 psf	0 psf	CCR
Column 38	149.14518 ft	714.03249 ft	0 psf	882.2704 psf	321.12016 psf	0 psf	0 psf	CCR

Column 39	150.12176 ft	713.72270 ft	0 psf	887.5241 psf	323.03236 psf	0 psf	0 psf	CCR
Column 40	151.09834 ft	713.41292 ft	0 psf	892.77781 psf	324.94455 psf	0 psf	0 psf	CCR
Column 41	152.07492 ft	713.10313 ft	0 psf	898.03152 psf	326.85674 psf	0 psf	0 psf	CCR
Column 42	153.05149 ft	712.79334 ft	0 psf	903.28522 psf	328.76893 psf	0 psf	0 psf	CCR
Column 43	154.02807 ft	712.48355 ft	0 psf	908.53893 psf	330.68113 psf	0 psf	0 psf	CCR
Column 44	154.99993 ft	712.18105 ft	0 psf	915.69988 psf	333.2875 psf	0 psf	0 psf	CCR
Column 45	155.96706 ft	711.88583 ft	0 psf	919.98796 psf	334.84823 psf	0 psf	0 psf	CCR
Column 46	156.93419 ft	711.59061 ft	0 psf	924.27604 psf	336.40897 psf	0 psf	0 psf	CCR
Column 47	157.90133 ft	711.29539 ft	0 psf	928.56412 psf	337.9697 psf	0 psf	0 psf	CCR
Column 48	158.86846 ft	711.00016 ft	0 psf	932.8522 psf	339.53043 psf	0 psf	0 psf	CCR
Column 49	159.83560 ft	710.70494 ft	0 psf	937.14028 psf	341.09117 psf	0 psf	0 psf	CCR
Column 50	160.80273 ft	710.40972 ft	0 psf	941.42836 psf	342.6519 psf	0 psf	0 psf	CCR
Column 51	161.76986 ft	710.11450 ft	0 psf	945.71644 psf	344.21263 psf	0 psf	0 psf	CCR
Column 52	162.77145 ft	709.81460 ft	0 psf	952.03993 psf	346.5142 psf	0 psf	0 psf	CCR
Column 53	163.80748 ft	709.51001 ft	0 psf	955.70627 psf	347.84863 psf	0 psf	0 psf	CCR
Column 54	164.84351 ft	709.20543 ft	0 psf	959.37261 psf	349.18307 psf	0 psf	0 psf	CCR
Column 55	165.87954 ft	708.90084 ft	0 psf	963.03895 psf	350.51751 psf	0 psf	0 psf	CCR
Column 56	166.90076 ft	708.62504 ft	0 psf	975.09128 psf	354.9042 psf	0 psf	0 psf	CCR
Column 57	167.90716 ft	708.37802 ft	0 psf	974.71902 psf	354.76871 psf	0 psf	0 psf	CCR
Column 58	168.91357 ft	708.13099 ft	0 psf	974.34675 psf	354.63322 psf	0 psf	0 psf	CCR
Column 59	169.91997 ft	707.88397 ft	0 psf	973.97449 psf	354.49772 psf	0 psf	0 psf	CCR
Column 60	170.92637 ft	707.63695 ft	0 psf	973.60222 psf	354.36223 psf	0 psf	0 psf	CCR
Column 61	171.93277 ft	707.38993 ft	0 psf	973.22996 psf	354.22674 psf	0 psf	0 psf	CCR
Column 62	172.93918 ft	707.14291 ft	0 psf	972.8577 psf	354.09124 psf	0 psf	0 psf	CCR
Column 63	173.94558 ft	706.89588 ft	0 psf	972.48543 psf	353.95575 psf	0 psf	0 psf	CCR
Column 64	174.95198 ft	706.64886 ft	0 psf	972.11317 psf	353.82026 psf	0 psf	0 psf	CCR

Column 65	175.95838 ft	706.40184 ft	0 psf	971.7409 psf	353.68476 psf	0 psf	0 psf	CCR
Column 66	176.96479 ft	706.15482 ft	0 psf	971.36864 psf	353.54927 psf	0 psf	0 psf	CCR
Column 67	177.97119 ft	705.90779 ft	0 psf	970.99638 psf	353.41378 psf	0 psf	0 psf	CCR
Column 68	178.97759 ft	705.66077 ft	0 psf	970.62411 psf	353.27829 psf	0 psf	0 psf	CCR
Column 69	179.98399 ft	705.41375 ft	0 psf	970.25185 psf	353.14279 psf	0 psf	0 psf	CCR
Column 70	180.99040 ft	705.16673 ft	0 psf	969.87958 psf	353.0073 psf	0 psf	0 psf	CCR
Column 71	181.99680 ft	704.91971 ft	0 psf	969.50732 psf	352.87181 psf	0 psf	0 psf	CCR
Column 72	182.85870 ft	704.70815 ft	0 psf	969.18851 psf	352.75577 psf	0 psf	0 psf	CCR
Column 73	183.73643 ft	704.49596 ft	0 psf	969.94771 psf	353.03209 psf	0 psf	0 psf	CCR
Column 74	184.77450 ft	704.24765 ft	0 psf	969.03451 psf	352.69972 psf	0 psf	0 psf	CCR
Column 75	185.81258 ft	703.99935 ft	0 psf	968.12132 psf	352.36734 psf	0 psf	0 psf	CCR
Column 76	186.85065 ft	703.75105 ft	0 psf	967.20813 psf	352.03497 psf	0 psf	0 psf	CCR
Column 77	187.88873 ft	703.50275 ft	0 psf	966.29493 psf	351.70259 psf	0 psf	0 psf	CCR
Column 78	188.92680 ft	703.25444 ft	0 psf	965.38174 psf	351.37022 psf	0 psf	0 psf	CCR
Column 79	189.93560 ft	703.01918 ft	0 psf	966.65285 psf	351.83286 psf	0 psf	0 psf	CCR
Column 80	190.91511 ft	702.79695 ft	0 psf	964.80335 psf	351.1597 psf	0 psf	0 psf	CCR
Column 81	191.89462 ft	702.57472 ft	0 psf	962.95386 psf	350.48654 psf	0 psf	0 psf	CCR
Column 82	192.87414 ft	702.35250 ft	0 psf	961.10436 psf	349.81338 psf	0 psf	0 psf	CCR
Column 83	193.85365 ft	702.13027 ft	0 psf	959.25487 psf	349.14022 psf	0 psf	0 psf	CCR
Column 84	194.83316 ft	701.90805 ft	0 psf	957.40537 psf	348.46706 psf	0 psf	0 psf	CCR
Column 85	195.81268 ft	701.68582 ft	0 psf	955.55587 psf	347.7939 psf	0 psf	0 psf	CCR
Column 86	196.79219 ft	701.46359 ft	0 psf	953.70638 psf	347.12073 psf	0 psf	0 psf	CCR
Column 87	197.77170 ft	701.24137 ft	0 psf	951.85688 psf	346.44757 psf	0 psf	0 psf	CCR
Column 88	198.75122 ft	701.01914 ft	0 psf	950.00739 psf	345.77441 psf	0 psf	0 psf	CCR
Column 89	199.73073 ft	700.79692 ft	0 psf	948.15789 psf	345.10125 psf	0 psf	0 psf	CCR
Column 90	200.71024 ft	700.57469 ft	0 psf	946.30839 psf	344.42809 psf	0 psf	0 psf	CCR

Column 91	201.82500 ft	700.32178 ft	0 psf	944.20353 psf	343.66198 psf	0 psf	0 psf	CCR
Column 92	203.07500 ft	700.03819 ft	0 psf	941.84331 psf	342.80293 psf	0 psf	0 psf	CCR
Column 93	204.21019 ft	699.78064 ft	0 psf	939.69988 psf	342.02278 psf	0 psf	0 psf	CCR
Column 94	205.23056 ft	699.54915 ft	0 psf	937.77323 psf	341.32154 psf	0 psf	0 psf	CCR
Column 95	206.24366 ft	699.33135 ft	0 psf	939.90027 psf	342.09572 psf	0 psf	0 psf	CCR
Column 96	207.24947 ft	699.12726 ft	0 psf	936.01276 psf	340.68079 psf	0 psf	0 psf	CCR
Column 97	208.25528 ft	698.92316 ft	0 psf	932.12525 psf	339.26585 psf	0 psf	0 psf	CCR
Column 98	209.26109 ft	698.71907 ft	0 psf	928.23774 psf	337.85091 psf	0 psf	0 psf	CCR
Column 99	210.26690 ft	698.51498 ft	0 psf	924.35024 psf	336.43597 psf	0 psf	0 psf	CCR
Column 100	211.27272 ft	698.31088 ft	0 psf	920.46273 psf	335.02103 psf	0 psf	0 psf	CCR
Column 101	212.27853 ft	698.10679 ft	0 psf	916.57522 psf	333.6061 psf	0 psf	0 psf	CCR
Column 102	213.28434 ft	697.90269 ft	0 psf	912.68771 psf	332.19116 psf	0 psf	0 psf	CCR
Column 103	214.29015 ft	697.69860 ft	0 psf	908.8002 psf	330.77622 psf	0 psf	0 psf	CCR
Column 104	215.29596 ft	697.49451 ft	0 psf	904.91269 psf	329.36128 psf	0 psf	0 psf	CCR
Column 105	216.30178 ft	697.29041 ft	0 psf	901.02518 psf	327.94634 psf	0 psf	0 psf	CCR
Column 106	217.30759 ft	697.08632 ft	0 psf	897.13767 psf	326.53141 psf	0 psf	0 psf	CCR
Column 107	218.31340 ft	696.88223 ft	0 psf	893.25016 psf	325.11647 psf	0 psf	0 psf	CCR
Column 108	219.31921 ft	696.67813 ft	0 psf	889.36265 psf	323.70153 psf	0 psf	0 psf	CCR
Column 109	220.32502 ft	696.47404 ft	0 psf	885.47514 psf	322.28659 psf	0 psf	0 psf	CCR
Column 110	221.32327 ft	696.28396 ft	0 psf	885.59843 psf	322.33147 psf	0 psf	0 psf	CCR
Column 111	222.31396 ft	696.10791 ft	0 psf	879.68619 psf	320.17959 psf	0 psf	0 psf	CCR
Column 112	223.30465 ft	695.93185 ft	0 psf	873.77396 psf	318.02771 psf	0 psf	0 psf	CCR
Column 113	224.16823 ft	695.77839 ft	0 psf	868.62031 psf	316.15194 psf	0 psf	0 psf	CCR
Column 114	225.02936 ft	695.63768 ft	0 psf	867.35385 psf	315.69099 psf	0 psf	0 psf	CCR
Column 115	226.01517 ft	695.48713 ft	0 psf	859.39196 psf	312.79309 psf	0 psf	0 psf	CCR
Column 116	227.00097 ft	695.33658 ft	0 psf	851.43006 psf	309.8952 psf	0 psf	0 psf	CCR

Column 117	227.98678 ft	695.18603 ft	0 psf	843.46817 psf	306.99731 psf	0 psf	0 psf	CCR
Column 118	228.97258 ft	695.03548 ft	0 psf	835.50627 psf	304.09941 psf	0 psf	0 psf	CCR
Column 119	229.95839 ft	694.88493 ft	0 psf	827.54437 psf	301.20152 psf	0 psf	0 psf	CCR
Column 120	230.94419 ft	694.73438 ft	0 psf	819.58248 psf	298.30363 psf	0 psf	0 psf	CCR
Column 121	231.93000 ft	694.58383 ft	0 psf	811.62058 psf	295.40573 psf	0 psf	0 psf	CCR
Column 122	233.04217 ft	694.41610 ft	0 psf	803.08363 psf	292.29854 psf	0 psf	0 psf	CCR
Column 123	234.28072 ft	694.23117 ft	0 psf	792.72201 psf	288.52722 psf	0 psf	0 psf	CCR
Column 124	235.38552 ft	694.06622 ft	0 psf	783.4794 psf	285.16318 psf	0 psf	0 psf	CCR
Column 125	236.35655 ft	693.92123 ft	0 psf	775.35581 psf	282.20644 psf	0 psf	0 psf	CCR
Column 126	237.32758 ft	693.77625 ft	0 psf	767.23222 psf	279.24969 psf	0 psf	0 psf	CCR
Column 127	238.29862 ft	693.63126 ft	0 psf	759.10862 psf	276.29294 psf	0 psf	0 psf	CCR
Column 128	239.26965 ft	693.48628 ft	0 psf	750.98503 psf	273.3362 psf	0 psf	0 psf	CCR
Column 129	240.24068 ft	693.34130 ft	0 psf	742.86144 psf	270.37945 psf	0 psf	0 psf	CCR
Column 130	241.21171 ft	693.19631 ft	0 psf	734.73785 psf	267.42271 psf	0 psf	0 psf	CCR
Column 131	242.18275 ft	693.05133 ft	0 psf	726.61425 psf	264.46596 psf	0 psf	0 psf	CCR
Column 132	243.15378 ft	692.90635 ft	0 psf	718.49066 psf	261.50921 psf	0 psf	0 psf	CCR
Column 133	244.12481 ft	692.76136 ft	0 psf	710.36707 psf	258.55247 psf	0 psf	0 psf	CCR
Column 134	245.09155 ft	692.63024 ft	0 psf	705.58199 psf	256.81084 psf	0 psf	0 psf	CCR
Column 135	246.05400 ft	692.51299 ft	0 psf	695.26873 psf	253.05712 psf	0 psf	0 psf	CCR
Column 136	247.01644 ft	692.39573 ft	0 psf	684.95548 psf	249.30341 psf	0 psf	0 psf	CCR
Column 137	247.97888 ft	692.27847 ft	0 psf	674.64222 psf	245.54969 psf	0 psf	0 psf	CCR
Column 138	248.94133 ft	692.16122 ft	0 psf	664.32897 psf	241.79597 psf	0 psf	0 psf	CCR
Column 139	249.90377 ft	692.04396 ft	0 psf	654.01571 psf	238.04225 psf	0 psf	0 psf	CCR
Column 140	250.86622 ft	691.92670 ft	0 psf	643.70246 psf	234.28853 psf	0 psf	0 psf	CCR
Column 141	251.82866 ft	691.80945 ft	0 psf	633.3892 psf	230.53482 psf	0 psf	0 psf	CCR
Column 142	252.79110 ft	691.69219 ft	0 psf	623.07595 psf	226.7811 psf	0 psf	0 psf	CCR

Column 143	253.75358 ft	691.57493 ft	0 psf	612.76209 psf	223.02716 psf	0 psf	0 psf	CCR
Column 144	254.72734 ft	691.61873 ft	0 psf	642.68899 psf	341.7238 psf	0 psf	0 psf	Final Cover
Column 145	255.71236 ft	691.82360 ft	0 psf	581.96321 psf	309.43533 psf	0 psf	0 psf	Final Cover
Column 146	256.69738 ft	692.02847 ft	0 psf	521.23743 psf	277.14686 psf	0 psf	0 psf	Final Cover
Column 147	257.68240 ft	692.23334 ft	0 psf	460.51165 psf	244.85839 psf	0 psf	0 psf	Final Cover
Column 148	258.66742 ft	692.43820 ft	0 psf	399.78587 psf	212.56992 psf	0 psf	0 psf	Final Cover
Column 149	259.65243 ft	692.64307 ft	0 psf	339.06009 psf	180.28145 psf	0 psf	0 psf	Final Cover
Column 150	260.63745 ft	692.84794 ft	0 psf	278.33431 psf	147.99298 psf	0 psf	0 psf	Final Cover
Column 151	261.62247 ft	693.05281 ft	0 psf	217.60853 psf	115.70451 psf	0 psf	0 psf	Final Cover
Column 152	262.60749 ft	693.25767 ft	0 psf	156.88275 psf	83.416036 psf	0 psf	0 psf	Final Cover
Column 153	263.61306 ft	693.46682 ft	0 psf	94.889892 psf	50.453851 psf	0 psf	0 psf	Final Cover
Column 154	264.63919 ft	693.68023 ft	0 psf	31.629964 psf	16.81795 psf	0 psf	0 psf	Final Cover

Appendix C

Leachate Calculations

SCS ENGINEERS

		Sheet No. 1 of 6	
		Calc. No.	
		Rev. No.	
Job No. 25222259.00	Job: Edgewater I-43 Ash Disposal Facility	By: RPR	Date: 04/11/24
Client: Wisconsin Power & Light	Subject: Leachate Pump Design	Chk'd: MRH	Date: 04/11/24

Purpose:

To size the contact water swale leachate sump pump to pump leachate from the contact water swale sump to the contact water basin.

Approach:

Determine the total dynamic head that the pump will operate against under various pumping rates.

The total dynamic head is a combination of the static head and friction losses from flow through pipe/fittings.

Plot the resulting system curve on a representative pump curve to determine the suitability of a pump.

Calculations:

Pump System Layout

Contact Water Swale Sump -----> Contact Water Swale Vault -----> Contact Water Pond

Pipe Header Lengths	Pipe Length		Pipe Material
Sump to Vault	50	ft	2" HDPE
Vault to Contact Water Pond	75	ft	3" HDPE

Results:

For the contact water sump pump, a EPG Model 5-2/1 - 1/2 HP pump will pump at 15 GPM.

Calculations (cont.):

Static Heads Elevation:

Contact Water Swale Sump 673.70

Contact Water Swale Vault (High Point)* 693.00

* Assumed to be 3.5' above course aggregate surface elevation

Static Head 19.30 ft.

Fittings and Equivalent Length (see Sheet 5)

Contact Water Swale Vault

	Eq. Length (ft)				Total Eq. Length (ft)
Vacuum Relief Valve, 2"	1	X	**60**	=	60
Gate Valve, 2" (3/4 closed)	1	X	**150**	=	150
Flow Meter, 2"	1	X	**60**	=	60
Ball Valve, 2" (open)	1	X	**60**	=	60
Tee, 2"	1	X	**13**	=	13
90° Elbow, 2"	7	X	**6**	=	42
Reducer 2" - 3"	1	X	**2**	=	2
			Total:		385

Contact Water Swale Sump to Vault

Actual Length (2" HDPE)		50
	Equivalent Length =	435

Vault to Contact Water Pond

	Eq. Length (ft)				Total Eq. Length (ft)
45° Elbow, 3"	1	X	**4**	=	4
			Total:		4
Actual Length (3" HDPE)					75
			Equivalent Length =		79

Calculations (cont.):

Scenario 1A -Pumping from contact water swale sump to contact water Pond - 10 gpm

Flowrate (GPM)	Static Head (Ft)	Equivalent Length (Ft)	Head Loss Per 100 Ft.	Head Loss (Ft)	Total Dynamic Head (Ft)
2" Pipe Contact Water Swale Sump to Vault)					
10	19.3	435	0.24	1.04	20.3
3" Pipe (Vault to Contact Water Pond)					
10	0	79	0.04	0.03	0.0
				Total Dynamic Head (ft):	**20.4**

Scenario 1B -Pumping from contact water swale sump to contact water Pond - 20 gpm

Flowrate (GPM)	Static Head (Ft)	Equivalent Length (Ft)	Head Loss Per 100 Ft.	Head Loss (Ft)	Total Dynamic Head (Ft)
2" Pipe Contact Water Swale Sump to Vault)					
20	19.3	435	0.85	3.70	23.0
3" Pipe (Vault to Contact Water Pond)					
20	0	79	0.13	0.10	0.1
				Total Dynamic Head (ft):	**23.1**

Scenario 1C -Pumping from contact water swale sump to contact water Pond - 30 gpm

Flowrate (GPM)	Static Head (Ft)	Equivalent Length (Ft)	Head Loss Per 100 Ft.	Head Loss (Ft)	Total Dynamic Head (Ft)
2" Pipe Contact Water Swale Sump to Vault)					
30	19.3	435	1.80	7.83	27.1
3" Pipe (Vault to Contact Water Pond)					
30	0	79	0.27	0.21	0.2
				Total Dynamic Head (ft):	**27.3**

Engineering & Design Data

SPEARS

FLOW VELOCITY & FRICTION LOSS

SDR 13.5

Flow Rate (Gallons/Minute)	cubic ft/sec	Velocity (ft/s)	Friction Head Loss (ft water/100ft)	Friction Pressure (psi/100ft)	Velocity (ft/s)	Friction Head Loss (ft water/100ft)	Friction Pressure (psi/100ft)	Velocity (ft/s)	Friction Head Loss (ft water/100ft)	Friction Pressure (psi/100ft)	Velocity (ft/s)	Friction Head Loss (ft water/100ft)	Friction Pressure (psi/100ft)	Velocity (ft/s)	Friction Head Loss (ft water/100ft)	Friction Pressure (psi/100ft)	Velocity (ft/s)	Friction Head Loss (ft water/100ft)	Friction Pressure (psi/100ft)	Velocity (ft/s)	Friction Head Loss (ft water/100ft)	Friction Pressure (psi/100ft)	Velocity (ft/s)	Friction Head Loss (ft water/100ft)	Friction Pressure (psi/100ft)	Flow Rate (Gallons/Minute)
GPM		1/2"			3/4"			1"			1-1/4"			1-1/2"			2"			2-1/2"			3"			GPM
1	0.002	0.85	1.03	0.45	0.54	0.34	0.15																			1
2	0.004	1.69	2.05	0.89	1.07	0.68	0.29	0.68	0.40	0.17	0.42	0.13	0.06	0.32	0.065	0.028	0.20	0.03	0.013							2
5	0.011	4.22	11.58	5.01	2.68	3.82	1.65	1.69	1.24	0.54	1.05	0.39	0.17	0.80	0.20	0.088	0.51	0.075	0.033	0.35	0.038	0.016	0.24	0.02	0.009	5
7	0.016	5.91	21.24	9.20	3.75	7.01	3.03	2.36	2.28	0.99	1.47	0.72	0.31	1.12	0.37	0.16	0.72	0.125	0.054	0.49	0.53	0.023	0.33	0.03	0.012	7
10	0.022	8.44	40.46	17.52	5.35	13.34	5.78	3.37	4.33	1.87	2.10	1.37	0.59	1.60	0.71	0.31	1.02	0.24	0.10	0.70	0.09	0.039	0.47	0.04	0.017	10
15	0.033	4"			8.03	28.27	12.24	5.06	9.18	3.97	3.15	2.91	1.26	2.40	1.50	0.65	1.53	0.50	0.22	1.04	0.20	0.087	0.70	0.08	0.035	15
20	0.045	0.57	0.04	0.017	10.70	48.17	20.86	6.74	15.64	6.77	4.21	4.96	2.91	3.20	2.55	1.10	2.04	0.85	0.37	1.39	0.34	0.15	0.94	0.13	0.056	20
25	0.056	0.71	0.06	0.026	5"			8.43	23.65	10.24	5.26	7.49	3.24	4.00	3.85	1.67	2.55	1.29	0.56	1.74	0.51	0.22	1.17	0.190.	082	25
30	0.067	0.85	0.08	0.035	0.56	0.03	0.013	10.11	33.15	14.35	6.31	10.50	4.55	4.80	5.40	2.34	3.05	1.80	0.78	2.09	0.71	0.31	1.41	0.27	0.12	30
35	0.078	0.99	0.11	0.048	0.65	0.04	0.017				7.36	13.97	6.05	5.60	7.19	3.11	3.57	2.40	1.04	2.44	0.95	0.41	1.64	0.36	0.16	35
40	0.089	1.14	0.14	0.060	0.74	0.05	0.022				8.41	17.90	7.75	6.40	9.20	3.98	4.08	3.07	1.33	2.78	1.21	0.52	1.88	0.46	0.20	40
45	0.100	1.28	0.17	0.074	0.84	0.06	0.026	6"			9.46	22.26	9.64	7.20	11.44	4.95	4.59	3.82	1.65	3.13	1.51	0.65	2.11	0.58	0.25	45
50	0.111	1.42	0.21	0.091	0.93	0.07	0.030	0.66	0.03	0.013	10.52	27.05	11.71	8.00	13.91	6.02	5.10	4.64	2.01	3.48	1.83	0.79	2.35	0.70	0.30	50
60	0.134	1.70	0.29	0.13	1.12	0.10	0.043	0.79	0.04	0.017				9.60	19.50	8.44	6.12	6.50	2.81	4.18	2.57	1.11	2.82	0.98	0.42	60
70	0.156	1.99	0.38	0.16	1.30	0.14	0.061	0.92	0.06	0.026							7.14	8.65	3.75	4.87	3.42	1.48	3.29	1.31	0.57	70
75	0.167	2.13	0.44	0.19	1.40	0.16	0.069	0.98	0.07	0.030							7.65	9.83	4.26	5.22	3.88	1.68	3.52	1.49	0.65	75
80	0.178	2.27	0.49	0.21	1.49	0.18	0.078	1.05	0.08	0.035							8.16	11.08	4.80	5.57	4.37	1.89	3.76	1.68	0.73	80
90	0.201	2.56	0.61	0.26	1.67	0.22	0.095	1.18	0.09	0.039							9.18	13.78	5.97	6.27	5.44	2.36	4.23	2.09	0.90	90
100	0.223	2.84	0.74	0.32	1.86	0.27	0.12	1.31	0.11	0.048							10.20	16.75	7.25	6.96	6.61	2.86	4.70	2.54	1.10	100
125	0.279	3.55	1.13	0.49	2.33	0.40	0.18	1.64	0.17	0.074										8.70	10.01	4.33	5.88	3.84	1.66	125
150	0.334	4.26	1.58	0.68	2.79	0.56	0.24	1.97	0.24	0.10										10.44	14.01	6.07	7.04	5.37	2.33	150
175	0.390	4.97	2.10	0.91	3.26	0.75	0.33	2.30	0.32	0.14													8.22	7.15	3.10	175
200	0.446	5.68	2.69	1.16	3.72	0.96	0.42	2.62	0.41	0.18													9.39	9.15	3.96	200
250	0.557	7.10	4.07	1.76	4.66	1.46	0.63	3.28	0.62	0.27													11.74	13.86	6.00	250
300	0.668	8.52	5.69	2.46	5.58	2.03	0.88	3.93	0.87	0.38																300
350	0.780	9.94	7.58	3.29	6.52	2.70	1.17	4.59	1.16	0.50																350
400	0.891	11.36	9.70	4.20	7.44	3.46	1.50	5.24	1.48	0.64																400
450	1.003				8.37	4.31	1.87	5.90	1.84	0.80																450
500	1.114				9.30	5.24	2.27	6.56	2.23	0.97																500
750								9.83	4.73	2.05																750
1000	2.228							13.11	8.06	3.49																1000

NOTE: Spears® recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to Spears® engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID, actual ID may vary.

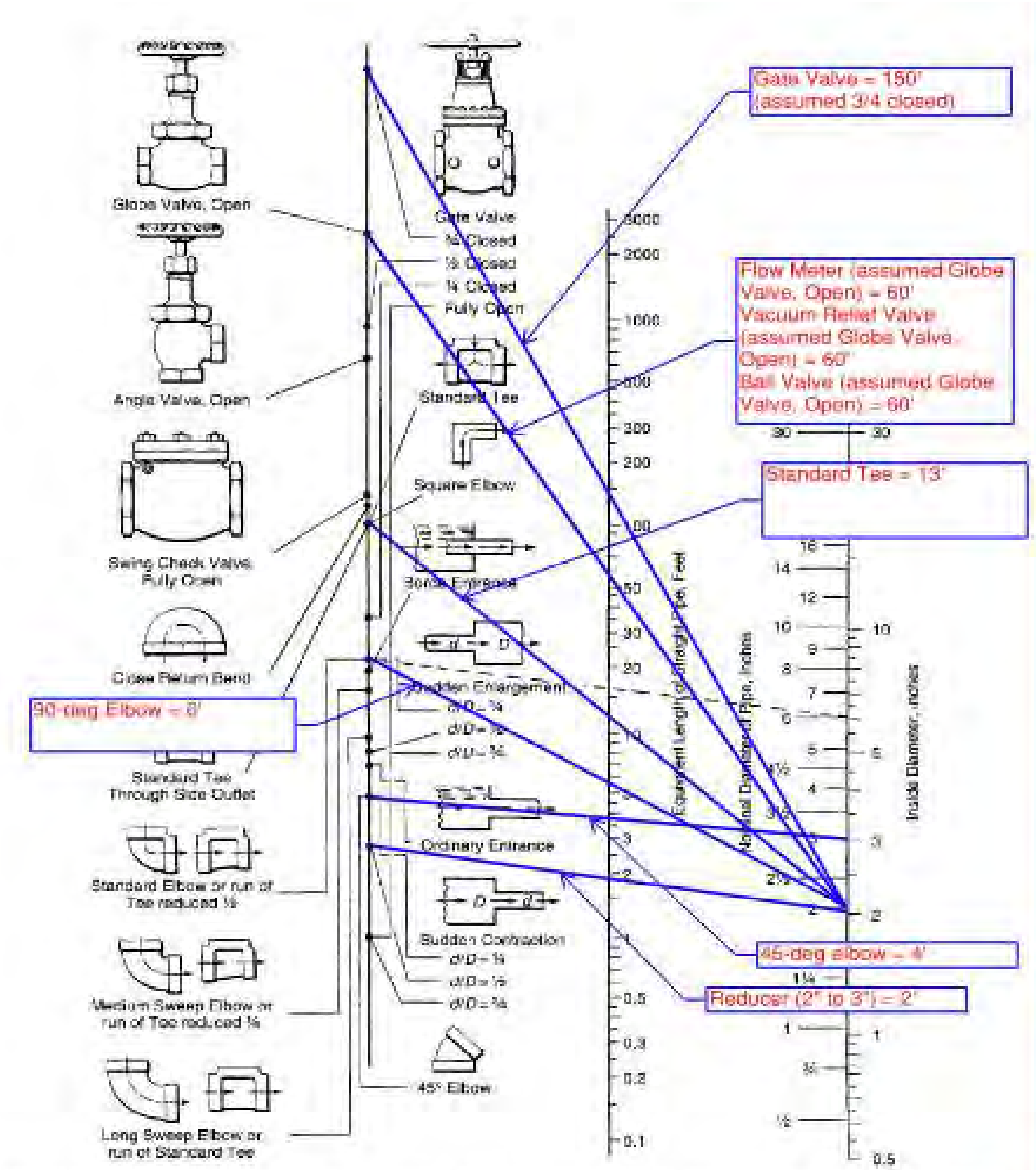


Figure 4-24a Equivalent length resistance of valves and fittings to flow of fluids. Note: Apply to 2 in. and similar threaded pipe for process applications

Source Crane Co Technical Paper No 409, Engineering Division, 1942

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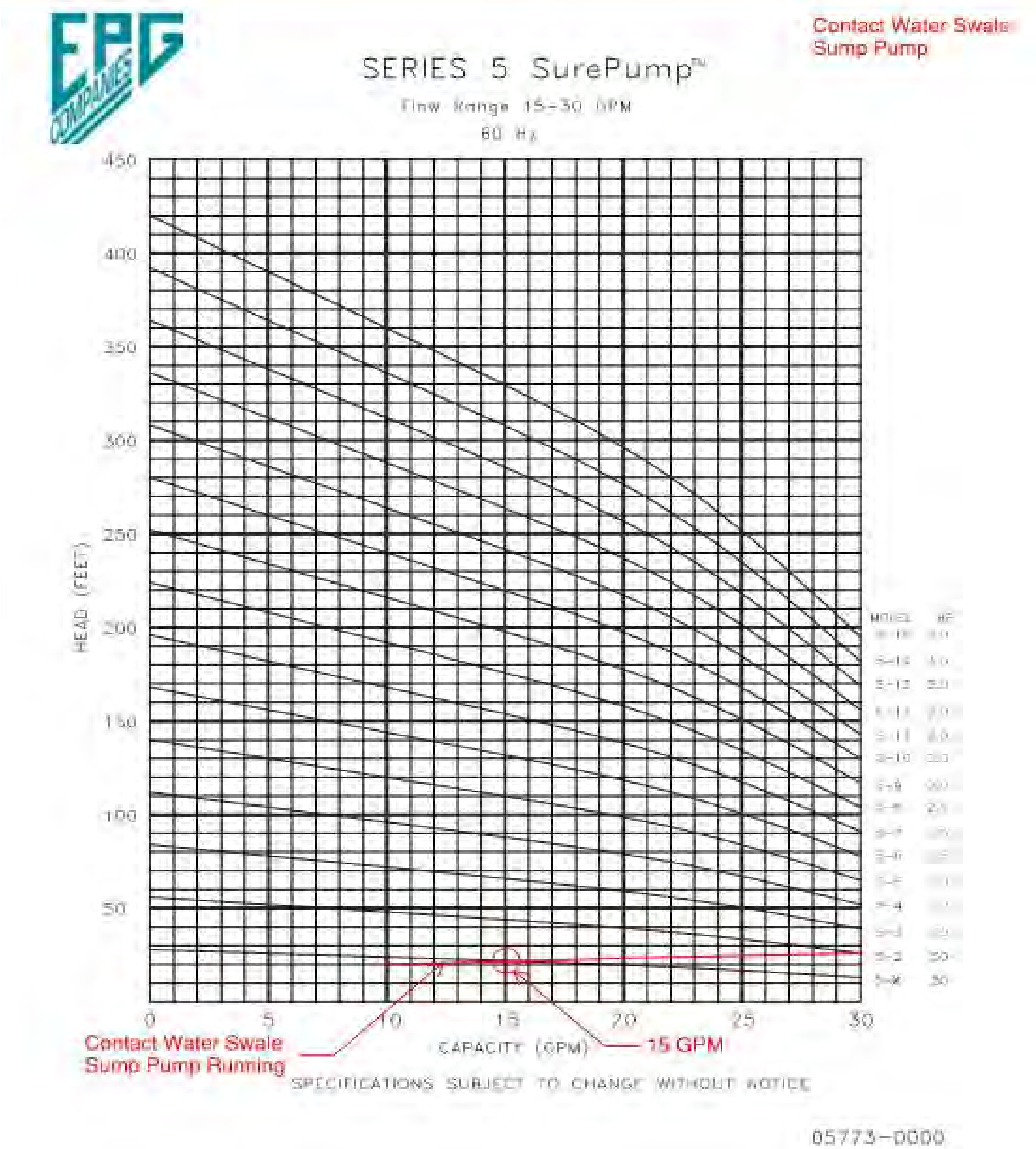
		Sheet No.	6 of 6
		Calc. No.	
		Rev. No.	
Job No. 25222259.00	Job: Edgewater I-43 Ash Disposal Facility	By: RPR	Date: 04/11/24
Client: Wisconsin Power & Light	Subject: Leachate Pump Design	Chk'd: MRH	Date: 04/11/24



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		Sheet No. 1 of 2	
		Calc. No.	
		Rev. No.	
Job No. 25222259.00	Job: Edgewater I-43 Ash Disposal Facility	By: RPR	Date: 12/5/23
Client: Wisconsin Power & Light	Subject: Leachate Collection	Chk'd: KRG	Date: 12/7/23

Hydraulic Capacity Calculations for Leachate Drainage Layer

Purpose:

To determine whether the maximum head in the leachate drainage blanket exceeds 1 foot during active and post-closure conditions, per NR 504.06(5)(a).

Approach:

The maximum head is calculated for 2 cases: active life (Case 1) and post-closure conditions (Case 2).

To estimate the maximum head in the leachate collection system drainage layer (Moore, 1982):

h_{max} = (L/2n) [sqrt(e/k + $\tan^2$ a) - tan a]

where: h_{max} = hydraulic head build up

e = infiltration rate

k = permeability of the drainage layer

L = length of the flow path to the leachate piping (maximum)

a = slope of the base liner in direction of flow

n = porosity of the drainage layer

References:

Moore, C.A., 1982, Landfill and Surface Impoundment Performance Evaluation, Revised Ed., USEPA Publication SW-869A.

Assumptions:

For both Cases:

a = 0% min. (perpendicular to pipe)

L = 6 feet (bottom of contact water swale ~12' wide, pipe in center)

For Case 1, active life:

k =0.01 cm/sec (CQA plan)

e = 6 in/year (per NR 512.12(3)(a))

n = 0.4 (typical for sand)

For Case 2, post-closure, reduced hydraulic conductivity

k = 0.001 cm/sec (required by NR 514.07(8)(c)3.c.), post-closure assume K is 10% of original 0.01 cm/sec)

e = 1 in/year (per NR 512.12(3)(a))

n = 0.2 (assume porosity is also reduced due to clogging post-closure)

Hydraulic Capacity Calculations (continued)

Calculations:

h_{max} = (L/2n) [sqrt(e/k + $\tan^2$ α) - tan α]

For Case 1, active life w/o leachate recirculation:

tan α	=	0.00					
L	=	6	ft				
k	=	0.01	cm/sec				
e	=	6	inches/year	x	2.54 cm/inch	/	((86400 sec/day)(365 day/year))
		4.8E-07	cm/sec				
n	=	0.4					
h_{max}	=	0.05	ft				

For Case 2, post-closure, reduced hydraulic conductivity

tan α	=	0.00					
L	=	6	ft				
k	=	0.001	cm/sec				
e	=	1	inches/year	x	2.54 cm/inch	/	((86400 sec/day)(365 day/year))
		8.1E-08	cm/sec				
n	=	0.2					
h_{max}	=	0.13	ft				

Conclusion:

The hydraulic capacity of the leachate drainage layer is adequate to convey the leachate to the collection pipe under active conditions and post-closure conditions.

Leachate Sump Volume and Pump Capacity Calculations

Purpose:
To demonstrate that the proposed contact water swale sump is of sufficient size and volume to adequately control leachate and maintain accumulation in accordance with NR 504.06(5)(j)1 without any unnecessary pump cycling.

Approach:
Estimate the leachate generation rate to each sump assuming an annual leachate collection rate of 6 inches as specified by NR 504.06(5)(j)1.

Calculate the sump volume based on the sump geometry shown in the Plan Modification Plan Set. The available volume is determined by calculating the overall sump volume between the pump on and off levels, minus the volume occupied by the granular bedding.

Determine the pumping intervals by dividing the available volume of the sump by the daily leachate generation rate. (This is the number of times the sump will fill and be required to be pumped on a daily basis.)

Assumptions:
The contact water swale sump will collect leachate from the contat water swale and Phase 4, Module 1.
Phase 3, Module 2 will drain internally, and Phase 3, Module 1 will drain to Phase 3, Module 2.
The leachate sump will be filled with a granular material with a porosity of 40 percent.
Leachate generation is estimated assuming the entire area is open.
The annual leachate collection rate during open/active conditions is 6 inches per NR 504.06(5)(j)1.
The pump on liquid level will occur at the bottom of the incoming leachate collection pipe. The pump off level will occur at 1 foot above the sump bottom.

Results: (2-foot deep sump and 1-foot above Liner)
The leachate generation rate for the sump during open/active conditions is 3,390 gal/day.
Refer to Sheet 2 for the generation rates for the sump.
The functional capacity in the sump, accounting for the stone porosity and solids buildup is 859 gallons.
Refer to Sheet 3 for the sump volume calculation.
The leachate sump pump is adequately sized to handle the estimated worst-case leachate volume at contact water swale with estimated filling times of 6.1 hours (Sheet 3)

Calculations:

Estimate the annual leachate collection volume based on a 6-inch per year generation rate for open conditions and a 1-inch per year generation rate for closed conditions.

Area	Sq. Ft.	Acre
Contact Water Swale	90,743	2.08
Ph. 4, Mod. 1	240,122	5.51
	Total:	7.60

Open Conditions

6 inches per year for leachate collection:

Infiltration from precip=(6 in/yr)x(1 ft/12 in)x(43,560 sf/ac)x(7.48 gal/cf)x(1 yr/365 days)= 446.3 gal/acre/day

Closed Conditions

1 inches per year for precipitation:

Infiltration from precip=(1 in/yr)x(1 ft/12 in)x(43,560 sf/ac)x(7.48 gal/cf)x(1 yr/365 days)= 74.4 gal/acre/day

Calculate the maximum leachate generation rate to the sump under open/active conditions and closed conditions.

Condition	Average Leachate Collection Rate (gal/acre/day)	Area to Sump (acres)	Leachate Generation Rate (gal/day)
Open/Active	446.3	7.60	3,390
Closed	74.4	7.60	565

Contact Water Basin Sump Volume

	EL	Area (sf)	Volume (cf)	Cum Vol (cf)	
Base	673.70	101	0	0	
	674.00	138	36	36	
	674.25	171	39	74	
	674.50	207	47	122	
Pump Off	674.75	246	57	178	
	675.00	284	66	245	
	675.25	327	76	321	
	675.50	373	88	408	
Top of Sump	675.75	849	153	561	Pump on
	676.00	1,258	263	825	
	676.25	1,646	363	1,188	
	676.50	2,079	466	1,653	
	676.75	2,652	591	2,245	

Note: Areas of sump obtained from AutoCAD drawings of base grades.

Calculations:

Calculate the sump volume:

The sump has the dimensions and slopes as indicated on the sump detail in the Plan of Operation addendum plan set.

The general sump configuration is summarized below:

Operating volume = (Pump on volume - Pump off volume) * 7.48 gal/cf

Operating volume = (555 cf - 163 cf) x 7.48 gal/cf = 2,864 gal

Assuming 40% porosity for the coarse aggregate in the sump, the available capacity for leachate is as follows:

Available Volume = 0.40 x sump operating vol. = 1,146 gal

Estimate sump filling time based on the leachate generation rates and sump volumes:

For Open/Active Conditions with leachate recirculation:

Fill Time = Operating Volume (gal)/(Leachate Generation Rate (gal/day) x 24 hrs/day)

Phase	Available Volume (gals)	25% Reduced Available Volume to Account for Solids Buildup	Leachate Generation Rate (gal/day)	Fill Time (hours)
Contact Water Swale	1,146	859	3,390	6.1

For Closed Conditions

Phase	Available Volume (gals)	25% Reduced Available Volume to Account for Solids Buildup	Leachate Generation Rate (gal/day)	Fill Time (hours)
Contact Water Swale	1,146	859	565	36.5

Sump filling times provide adequate pump rest time during active conditions with open and closed conditions.

Calculations:

Determine pumping rates and times based on assumed sump filling rate (see Page 3).

Filling rate (gpm) = Sump Volume (gal) / Sump Fill Time (hr) / 60 min/hr

Dewatering Time (hr) = Sump Volume (gal) / (Pumping Rate - Filling Rate (gpm)) / 60 min/hr

Pump Rest Time (hr) = Sump Fill Time (hr)

Open Conditions (pump will pump at 15 gpm, see pump sizing calculation)

Phase	Available Sump Volume, gal	Sump Fill Time, hrs	Filling Rate, gpm	Pumping Rate, gpm	Dewatering Time, hrs	Total Cyle Time, hrs
Swale	859	6.1	2.4	15	1.1	7.2

Closed Conditions (pump will pump at 15 gpm, see pump sizing calculation)

Phase	Operating Sump Volume, gal	Sump Fill Time, hrs	Filling Rate, gpm	Pumping Rate, gpm	Dewatering Time, hrs	Total Cyle Time, hrs
Swale	859	36.5	0.4	15	1.0	37.5

Conclusion:

The required pumping rates for dewatering are achievable with available pumps. The sump is adequately sized to maintain liquid level within the sump based on a peak generation rate of 6" of leachate collection per year.

Appendix D

Stormwater Calculations

Storm Water Management Calculations

Purpose:
The purpose of the storm water runoff calculations is to demonstrate that the proposed storm water management features for the Contact Water Swale Liner Conversion and Fully Developed Site closure conditions can accommodate and safely convey the runoff from a 25-year, 24-hour storm event during post construction conditions.

Items addressed in these calculations consist of;

- Diversion Berms
- Swales
- Rock Chute
- Downslope Flumes & Energy Dissipaters
- Existing Culverts
- Existing North Sedimentation Pond
- Existing South Sedimentation Pond
- Proposed Outfall Structure in South Sedimentation Pond

The proposed storm water management conditions are shown on **Sheet 1** (Contact Water Swale Liner Conversion Closure) and **Sheet 2** (Fully Developed Site Closure).

The calculations support the design of the following proposed storm water management features:

Feature	Purpose	Design Method
Swales	Convey storm water runoff to the North Sedimentation Pond and South Pond	HydroCAD runoff modeling and Swale Calculation
Rock Chutes	Erosion protection from culvert and concentrated flow discharges	HydroCAD runoff modeling and Rock Chute Calculations
Downslope Flumes & Energy Dissipators	Convey storm water from diversion berms down slope to discharge locations during post construction conditions	HydroCAD runoff modeling and Downslope Flume Calculations
Existing Culverts	Convey storm water under access points in swales during post construction conditions.	HydroCAD runoff modeling and HY-8 hydraulic modeling
North Sedimentation Pond	To safely handle 25-year, 24-hour storm event without overtopping the perimeter road.	HydroCAD runoff modeling
South Sedimentation Pond	To safely handle 25-year, 24-hour storm event without overtopping.	HydroCAD runoff modeling and Buoyancy Calculation
Outfall Riprap Apron	Erosion protection from Outfall concentrated flow	HydroCAD runoff modeling and Riprap Apron Calculation

Approach:
Hydrograph Generation
HydroCAD was used to model the storm water management systems and develop the hydrographs using TR-20 methodologies. The model is designed to simulate the surface runoff response of a watershed to a precipitation event. Input parameters for the model include precipitation depth for the

design storm events from NOAA ATLAS 14, storm type and curve (MSE 24-hr and 4), contributing drainage areas, runoff curve numbers, and time of concentration.

Diversion Berms

Diversion berms were sized for the 25-year, 24-hour storm event using the Manning's Equation to determine the depth of flow and velocity in the swale based on the swale geometry and peak flow for the storm event (as determined by the Hydrograph Generation Calculations).

Swale Sizing

The proposed swales were sized for the 25-year, 24-hour storm event. Existing swales were checked to confirm that they will still handle the 25-year, 24-hour storm event. A spreadsheet based on Manning's equation was used to determine the depth of flow and velocity in the swales based on the swale geometry and peak flow in the swales (as determined by the Hydrograph Generation models).

Rock Cute Sizing

Rock chutes were sized for the 25-year, 24-hour storm event. Rock Chutes were sized based on the flow to each culvert location. The NRCS Rock Chute Design spreadsheet was used to size the chute and riprap.

Downslope Flumes and Energy Dissipaters Sizing

Flumes and energy dissipaters were sized for the 25-year, 24-hour storm event. Manning's equation and the orifice equation were used to size the flumes. Energy dissipaters were sized using tables from the reference book "Hydraulic Design of Energy Dissipaters for Culverts and Channels" US Department of Transportation, Federal Highway Administration, July 2006.

Existing Culverts

Existing culverts were reviewed for capacity to convey the 25-year, 24-hour storm event previously. The culverts were rechecked for sizing based on updating the storm event to a MSE Type 4 and/or changes in flow patterns to the individual culvert.

Sedimentation Pond Sizing

The North Sedimentation Pond was checked to confirm the Pond can handle the 25-year, 24-hour storm and safely pass the 100-year, 24-hour storm event. The North Sedimentation Pond was also checked to confirm particle settling out during the design storm event.

The South Sedimentation Pond was checked to confirm the Pond could handle the 25-year, 24-hour storm event. The emergency spillway was sized for the 100-year, 24-hour storm event.

The HydroCAD model was used in conjunction with engineering calculations to evaluate the ability of the North Sedimentation Pond to meet the requirements of NR 504.09.

South Sedimentation Pond Outfall

The outfall structure was designed to withstand uplift.

Outfall Riprap Apron

The riprap apron for the South Sedimentation Pond outfall was sized for the 25-year, 24-hour storm event.

Key Assumptions:

- Drainage areas and time of concentration flow paths are as shown on **Sheet 1** for Early Closure Conditions and **Sheet 2** for Full Closure Conditions.
- A MSE 4 rainfall distribution was used based on the National Engineering Handbook Part 650. The precipitation depth for the 25-year, 24-hour storm was assumed to be 4.79 inches, based on NOAA ATLAS 14 Point Precipitation Frequency Estimates (NOAA's National Weather Service Hydrometeorological Design Studies Center Precipitation Frequency Data Server.
- Runoff curve numbers were based on tables presented in Urban Hydrology for Small Watersheds, and were assumed as follows and as listed in the modeling.

Cover Type	CN
Water	98 – Water Surface
Grass outside cover	79 – Open spaces (lawns, parks, etc) in fair condition with hydrologic soil group C
Final Cover	79 – Open spaces (lawns, parks, etc) in fair condition with hydrologic soil group C
Gravel	96 – Gravel

- Other assumptions are included with the calculations attached.

Results:

Hydrograph Generation

The hydrograph modeling results for the 25-year and 100-year, 24-hour storm events are included in the Post Construction Conditions Hydrograph Generation section below.

Diversion Berm Sizing

The proposed final berms will be constructed as shown on the Drawings. The diversion berms will contain the runoff from the 25-year, 24-hour storm event. Refer to the Diversion Berm Design section below.

Swale Sizing

The proposed swales will be constructed as shown on the Drawings. The swales have the capacity to safely convey the 25-year, 24-hour storm event and maintain a minimum 0.5 foot of freeboard. Refer to the Swale Sizing section below. Existing South and North swales can handle the updated peak runoff.

Appropriate erosion control products (Type 1, Class B) were selected based on the velocities and shear stress in the swales. Refer to the Swale Sizing section below for the evaluation.

Rock Chute Sizing

The proposed rock chute will be constructed as shown in the Drawings. The rock chutes will accommodate the runoff from the 25-year, 24-hour storm event. Refer to the Rock Chute Sizing section below.

Downslope Flume and Energy Dissipator Sizing

The downslope flumes and energy dissipators will be constructed as shown on the Drawings. The downslope flumes are designed to contain the runoff from the 25-year, 24-hour storm event. Energy dissipators at the bottom of the downslope flumes have been designed to handle the peak velocities. Refer to the Downslope Flume and Energy Dissipator Sizing section below for detailed calculations.

Existing Culverts

The existing culverts as shown on the Drawings were modeled to confirm each culvert could handle the 25-year, 24-hour storm event. Culverts not handling the 25-year, 24-hour runoff volume were removed, where feasible, or replaced with larger diameter culverts based on the model. Refer to the Existing Culvert section below for detailed calculations.

Sedimentation Pond Sizing

The outlet structure for the North Sedimentation Pond was sized to control runoff from the 25-year, 24-hour storm event, assuming the starting water elevation is at the bottom of the lowest outlet structure opening. The North Sedimentation Pond can continue to settle out particles 0.15 microns and larger in diameter under the updated model conditions. The South Sedimentation Pond can handle the runoff from the 25-year, 24-year storm event, when the water surface is at the bottom of the lowest outlet structure. The emergency spillway will pass the 100-year, 24-hour storm event at both ponds. Refer to the Sedimentation Pond Sizing section of this appendix for the detailed calculations.

South Sedimentation Pond Outfall

The outfall structure weight as designed is sufficient to avoid uplift forces. Refer to the Outfall Structure section of this appendix for detailed calculations.

Outfall Riprap Apron

The riprap apron for the South Sedimentation Pond outfall will be constructed as shown on the Drawings. The apron will accommodate the runoff from the or the 25-year, 24-hour storm event. Though the flow is low enough for WisDOT Select Crushed Material, WisDOT Light Riprap will be used to account for additional flow from the swale. Refer to the Outfall Structure section of this appendix for detailed calculations.

LEGEND

- APPROVED LIMITS OF WASTE
- EXISTING GRADE (2' CONTOUR)
- EXISTING GRADE (10' CONTOUR)
- EXISTING CULVERT
- EXISTING HAUL ROAD
- LEACHATE FORCEMAIN
- ELECTRIC AND INSTRUMENT CONDUITS
- PROPOSED GRADE (2' CONTOUR)
- PROPOSED GRADE (10' CONTOUR)
- PROPOSED DIVERSION BERM
- PROPOSED DOWNSLOPE FLUME
- DRAINAGE DIVIDE
- FLOW PATH

NOTES:

1. SEE SHEET 2 FOR ADDITIONAL BASE MAP LEGEND ITEMS AND NOTES.
2. PROPOSED GRADES REPRESENT TOP OF FINAL COVER.

PROJECT NO.	25222259.00
DRAWN:	01/05/2024
REVISED:	05/24/2024
DRAWN BY:	KP/RJG
CHECKED BY:	SJL
APPROVED BY:	MH

WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

ENGINEER

PLAN MODIFICATION ADDENDUM NO. 1
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

SITE

STORM WATER - CONTACT WATER SWALE LINER CONVERSION

SHEET
1 of 2

LEGEND

- APPROVED LIMITS OF WASTE
- EXISTING GRADE (2' CONTOUR)
- 690 EXISTING GRADE (10' CONTOUR)
- EXISTING CULVERT
- EXISTING HAUL ROAD
- FM LEACHATE FORCEMAIN
- E/I ELECTRIC AND INSTRUMENT CONDUITS
- PROPOSED GRADE (2' CONTOUR)
- 690 PROPOSED GRADE (10' CONTOUR)
- PROPOSED DIVERSION BERM
- PROPOSED DOWNSLOPE FLUME
- DRAINAGE DIVIDE
- FLOW PATH

NOTES:

1. SEE SHEET 2 FOR ADDITIONAL BASE MAP LEGEND ITEMS AND NOTES.
2. PROPOSED GRADES REPRESENT TOP OF FINAL COVER GRADES.

150 0 150

SCALE: 1" = 150'

N

PROJECT NO.	25222259.00
DRAWN:	01/05/2024
REVISED:	05/24/2024
DRAWN BY:	KP/RJG
CHECKED BY:	SJL
APPROVED BY:	MH

WISCONSIN POWER AND LIGHT COMPANY
EDGEWATER GENERATING STATION
3739 LAKESHORE DRIVE
SHEBOYGAN, WI 53081

CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

ENGINEER

PLAN MODIFICATION ADDENDUM NO. 1
EDGEWATER GENERATING STATION
EDGEWATER I-43 ASH DISPOSAL FACILITY
TOWN OF WILSON, WISCONSIN

SITE

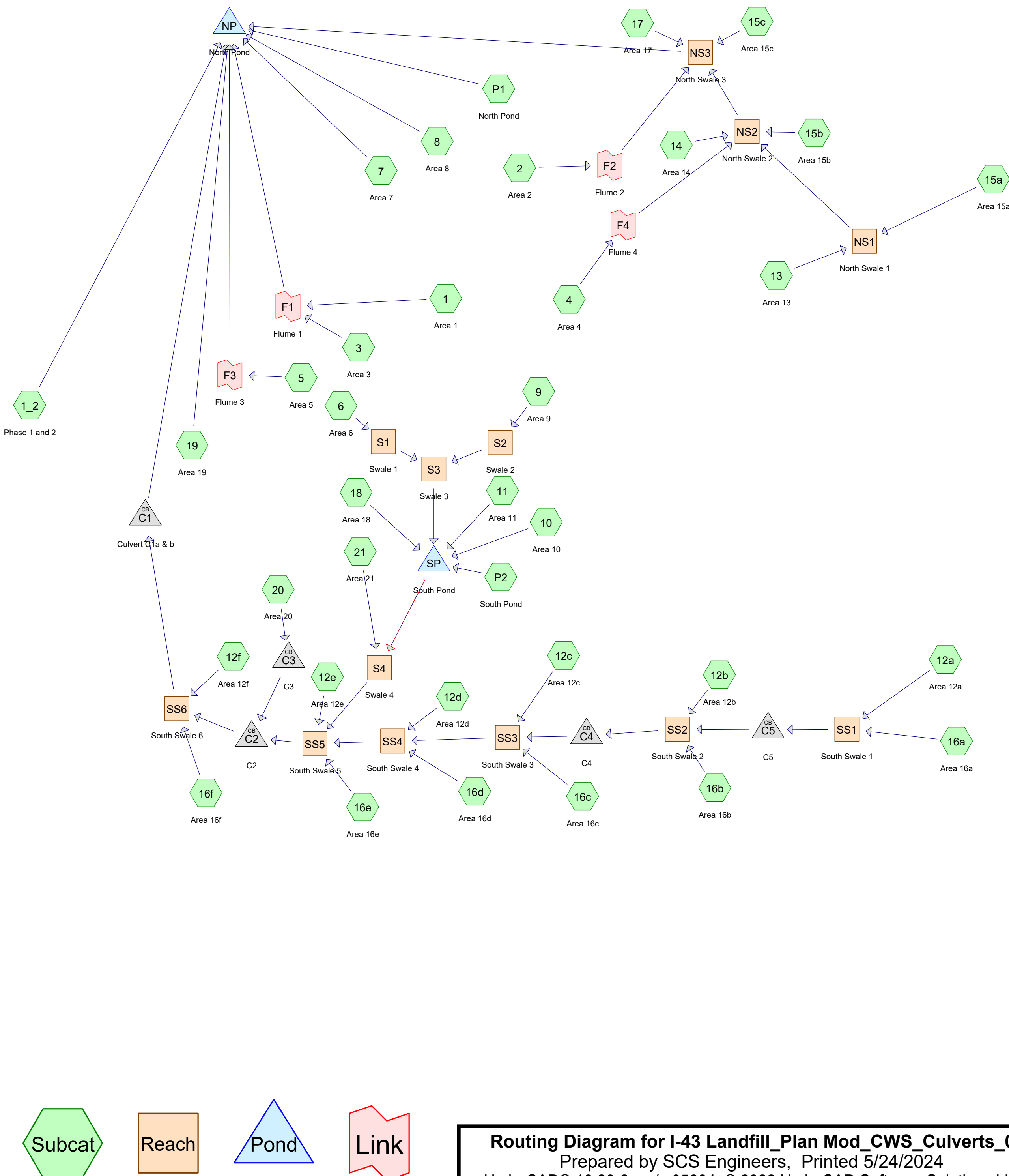
STORM WATER – FULLY DEVELOPED SITE CLOSURE

SHEET

2 of 2

Contact Water Swale Closure Conditions Hydrograph Generation

- 25-year, 24-hour Storm Event
- 100-year, 24-hour Storm Event



Routing Diagram for I-43 Landfill_Plan Mod_CWS_Culverts_0.3
Prepared by SCS Engineers, Printed 5/24/2024
HydroCAD® 10.20-2g s/n 05804 © 2022 HydroCAD Software Solutions LLC

Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	25-yr	MSE 24-hr	4	Default	24.00	1	4.80	2
2	100-yr	MSE 24-hr	4	Default	24.00	1	6.55	2

Time span=0.00-90.00 hrs, dt=0.01 hrs, 9001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1: Area 1 Runoff Area=28,521 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=347' Tc=15.8 min CN=79 Runoff=1.93 cfs 0.144 af

Subcatchment1_2: Phase 1 and 2 Runoff Area=2,282,700 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=3,476' Tc=25.0 min CN=79 Runoff=122.93 cfs 11.486 af

Subcatchment2: Area 2 Runoff Area=28,787 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=491' Tc=15.8 min CN=79 Runoff=1.95 cfs 0.145 af

Subcatchment3: Area 3 Runoff Area=45,292 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=449' Tc=16.3 min CN=79 Runoff=3.02 cfs 0.228 af

Subcatchment4: Area 4 Runoff Area=52,914 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=475' Tc=15.6 min CN=79 Runoff=3.61 cfs 0.266 af

Subcatchment5: Area 5 Runoff Area=37,768 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=442' Tc=15.9 min CN=79 Runoff=2.54 cfs 0.190 af

Subcatchment6: Area 6 Runoff Area=61,616 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=114' Slope=0.2500 '/' Tc=5.9 min CN=79 Runoff=6.05 cfs 0.310 af

Subcatchment7: Area 7 Runoff Area=81,807 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=200' Tc=12.4 min CN=79 Runoff=6.18 cfs 0.412 af

Subcatchment8: Area 8 Runoff Area=63,362 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=198' Tc=13.8 min CN=79 Runoff=4.56 cfs 0.319 af

Subcatchment9: Area 9 Runoff Area=48,089 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=133' Tc=6.0 min CN=79 Runoff=4.70 cfs 0.242 af

Subcatchment10: Area 10 Runoff Area=63,729 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=138' Tc=4.2 min CN=79 Runoff=6.71 cfs 0.321 af

Subcatchment11: Area 11 Runoff Area=10,561 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=98' Slope=0.0610 '/' Tc=10.0 min CN=79 Runoff=0.87 cfs 0.053 af

Subcatchment12a: Area 12a Runoff Area=98,996 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=180' Tc=14.4 min CN=79 Runoff=7.00 cfs 0.498 af

Subcatchment12b: Area 12b Runoff Area=47,686 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=204' Tc=14.2 min CN=79 Runoff=3.38 cfs 0.240 af

Subcatchment12c: Area 12c Runoff Area=5,888 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=19' Slope=0.0050 '/' Tc=5.0 min CN=79 Runoff=0.60 cfs 0.030 af

Subcatchment12d: Area 12d Runoff Area=1,651 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=23' Slope=0.0050 '/' Tc=8.5 min CN=79 Runoff=0.14 cfs 0.008 af

Subcatchment12e: Area 12e Runoff Area=4,957 sf 0.00% Impervious Runoff Depth=3.09"
Flow Length=47' Tc=4.1 min CN=84 Runoff=0.60 cfs 0.029 af

Subcatchment12f: Area 12f Runoff Area=9,031 sf 0.00% Impervious Runoff Depth=2.90"
Flow Length=52' Slope=0.0788 '/' Tc=5.4 min CN=82 Runoff=0.99 cfs 0.050 af

Subcatchment13: Area 13 Runoff Area=174,279 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=205' Tc=14.5 min CN=79 Runoff=12.25 cfs 0.877 af

Subcatchment14: Area 14 Runoff Area=59,877 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=125' Slope=0.2500 '/' Tc=5.9 min CN=79 Runoff=5.88 cfs 0.301 af

Subcatchment15a: Area 15a Runoff Area=99,614 sf 5.36% Impervious Runoff Depth=2.99"
Flow Length=58' Tc=3.3 min CN=83 Runoff=12.10 cfs 0.571 af

Subcatchment15b: Area 15b Runoff Area=11,056 sf 0.00% Impervious Runoff Depth=3.18"
Flow Length=33' Slope=0.1176 '/' Tc=2.4 min CN=85 Runoff=1.43 cfs 0.067 af

Subcatchment15c: Area 15c Runoff Area=9,032 sf 0.00% Impervious Runoff Depth=2.90"
Flow Length=1,656' Tc=7.2 min CN=82 Runoff=0.92 cfs 0.050 af

Subcatchment16a: Area 16a Runoff Area=37,043 sf 0.00% Impervious Runoff Depth=3.28"
Flow Length=50' Tc=5.6 min CN=86 Runoff=4.46 cfs 0.232 af

Subcatchment16b: Area 16b Runoff Area=23,150 sf 0.00% Impervious Runoff Depth=3.18"
Flow Length=78' Tc=1.8 min CN=85 Runoff=3.04 cfs 0.141 af

Subcatchment16c: Area 16c Runoff Area=22,754 sf 0.00% Impervious Runoff Depth=2.99"
Flow Length=54' Tc=3.0 min CN=83 Runoff=2.79 cfs 0.130 af

Subcatchment16d: Area 16d Runoff Area=7,112 sf 0.00% Impervious Runoff Depth=2.99"
Flow Length=65' Tc=4.2 min CN=83 Runoff=0.84 cfs 0.041 af

Subcatchment16e: Area 16e Runoff Area=11,038 sf 0.00% Impervious Runoff Depth=2.90"
Flow Length=75' Tc=4.7 min CN=82 Runoff=1.24 cfs 0.061 af

Subcatchment16f: Area 16f Runoff Area=19,413 sf 0.00% Impervious Runoff Depth=2.99"
Flow Length=75' Tc=4.7 min CN=83 Runoff=2.24 cfs 0.111 af

Subcatchment17: Area 17 Runoff Area=18,834 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=140' Slope=0.2500 '/' Tc=6.0 min CN=79 Runoff=1.84 cfs 0.095 af

Subcatchment18: Area 18 Runoff Area=20,237 sf 0.00% Impervious Runoff Depth=2.72"
Flow Length=55' Slope=0.0714 '/' Tc=5.9 min CN=80 Runoff=2.05 cfs 0.105 af

Subcatchment19: Area 19 Runoff Area=5,416 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=141' Slope=0.2500 '/' Tc=6.0 min CN=79 Runoff=0.53 cfs 0.027 af

Subcatchment20: Area 20 Runoff Area=53,255 sf 0.00% Impervious Runoff Depth=2.72"
Flow Length=100' Slope=0.0050 '/' Tc=2.3 min CN=80 Runoff=6.08 cfs 0.277 af

Subcatchment21: Area 21 Runoff Area=7,329 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=62' Slope=0.0758 '/' Tc=6.4 min CN=79 Runoff=0.70 cfs 0.037 af

SubcatchmentP1: North Pond Runoff Area=342,674 sf 100.00% Impervious Runoff Depth=4.56"
Tc=0.0 min CN=98 Runoff=54.53 cfs 2.992 af

SubcatchmentP2: South Pond Runoff Area=3.099 ac 100.00% Impervious Runoff Depth=4.56"
Tc=0.0 min CN=98 Runoff=21.48 cfs 1.179 af

Reach NS1: North Swale 1 Avg. Flow Depth=0.41' Max Vel=3.64 fps Inflow=20.02 cfs 1.447 af
n=0.030 L=1,043.0' S=0.0209 '/' Capacity=302.62 cfs Outflow=17.15 cfs 1.447 af

Reach NS2: North Swale 2 Avg. Flow Depth=0.59' Max Vel=3.33 fps Inflow=24.00 cfs 2.082 af
n=0.030 L=381.0' S=0.0115 '/' Capacity=224.48 cfs Outflow=23.59 cfs 2.082 af

Reach NS3: North Swale 3 Avg. Flow Depth=0.54' Max Vel=4.12 fps Inflow=26.58 cfs 2.372 af
n=0.030 L=195.0' S=0.0193 '/' Capacity=290.78 cfs Outflow=26.50 cfs 2.372 af

Reach S1: Swale 1 Avg. Flow Depth=0.34' Max Vel=2.20 fps Inflow=6.05 cfs 0.310 af
n=0.030 L=423.0' S=0.0118 '/' Capacity=45.58 cfs Outflow=5.46 cfs 0.310 af

Reach S2: Swale 2 Avg. Flow Depth=0.30' Max Vel=2.10 fps Inflow=4.70 cfs 0.242 af
n=0.030 L=320.0' S=0.0125 '/' Capacity=46.88 cfs Outflow=4.37 cfs 0.242 af

Reach S3: Swale 3 Avg. Flow Depth=0.48' Max Vel=3.16 fps Inflow=9.78 cfs 0.552 af
n=0.030 L=68.7' S=0.0146 '/' Capacity=37.92 cfs Outflow=9.74 cfs 0.552 af

Reach S4: Swale 4 Avg. Flow Depth=0.14' Max Vel=0.75 fps Inflow=1.20 cfs 2.028 af
n=0.030 L=125.0' S=0.0032 '/' Capacity=123.75 cfs Outflow=1.14 cfs 2.027 af

Reach SS1: South Swale 1 Avg. Flow Depth=0.32' Max Vel=2.56 fps Inflow=9.79 cfs 0.731 af
n=0.030 L=686.0' S=0.0140 '/' Capacity=247.65 cfs Outflow=9.07 cfs 0.731 af

Reach SS2: South Swale 2 Avg. Flow Depth=0.38' Max Vel=2.92 fps Inflow=12.82 cfs 1.112 af
n=0.030 L=327.0' S=0.0146 '/' Capacity=253.11 cfs Outflow=12.71 cfs 1.112 af

Reach SS3: South Swale 3 Avg. Flow Depth=0.45' Max Vel=2.56 fps Inflow=13.51 cfs 1.272 af
n=0.030 L=320.0' S=0.0093 '/' Capacity=201.47 cfs Outflow=13.35 cfs 1.272 af

Reach SS4: South Swale 4 Avg. Flow Depth=0.26' Max Vel=4.72 fps Inflow=13.56 cfs 1.321 af
n=0.030 L=114.0' S=0.0605 '/' Capacity=514.50 cfs Outflow=13.55 cfs 1.321 af

Reach SS5: South Swale 5 Avg. Flow Depth=0.66' Max Vel=1.82 fps Inflow=14.75 cfs 3.439 af
n=0.030 L=140.0' S=0.0030 '/' Capacity=114.55 cfs Outflow=14.69 cfs 3.438 af

Reach SS6: South Swale 6 Avg. Flow Depth=0.71' Max Vel=1.88 fps Inflow=17.37 cfs 3.876 af
n=0.030 L=215.0' S=0.0030 '/' Capacity=114.10 cfs Outflow=16.57 cfs 3.875 af

Pond C1: Culvert C1a & b Peak Elev=688.88' Inflow=16.57 cfs 3.875 af
Outflow=16.57 cfs 3.875 af

Pond C2: C2 Peak Elev=691.21' Inflow=15.73 cfs 3.715 af
24.0" Round Culvert n=0.012 L=46.0' S=0.0030 '/' Outflow=15.73 cfs 3.715 af

Pond C3: C3 Peak Elev=696.36' Inflow=6.08 cfs 0.277 af
12.0" Round Culvert n=0.012 L=48.0' S=0.0146 '/' Outflow=6.08 cfs 0.277 af

Pond C4: C4 Peak Elev=701.35' Inflow=12.71 cfs 1.112 af
24.0" Round Culvert n=0.013 L=40.5' S=0.0121 '/' Outflow=12.71 cfs 1.112 af

Pond C5: C5 Peak Elev=707.50' Inflow=9.07 cfs 0.731 af
18.0" Round Culvert n=0.025 L=38.0' S=0.0034 '/' Outflow=9.07 cfs 0.731 af

Pond NP: North Pond Peak Elev=684.79' Storage=13.287 af Inflow=184.24 cfs 22.044 af
Primary=17.29 cfs 21.803 af Secondary=0.00 cfs 0.000 af Outflow=17.29 cfs 21.803 af

Pond SP: South Pond Peak Elev=690.69' Storage=636,660 cf Inflow=34.99 cfs 2.210 af
Primary=0.71 cfs 1.991 af Secondary=0.00 cfs 0.000 af Outflow=0.71 cfs 1.991 af

Link F1: Flume 1 Inflow=4.95 cfs 0.371 af
Primary=4.95 cfs 0.371 af

Link F2: Flume 2 Inflow=1.95 cfs 0.145 af
Primary=1.95 cfs 0.145 af

Link F3: Flume 3 Inflow=2.54 cfs 0.190 af
Primary=2.54 cfs 0.190 af

Link F4: Flume 4 Inflow=3.61 cfs 0.266 af
Primary=3.61 cfs 0.266 af

Total Runoff Area = 92.527 ac Runoff Volume = 22.265 af Average Runoff Depth = 2.89"
88.02% Pervious = 81.438 ac 11.98% Impervious = 11.088 ac

Summary for Subcatchment 1: Area 1

Runoff = 1.93 cfs @ 12.24 hrs, Volume= 0.144 af, Depth= 2.63"
Routed to Link F1 : Flume 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	28,521	79	
	28,521		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.5	106	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	141	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
15.8	347	Total			

Summary for Subcatchment 1_2: Phase 1 and 2

Runoff = 122.93 cfs @ 12.36 hrs, Volume= 11.486 af, Depth= 2.63"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	2,282,700	79	Closed Landfill
	2,282,700		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.0	100	0.0400	0.14		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.8	400	0.0400	1.40		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.2	2,976	0.0120	6.04	380.82	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=3.00' Z= 10.0 & 4.0 '/' Top.W=42.00' n= 0.035 Earth, dense weeds
25.0	3,476	Total			

Summary for Subcatchment 2: Area 2

Runoff = 1.95 cfs @ 12.24 hrs, Volume= 0.145 af, Depth= 2.63"
Routed to Link F2 : Flume 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	28,787	79	
	28,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.1	78	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	203	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	110	0.2500	20.09	10.95	**Pipe Channel,** 10.0" Round Area= 0.5 sf Perim= 2.6' r= 0.21' n= 0.013 Corrugated PE, smooth interior
15.8	491	Total			

Summary for Subcatchment 3: Area 3

Runoff = 3.02 cfs @ 12.25 hrs, Volume= 0.228 af, Depth= 2.63"
Routed to Link F1 : Flume 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	45,292	79	
	45,292		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.5	108	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	241	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
16.3	449	Total			

Summary for Subcatchment 4: Area 4

Runoff = 3.61 cfs @ 12.24 hrs, Volume= 0.266 af, Depth= 2.63"
Routed to Link F4 : Flume 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	52,914	79	
	52,914		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.1	83	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.9	173	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	119	0.2500	22.68	17.81	**Pipe Channel, Flume 4** 12.0" Round Area= 0.8 sf Perim= 3.1' r= 0.25' n= 0.013 Corrugated PE, smooth interior
15.6	475	Total			

Summary for Subcatchment 5: Area 5

Runoff = 2.54 cfs @ 12.24 hrs, Volume= 0.190 af, Depth= 2.63"
Routed to Link F3 : Flume 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	37,768	79	
	37,768		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.0	73	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	269	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Diversion Berm** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
15.9	442	Total			

Summary for Subcatchment 6: Area 6

Runoff = 6.05 cfs @ 12.13 hrs, Volume= 0.310 af, Depth= 2.63"
Routed to Reach S1 : Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	61,616	79	
	61,616		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.1	14	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
5.9	114	Total			

Summary for Subcatchment 7: Area 7

Runoff = 6.18 cfs @ 12.20 hrs, Volume= 0.412 af, Depth= 2.63"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	81,807	79	
	81,807		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.3	63	0.0300	0.11		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.6	37	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	100	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.4	200	Total			

Summary for Subcatchment 8: Area 8

Runoff = 4.56 cfs @ 12.22 hrs, Volume= 0.319 af, Depth= 2.63"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	62,504	79	
	858	96	Gravel surface, HSG C
	63,362	79	Weighted Average
	63,362		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.5	91	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	9	0.2500	0.18		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	98	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
13.8	198	Total			

Summary for Subcatchment 9: Area 9

Runoff = 4.70 cfs @ 12.13 hrs, Volume= 0.242 af, Depth= 2.63"
Routed to Reach S2 : Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	48,089	79	
	48,089		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.0	5	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	28	0.0800	1.98		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
6.0	133	Total			

Summary for Subcatchment 10: Area 10

Runoff = 6.71 cfs @ 12.12 hrs, Volume= 0.321 af, Depth= 2.63"
Routed to Pond SP : South Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	63,729	79	
	63,729		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.0	100	0.2500	0.42		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
0.1	19	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	19	0.2000	3.13		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
4.2	138	Total			

Summary for Subcatchment 11: Area 11

Runoff = 0.87 cfs @ 12.18 hrs, Volume= 0.053 af, Depth= 2.63"
Routed to Pond SP : South Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	10,561	79	
	10,561		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0	98	0.0610	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment 12a: Area 12a

Runoff = 7.00 cfs @ 12.23 hrs, Volume= 0.498 af, Depth= 2.63"
Routed to Reach SS1 : South Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	98,996	79	
	98,996		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	57	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	23	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.4	180	Total			

Summary for Subcatchment 12b: Area 12b

Runoff = 3.38 cfs @ 12.23 hrs, Volume= 0.240 af, Depth= 2.63"
Routed to Reach SS2 : South Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	47,328	79	
	358	96	Gravel surface, HSG C
	47,686	79	Weighted Average
	47,686		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.3	24	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.3	57	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	23	0.3333	4.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.2	204	Total			

Summary for Subcatchment 12c: Area 12c

Runoff = 0.60 cfs @ 12.12 hrs, Volume= 0.030 af, Depth= 2.63"
Routed to Reach SS3 : South Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	5,888	79	
	5,888		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0	19	0.0050	0.06		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"

Summary for Subcatchment 12d: Area 12d

Runoff = 0.14 cfs @ 12.16 hrs, Volume= 0.008 af, Depth= 2.63"
Routed to Reach SS4 : South Swale 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	1,651	79	
	1,651		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.5	23	0.0050	0.04		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment 12e: Area 12e

Runoff = 0.60 cfs @ 12.12 hrs, Volume= 0.029 af, Depth= 3.09"
Routed to Reach SS5 : South Swale 5

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	3,521	79	
	1,436	96	Gravel surface, HSG C
	4,957	84	Weighted Average
	4,957		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.3	9	0.0050	0.44		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
3.8	38	0.0400	0.17		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
4.1	47	Total			

Summary for Subcatchment 12f: Area 12f

Runoff = 0.99 cfs @ 12.13 hrs, Volume= 0.050 af, Depth= 2.90"
Routed to Reach SS6 : South Swale 6

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	7,374	79	
	1,657	96	Gravel surface, HSG C
	9,031	82	Weighted Average
	9,031		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	52	0.0788	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment 13: Area 13

Runoff = 12.25 cfs @ 12.23 hrs, Volume= 0.877 af, Depth= 2.63"
Routed to Reach NS1 : North Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	174,279	79	
	174,279		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	56	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	49	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.5	205	Total			

Summary for Subcatchment 14: Area 14

Runoff = 5.88 cfs @ 12.13 hrs, Volume= 0.301 af, Depth= 2.63"
Routed to Reach NS2 : North Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	59,877	79	
	59,877		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.1	25	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
5.9	125	Total			

Summary for Subcatchment 15a: Area 15a

Runoff = 12.10 cfs @ 12.11 hrs, Volume= 0.571 af, Depth= 2.99"
Routed to Reach NS1 : North Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	78,118	79	
	5,343	98	Paved roads w/curbs & sewers, HSG C
	16,153	96	Gravel surface, HSG C
	99,614	83	Weighted Average
	94,271		94.64% Pervious Area
	5,343		5.36% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	32	0.0050	0.57		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
2.4	26	0.1538	0.18		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
3.3	58	Total			

Summary for Subcatchment 15b: Area 15b

Runoff = 1.43 cfs @ 12.10 hrs, Volume= 0.067 af, Depth= 3.18"
Routed to Reach NS2 : North Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	7,026	79	
	4,030	96	Gravel surface, HSG C
	11,056	85	Weighted Average
	11,056		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	11	0.1176	1.62		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
2.3	22	0.1176	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.4	33	Total			

Summary for Subcatchment 15c: Area 15c

Runoff = 0.92 cfs @ 12.14 hrs, Volume= 0.050 af, Depth= 2.90"
Routed to Reach NS3 : North Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	7,178	79	
	1,854	96	Gravel surface, HSG C
	9,032	82	Weighted Average
	9,032		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	14	0.1250	1.74		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
4.4	50	0.1250	0.19		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.7	1,592	0.0167	9.92	610.36	**Trap/Vee/Rect Channel Flow,** Bot.W=10.00' D=3.00' Z= 4.0 & 3.0 '/' Top.W=31.00' n= 0.030 Earth, grassed & winding
7.2	1,656	Total			

Summary for Subcatchment 16a: Area 16a

Runoff = 4.46 cfs @ 12.13 hrs, Volume= 0.232 af, Depth= 3.28"
Routed to Reach SS1 : South Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	20,948	79	
	16,095	96	Gravel surface, HSG C
	37,043	86	Weighted Average
	37,043		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.7	13	0.0050	0.06		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
0.7	21	0.0050	0.52		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.2	16	0.3300	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
5.6	50	Total			

Summary for Subcatchment 16b: Area 16b

Runoff = 3.04 cfs @ 12.10 hrs, Volume= 0.141 af, Depth= 3.18"
Routed to Reach SS2 : South Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	14,694	79	
	8,456	96	Gravel surface, HSG C
	23,150	85	Weighted Average
	23,150		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.7	64	0.0450	1.57		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.1	14	0.3333	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.8	78	Total			

Summary for Subcatchment 16c: Area 16c

Runoff = 2.79 cfs @ 12.11 hrs, Volume= 0.130 af, Depth= 2.99"
Routed to Reach SS3 : South Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	17,622	79	
	5,132	96	Gravel surface, HSG C
	22,754	83	Weighted Average
	22,754		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.8	24	0.2500	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	7	0.1666	0.14		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.1	18	0.1667	2.05		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
0.3	5	0.3333	0.26		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
3.0	54	Total			

Summary for Subcatchment 16d: Area 16d

Runoff = 0.84 cfs @ 12.12 hrs, Volume= 0.041 af, Depth= 2.99"
Routed to Reach SS4 : South Swale 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	5,564	79	
	1,548	96	Gravel surface, HSG C
	7,112	83	Weighted Average
	7,112		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.7	38	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	14	0.0050	0.48		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.0	13	0.3300	0.21		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.2	65	Total			

Summary for Subcatchment 16e: Area 16e

Runoff = 1.24 cfs @ 12.12 hrs, Volume= 0.061 af, Depth= 2.90"
Routed to Reach SS5 : South Swale 5

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	8,772	79	
	2,266	96	Gravel surface, HSG C
	11,038	82	Weighted Average
	11,038		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.9	43	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	16	0.0050	0.49		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.3	16	0.2500	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.7	75	Total			

Summary for Subcatchment 16f: Area 16f

Runoff = 2.24 cfs @ 12.12 hrs, Volume= 0.111 af, Depth= 2.99"
Routed to Reach SS6 : South Swale 6

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	14,568	79	
	4,845	96	Gravel surface, HSG C
	19,413	83	Weighted Average
	19,413		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.9	43	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	16	0.0050	0.49		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.3	16	0.2500	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.7	75	Total			

Summary for Subcatchment 17: Area 17

Runoff = 1.84 cfs @ 12.13 hrs, Volume= 0.095 af, Depth= 2.63"
Routed to Reach NS3 : North Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	18,834	79	
	18,834		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.2	40	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
6.0	140	Total			

Summary for Subcatchment 18: Area 18

Runoff = 2.05 cfs @ 12.13 hrs, Volume= 0.105 af, Depth= 2.72"
Routed to Pond SP : South Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	19,430	79	
	807	96	Gravel surface, HSG C
	20,237	80	Weighted Average
	20,237		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.9	55	0.0714	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment 19: Area 19

Runoff = 0.53 cfs @ 12.13 hrs, Volume= 0.027 af, Depth= 2.63"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	5,416	79	
	5,416		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.2	41	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
6.0	141	Total			

Summary for Subcatchment 20: Area 20

Runoff = 6.08 cfs @ 12.10 hrs, Volume= 0.277 af, Depth= 2.72"
Routed to Pond C3 : C3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	50,854	79	
	2,401	96	Gravel surface, HSG C
	53,255	80	Weighted Average
	53,255		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.3	100	0.0050	0.71		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"

Summary for Subcatchment 21: Area 21

Runoff = 0.70 cfs @ 12.14 hrs, Volume= 0.037 af, Depth= 2.63"
Routed to Reach S4 : Swale 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	7,177	79	
	152	96	Gravel surface, HSG C
	7,329	79	Weighted Average
	7,329		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.4	62	0.0758	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment P1: North Pond

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 54.53 cfs @ 12.09 hrs, Volume= 2.992 af, Depth= 4.56"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

Area (sf)	CN	Description
342,674	98	Water Surface
342,674		100.00% Impervious Area

Summary for Subcatchment P2: South Pond

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 21.48 cfs @ 12.09 hrs, Volume= 1.179 af, Depth= 4.56"
Routed to Pond SP : South Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

Area (ac)	CN	Description
3.099	98	Water Surface, HSG C
3.099		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0					**Direct Entry,**

Summary for Reach NS1: North Swale 1

Inflow Area = 6.288 ac, 1.95% Impervious, Inflow Depth = 2.76" for 25-yr event
Inflow = 20.02 cfs @ 12.12 hrs, Volume= 1.447 af
Outflow = 17.15 cfs @ 12.23 hrs, Volume= 1.447 af, Atten= 14%, Lag= 6.9 min
Routed to Reach NS2 : North Swale 2

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.64 fps, Min. Travel Time= 4.8 min
Avg. Velocity = 0.93 fps, Avg. Travel Time= 18.8 min

Peak Storage= 4,910 cf @ 12.15 hrs
Average Depth at Peak Storage= 0.41' , Surface Width= 12.88'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 302.62 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 1,043.0' Slope= 0.0209 '/'
Inlet Invert= 714.00', Outlet Invert= 692.16'

‡

Summary for Reach NS2: North Swale 2

[62] Hint: Exceeded Reach NS1 OUTLET depth by 0.20' @ 12.39 hrs

Inflow Area = 9.131 ac, 1.34% Impervious, Inflow Depth = 2.74" for 25-yr event
Inflow = 24.00 cfs @ 12.22 hrs, Volume= 2.082 af
Outflow = 23.59 cfs @ 12.28 hrs, Volume= 2.082 af, Atten= 2%, Lag= 3.2 min
Routed to Reach NS3 : North Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.33 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 0.82 fps, Avg. Travel Time= 7.7 min

Peak Storage= 2,698 cf @ 12.25 hrs
Average Depth at Peak Storage= 0.59' , Surface Width= 14.11'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 224.48 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 381.0' Slope= 0.0115 '/'
Inlet Invert= 692.16', Outlet Invert= 687.77'

‡

Summary for Reach NS3: North Swale 3

[61] Hint: Exceeded Reach NS2 outlet invert by 0.54' @ 12.28 hrs

Inflow Area = 10.431 ac, 1.18% Impervious, Inflow Depth = 2.73" for 25-yr event
Inflow = 26.58 cfs @ 12.27 hrs, Volume= 2.372 af
Outflow = 26.50 cfs @ 12.29 hrs, Volume= 2.372 af, Atten= 0%, Lag= 1.3 min
Routed to Pond NP : North Pond

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.12 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 1.03 fps, Avg. Travel Time= 3.2 min

Peak Storage= 1,256 cf @ 12.28 hrs
Average Depth at Peak Storage= 0.54' , Surface Width= 13.79'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 290.78 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 195.0' Slope= 0.0193 '/'
Inlet Invert= 687.77', Outlet Invert= 684.00'

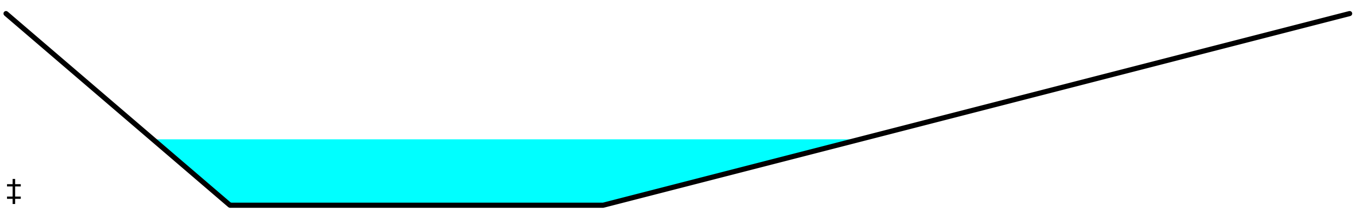
Summary for Reach S1: Swale 1

Inflow Area = 1.415 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 6.05 cfs @ 12.13 hrs, Volume= 0.310 af
Outflow = 5.46 cfs @ 12.21 hrs, Volume= 0.310 af, Atten= 10%, Lag= 4.8 min
Routed to Reach S3 : Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.20 fps, Min. Travel Time= 3.2 min
Avg. Velocity = 0.55 fps, Avg. Travel Time= 12.8 min

Peak Storage= 1,053 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.34' , Surface Width= 9.47'
Bank-Full Depth= 1.00' Flow Area= 11.5 sf, Capacity= 45.58 cfs

5.00' x 1.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 3.0 10.0 '/' Top Width= 18.00'
Length= 423.0' Slope= 0.0118 '/'
Inlet Invert= 700.00', Outlet Invert= 695.00'



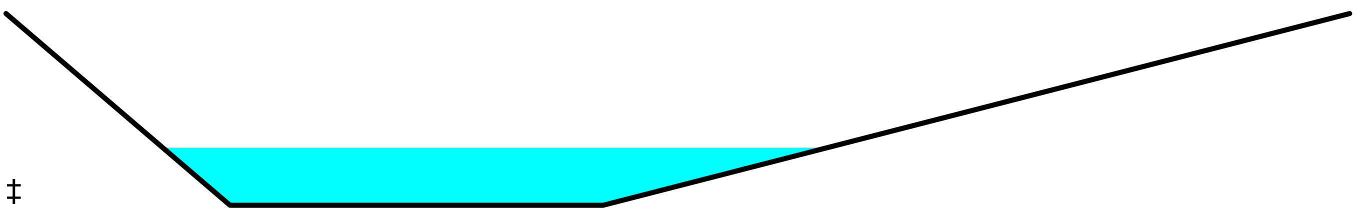
Summary for Reach S2: Swale 2

Inflow Area = 1.104 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 4.70 cfs @ 12.13 hrs, Volume= 0.242 af
Outflow = 4.37 cfs @ 12.20 hrs, Volume= 0.242 af, Atten= 7%, Lag= 3.9 min
Routed to Reach S3 : Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.10 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 0.53 fps, Avg. Travel Time= 10.1 min

Peak Storage= 668 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.30' , Surface Width= 8.91'
Bank-Full Depth= 1.00' Flow Area= 11.5 sf, Capacity= 46.88 cfs

5.00' x 1.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 3.0 10.0 '/' Top Width= 18.00'
Length= 320.0' Slope= 0.0125 '/'
Inlet Invert= 699.00', Outlet Invert= 695.00'



Summary for Reach S3: Swale 3

[62] Hint: Exceeded Reach S1 OUTLET depth by 0.18' @ 12.23 hrs
[62] Hint: Exceeded Reach S2 OUTLET depth by 0.23' @ 12.23 hrs

Inflow Area = 2.518 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 9.78 cfs @ 12.21 hrs, Volume= 0.552 af
Outflow = 9.74 cfs @ 12.22 hrs, Volume= 0.552 af, Atten= 0%, Lag= 0.6 min
Routed to Pond SP : South Pond

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.16 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 0.74 fps, Avg. Travel Time= 1.6 min

Peak Storage= 212 cf @ 12.21 hrs
Average Depth at Peak Storage= 0.48' , Surface Width= 7.88'
Bank-Full Depth= 1.00' Flow Area= 8.0 sf, Capacity= 37.92 cfs

5.00' x 1.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 3.0 '/' Top Width= 11.00'
Length= 68.7' Slope= 0.0146 '/'
Inlet Invert= 695.00', Outlet Invert= 694.00'

‡

Summary for Reach S4: Swale 4

[79] Warning: Submerged Pond SP Primary device # 1 OUTLET by 0.14'

Inflow Area = 7.956 ac, 38.95% Impervious, Inflow Depth > 3.06" for 25-yr event
Inflow = 1.20 cfs @ 12.14 hrs, Volume= 2.028 af
Outflow = 1.14 cfs @ 12.21 hrs, Volume= 2.027 af, Atten= 4%, Lag= 4.3 min
Routed to Reach SS5 : South Swale 5

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 0.75 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 0.40 fps, Avg. Travel Time= 5.3 min

Peak Storage= 192 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.14' , Surface Width= 11.16'
Bank-Full Depth= 2.00' Flow Area= 36.0 sf, Capacity= 123.75 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 26.00'
Length= 125.0' Slope= 0.0032 '/'
Inlet Invert= 689.50', Outlet Invert= 689.10'

Summary for Reach SS1: South Swale 1

Inflow Area = 3.123 ac, 0.00% Impervious, Inflow Depth = 2.81" for 25-yr event
Inflow = 9.79 cfs @ 12.15 hrs, Volume= 0.731 af
Outflow = 9.07 cfs @ 12.30 hrs, Volume= 0.731 af, Atten= 7%, Lag= 8.6 min
Routed to Pond C5 : C5

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.56 fps, Min. Travel Time= 4.5 min
Avg. Velocity = 0.66 fps, Avg. Travel Time= 17.4 min

Peak Storage= 2,434 cf @ 12.22 hrs
Average Depth at Peak Storage= 0.32' , Surface Width= 12.23'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 247.65 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 686.0' Slope= 0.0140 '/'
Inlet Invert= 714.00', Outlet Invert= 704.38'

‡

Summary for Reach SS2: South Swale 2

[79] Warning: Submerged Pond C5 Primary device # 1 INLET by 0.25'

Inflow Area = 4.749 ac, 0.00% Impervious, Inflow Depth = 2.81" for 25-yr event
Inflow = 12.82 cfs @ 12.27 hrs, Volume= 1.112 af
Outflow = 12.71 cfs @ 12.33 hrs, Volume= 1.112 af, Atten= 1%, Lag= 3.3 min
Routed to Pond C4 : C4

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.92 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 0.75 fps, Avg. Travel Time= 7.2 min

Peak Storage= 1,423 cf @ 12.29 hrs
Average Depth at Peak Storage= 0.38' , Surface Width= 12.68'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 253.11 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 327.0' Slope= 0.0146 '/'
Inlet Invert= 704.25', Outlet Invert= 699.46'

‡

Summary for Reach SS3: South Swale 3

[79] Warning: Submerged Pond C4 Primary device # 1 OUTLET by 0.45'

Inflow Area = 5.407 ac, 0.00% Impervious, Inflow Depth = 2.82" for 25-yr event
Inflow = 13.51 cfs @ 12.32 hrs, Volume= 1.272 af
Outflow = 13.35 cfs @ 12.38 hrs, Volume= 1.272 af, Atten= 1%, Lag= 3.5 min
Routed to Reach SS4 : South Swale 4

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.56 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 0.67 fps, Avg. Travel Time= 8.0 min

Peak Storage= 1,670 cf @ 12.34 hrs
Average Depth at Peak Storage= 0.45' , Surface Width= 13.15'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 201.47 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 320.0' Slope= 0.0093 '/'
Inlet Invert= 698.97', Outlet Invert= 696.00'

‡

Summary for Reach SS4: South Swale 4

[61] Hint: Exceeded Reach SS3 outlet invert by 0.26' @ 12.38 hrs

Inflow Area = 5.608 ac, 0.00% Impervious, Inflow Depth = 2.83" for 25-yr event
Inflow = 13.56 cfs @ 12.38 hrs, Volume= 1.321 af
Outflow = 13.55 cfs @ 12.39 hrs, Volume= 1.321 af, Atten= 0%, Lag= 0.7 min
Routed to Reach SS5 : South Swale 5

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.72 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.31 fps, Avg. Travel Time= 1.4 min

Peak Storage= 327 cf @ 12.38 hrs
Average Depth at Peak Storage= 0.26' , Surface Width= 11.84'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 514.50 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 114.0' Slope= 0.0605 '/'
Inlet Invert= 696.00', Outlet Invert= 689.10'

‡

Summary for Reach SS5: South Swale 5

[63] Warning: Exceeded Reach S4 INLET depth by 0.14' @ 12.40 hrs
[62] Hint: Exceeded Reach SS4 OUTLET depth by 0.40' @ 12.41 hrs

Inflow Area = 13.931 ac, 22.25% Impervious, Inflow Depth > 2.96" for 25-yr event
Inflow = 14.75 cfs @ 12.38 hrs, Volume= 3.439 af
Outflow = 14.69 cfs @ 12.42 hrs, Volume= 3.438 af, Atten= 0%, Lag= 2.2 min
Routed to Pond C2 : C2

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 1.82 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 0.43 fps, Avg. Travel Time= 5.5 min

Peak Storage= 1,133 cf @ 12.40 hrs
Average Depth at Peak Storage= 0.66' , Surface Width= 14.61'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 114.55 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 140.0' Slope= 0.0030 '/'
Inlet Invert= 689.10', Outlet Invert= 688.68'


‡

Summary for Reach SS6: South Swale 6

[79] Warning: Submerged Pond C2 Primary device # 1 INLET by 0.57'

Inflow Area = 15.806 ac, 19.61% Impervious, Inflow Depth > 2.94" for 25-yr event
Inflow = 17.37 cfs @ 12.12 hrs, Volume= 3.876 af
Outflow = 16.57 cfs @ 12.16 hrs, Volume= 3.875 af, Atten= 5%, Lag= 3.0 min
Routed to Pond C1 : Culvert C1a & b

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 1.88 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 0.43 fps, Avg. Travel Time= 8.2 min

Peak Storage= 1,894 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.71' , Surface Width= 14.94'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 114.10 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 215.0' Slope= 0.0030 '/'
Inlet Invert= 688.54', Outlet Invert= 687.90'

‡

Summary for Pond C1: Culvert C1a & b

[62] Hint: Exceeded Reach SS6 OUTLET depth by 0.29' @ 12.17 hrs

Inflow Area = 15.806 ac, 19.61% Impervious, Inflow Depth > 2.94" for 25-yr event
Inflow = 16.57 cfs @ 12.16 hrs, Volume= 3.875 af
Outflow = 16.57 cfs @ 12.16 hrs, Volume= 3.875 af, Atten= 0%, Lag= 0.0 min
Primary = 16.57 cfs @ 12.16 hrs, Volume= 3.875 af
Routed to Pond NP : North Pond

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 688.88' @ 12.16 hrs
Flood Elev= 691.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	687.71'	**24.0" Round C1a** L= 341.7' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 687.71' / 683.12' S= 0.0134 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf
#2	Primary	687.47'	**24.0" Round C1b** L= 341.6' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 687.47' / 683.25' S= 0.0124 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf

Primary OutFlow Max=16.53 cfs @ 12.16 hrs HW=688.88' (Free Discharge)
├─**1=C1a** (Inlet Controls 6.99 cfs @ 3.68 fps)
└─**2=C1b** (Inlet Controls 9.53 cfs @ 4.04 fps)

Summary for Pond C2: C2

[63] Warning: Exceeded Reach SS5 INLET depth by 1.45' @ 12.42 hrs
[79] Warning: Submerged Pond C3 Primary device # 1 OUTLET by 0.20'

Inflow Area = 15.153 ac, 20.45% Impervious, Inflow Depth > 2.94" for 25-yr event
Inflow = 15.73 cfs @ 12.41 hrs, Volume= 3.715 af
Outflow = 15.73 cfs @ 12.41 hrs, Volume= 3.715 af, Atten= 0%, Lag= 0.0 min
Primary = 15.73 cfs @ 12.41 hrs, Volume= 3.715 af
Routed to Reach SS6 : South Swale 6

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 691.21' @ 12.41 hrs
Flood Elev= 694.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	688.68'	**24.0" Round Culvert** L= 46.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 688.68' / 688.54' S= 0.0030 '/' Cc= 0.900 n= 0.012 Steel, smooth, Flow Area= 3.14 sf

Primary OutFlow Max=15.73 cfs @ 12.41 hrs HW=691.21' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 15.73 cfs @ 5.11 fps)

Summary for Pond C3: C3

[58] Hint: Peaked 2.36' above defined flood level

Inflow Area = 1.223 ac, 0.00% Impervious, Inflow Depth = 2.72" for 25-yr event
Inflow = 6.08 cfs @ 12.10 hrs, Volume= 0.277 af
Outflow = 6.08 cfs @ 12.10 hrs, Volume= 0.277 af, Atten= 0%, Lag= 0.0 min
Primary = 6.08 cfs @ 12.10 hrs, Volume= 0.277 af
Routed to Pond C2 : C2

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 696.36' @ 12.10 hrs
Flood Elev= 694.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	691.71'	**12.0" Round Culvert** L= 48.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 691.71' / 691.01' S= 0.0146 '/' Cc= 0.900 n= 0.012 Steel, smooth, Flow Area= 0.79 sf

Primary OutFlow Max=6.07 cfs @ 12.10 hrs HW=696.35' (Free Discharge)
└─**1=Culvert** (Inlet Controls 6.07 cfs @ 7.73 fps)

Summary for Pond C4: C4

[62] Hint: Exceeded Reach SS2 OUTLET depth by 1.51' @ 12.33 hrs

Inflow Area = 4.749 ac, 0.00% Impervious, Inflow Depth = 2.81" for 25-yr event
Inflow = 12.71 cfs @ 12.33 hrs, Volume= 1.112 af
Outflow = 12.71 cfs @ 12.33 hrs, Volume= 1.112 af, Atten= 0%, Lag= 0.0 min
Primary = 12.71 cfs @ 12.33 hrs, Volume= 1.112 af
Routed to Reach SS3 : South Swale 3

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 701.35' @ 12.33 hrs
Flood Elev= 702.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	699.46'	**24.0" Round Culvert** L= 40.5' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 699.46' / 698.97' S= 0.0121 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 3.14 sf

Primary OutFlow Max=12.70 cfs @ 12.33 hrs HW=701.35' (Free Discharge)
└─**1=Culvert** (Inlet Controls 12.70 cfs @ 4.13 fps)

Summary for Pond C5: C5

[62] Hint: Exceeded Reach SS1 OUTLET depth by 2.81' @ 12.30 hrs

Inflow Area = 3.123 ac, 0.00% Impervious, Inflow Depth = 2.81" for 25-yr event
Inflow = 9.07 cfs @ 12.30 hrs, Volume= 0.731 af
Outflow = 9.07 cfs @ 12.30 hrs, Volume= 0.731 af, Atten= 0%, Lag= 0.0 min
Primary = 9.07 cfs @ 12.30 hrs, Volume= 0.731 af
Routed to Reach SS2 : South Swale 2

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 707.50' @ 12.30 hrs
Flood Elev= 708.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	704.38'	**18.0" Round Culvert** L= 38.0' CMP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 704.38' / 704.25' S= 0.0034 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 1.77 sf

Primary OutFlow Max=9.07 cfs @ 12.30 hrs HW=707.50' (Free Discharge)
└─**1=Culvert** (Barrel Controls 9.07 cfs @ 5.13 fps)

Summary for Pond NP: North Pond

[62] Hint: Exceeded Reach NS3 OUTLET depth by 0.68' @ 14.15 hrs
[79] Warning: Submerged Pond C1 Primary device # 1 OUTLET by 1.67'
[79] Warning: Submerged Pond C1 Primary device # 2 OUTLET by 1.54'

Inflow Area = 92.527 ac, 11.98% Impervious, Inflow Depth > 2.86" for 25-yr event
Inflow = 184.24 cfs @ 12.33 hrs, Volume= 22.044 af
Outflow = 17.29 cfs @ 13.94 hrs, Volume= 21.803 af, Atten= 91%, Lag= 96.5 min
Primary = 17.29 cfs @ 13.94 hrs, Volume= 21.803 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Starting Elev= 681.75' Surf.Area= 2.820 ac Storage= 0.808 af
Peak Elev= 684.79' @ 13.94 hrs Surf.Area= 5.330 ac Storage= 13.287 af (12.479 af above start)

Plug-Flow detention time= 576.0 min calculated for 20.996 af (95% of inflow)
Center-of-Mass det. time= 457.3 min (1,385.6 - 928.3)

Volume	Invert	Avail.Storage	Storage Description
#1	681.46'	20.170 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
681.46	2.750	0.000	0.000
682.00	2.880	1.520	1.520
684.00	4.860	7.740	9.260
686.00	6.050	10.910	20.170

Device	Routing	Invert	Outlet Devices
#1	Primary	681.50'	**24.0" Round Culvert** L= 50.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 681.50' / 681.00' S= 0.0100 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	681.75'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#3	Device 1	682.25'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#4	Device 1	682.75'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#5	Device 1	683.25'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#6	Device 1	684.00'	**36.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#7	Secondary	685.00'	**Custom Weir/Orifice, Cv= 2.62 (C= 3.28)** Head (feet) 0.00 0.50 1.00 Width (feet) 10.00 20.00 30.00

Primary OutFlow Max=17.29 cfs @ 13.94 hrs HW=684.79' (Free Discharge)
└──**1=Culvert** (Barrel Controls 17.29 cfs @ 5.51 fps)
  ├──**2=Orifice/Grate** (Passes < 6.32 cfs potential flow)
  ├──**3=Orifice/Grate** (Passes < 5.72 cfs potential flow)
  ├──**4=Orifice/Grate** (Passes < 5.06 cfs potential flow)
  ├──**5=Orifice/Grate** (Passes < 4.30 cfs potential flow)
  └──**6=Orifice/Grate** (Passes < 21.65 cfs potential flow)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=681.75' (Free Discharge)
└──**7=Custom Weir/Orifice** (Controls 0.00 cfs)

Summary for Pond SP: South Pond

Inflow Area = 7.788 ac, 39.79% Impervious, Inflow Depth = 3.40" for 25-yr event
Inflow = 34.99 cfs @ 12.09 hrs, Volume= 2.210 af
Outflow = 0.71 cfs @ 16.09 hrs, Volume= 1.991 af, Atten= 98%, Lag= 240.3 min
Primary = 0.71 cfs @ 16.09 hrs, Volume= 1.991 af
Routed to Reach S4 : Swale 4
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Reach S4 : Swale 4

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Starting Elev= 690.00' Surf.Area= 104,799 sf Storage= 563,180 cf
Peak Elev= 690.69' @ 16.09 hrs Surf.Area= 108,753 sf Storage= 636,660 cf (73,480 cf above start)

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= 1,257.2 min (2,034.5 - 777.4)

Volume	Invert	Avail.Storage	Storage Description
#1	682.00'	1,159,218 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
682.00	4,661	0	0
683.00	34,274	19,468	19,468
684.00	54,009	44,142	63,609
685.00	67,049	60,529	124,138
686.00	76,841	71,945	196,083
687.00	84,846	80,844	276,927
688.00	92,571	88,709	365,635
689.00	98,860	95,716	461,351
690.00	104,799	101,830	563,180
691.00	110,544	107,672	670,852
692.00	116,064	113,304	784,156
693.00	121,865	118,965	903,120
694.00	127,659	124,762	1,027,882
695.00	135,013	131,336	1,159,218

Device	Routing	Invert	Outlet Devices
#1	Primary	690.00'	**12.0" Round Culvert** L= 50.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 690.00' / 689.50' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf
#2	Secondary	692.00'	**10.0' long x 50.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#3	Device 1	690.00'	**3.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#4	Device 1	691.00'	**3.0" Vert. Orifice/Grate X 6.00** C= 0.600 Limited to weir flow at low heads
#5	Device 1	692.00'	**36.0" Horiz. Orifice/Grate** C= 0.600

Limited to weir flow at low heads

Primary OutFlow Max=0.71 cfs @ 16.09 hrs HW=690.69' (Free Discharge)
└─**1=Culvert** (Passes 0.71 cfs of 1.55 cfs potential flow)
  ├─**3=Orifice/Grate** (Orifice Controls 0.71 cfs @ 3.61 fps)
  ├─**4=Orifice/Grate** (Controls 0.00 cfs)
  └─**5=Orifice/Grate** (Controls 0.00 cfs)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=690.00' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Summary for Link F1: Flume 1

Inflow Area = 1.695 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 4.95 cfs @ 12.25 hrs, Volume= 0.371 af
Primary = 4.95 cfs @ 12.25 hrs, Volume= 0.371 af, Atten= 0%, Lag= 0.0 min
Routed to Pond NP : North Pond

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F2: Flume 2

Inflow Area = 0.661 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 1.95 cfs @ 12.24 hrs, Volume= 0.145 af
Primary = 1.95 cfs @ 12.24 hrs, Volume= 0.145 af, Atten= 0%, Lag= 0.0 min
Routed to Reach NS3 : North Swale 3

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F3: Flume 3

Inflow Area = 0.867 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 2.54 cfs @ 12.24 hrs, Volume= 0.190 af
Primary = 2.54 cfs @ 12.24 hrs, Volume= 0.190 af, Atten= 0%, Lag= 0.0 min
Routed to Pond NP : North Pond

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F4: Flume 4

Inflow Area = 1.215 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 3.61 cfs @ 12.24 hrs, Volume= 0.266 af
Primary = 3.61 cfs @ 12.24 hrs, Volume= 0.266 af, Atten= 0%, Lag= 0.0 min
Routed to Reach NS2 : North Swale 2

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Time span=0.00-90.00 hrs, dt=0.01 hrs, 9001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1: Area 1 Runoff Area=28,521 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=347' Tc=15.8 min CN=79 Runoff=3.04 cfs 0.228 af

Subcatchment1_2: Phase 1 and 2 Runoff Area=2,282,700 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=3,476' Tc=25.0 min CN=79 Runoff=194.30 cfs 18.230 af

Subcatchment2: Area 2 Runoff Area=28,787 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=491' Tc=15.8 min CN=79 Runoff=3.07 cfs 0.230 af

Subcatchment3: Area 3 Runoff Area=45,292 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=449' Tc=16.3 min CN=79 Runoff=4.76 cfs 0.362 af

Subcatchment4: Area 4 Runoff Area=52,914 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=475' Tc=15.6 min CN=79 Runoff=5.69 cfs 0.423 af

Subcatchment5: Area 5 Runoff Area=37,768 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=442' Tc=15.9 min CN=79 Runoff=4.01 cfs 0.302 af

Subcatchment6: Area 6 Runoff Area=61,616 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=114' Slope=0.2500 '/' Tc=5.9 min CN=79 Runoff=9.46 cfs 0.492 af

Subcatchment7: Area 7 Runoff Area=81,807 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=200' Tc=12.4 min CN=79 Runoff=9.72 cfs 0.653 af

Subcatchment8: Area 8 Runoff Area=63,362 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=198' Tc=13.8 min CN=79 Runoff=7.18 cfs 0.506 af

Subcatchment9: Area 9 Runoff Area=48,089 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=133' Tc=6.0 min CN=79 Runoff=7.34 cfs 0.384 af

Subcatchment10: Area 10 Runoff Area=63,729 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=138' Tc=4.2 min CN=79 Runoff=10.44 cfs 0.509 af

Subcatchment11: Area 11 Runoff Area=10,561 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=98' Slope=0.0610 '/' Tc=10.0 min CN=79 Runoff=1.37 cfs 0.084 af

Subcatchment12a: Area 12a Runoff Area=98,996 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=180' Tc=14.4 min CN=79 Runoff=11.03 cfs 0.791 af

Subcatchment12b: Area 12b Runoff Area=47,686 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=204' Tc=14.2 min CN=79 Runoff=5.32 cfs 0.381 af

Subcatchment12c: Area 12c Runoff Area=5,888 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=19' Slope=0.0050 '/' Tc=5.0 min CN=79 Runoff=0.94 cfs 0.047 af

Subcatchment12d: Area 12d Runoff Area=1,651 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=23' Slope=0.0050 '/' Tc=8.5 min CN=79 Runoff=0.23 cfs 0.013 af

Subcatchment12e: Area 12e Runoff Area=4,957 sf 0.00% Impervious Runoff Depth=4.71"
Flow Length=47' Tc=4.1 min CN=84 Runoff=0.90 cfs 0.045 af

Subcatchment12f: Area 12f Runoff Area=9,031 sf 0.00% Impervious Runoff Depth=4.50"
Flow Length=52' Slope=0.0788 '/' Tc=5.4 min CN=82 Runoff=1.50 cfs 0.078 af

Subcatchment13: Area 13 Runoff Area=174,279 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=205' Tc=14.5 min CN=79 Runoff=19.29 cfs 1.392 af

Subcatchment14: Area 14 Runoff Area=59,877 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=125' Slope=0.2500 '/' Tc=5.9 min CN=79 Runoff=9.19 cfs 0.478 af

Subcatchment15a: Area 15a Runoff Area=99,614 sf 5.36% Impervious Runoff Depth=4.60"
Flow Length=58' Tc=3.3 min CN=83 Runoff=18.14 cfs 0.877 af

Subcatchment15b: Area 15b Runoff Area=11,056 sf 0.00% Impervious Runoff Depth=4.82"
Flow Length=33' Slope=0.1176 '/' Tc=2.4 min CN=85 Runoff=2.11 cfs 0.102 af

Subcatchment15c: Area 15c Runoff Area=9,032 sf 0.00% Impervious Runoff Depth=4.50"
Flow Length=1,656' Tc=7.2 min CN=82 Runoff=1.40 cfs 0.078 af

Subcatchment16a: Area 16a Runoff Area=37,043 sf 0.00% Impervious Runoff Depth=4.93"
Flow Length=50' Tc=5.6 min CN=86 Runoff=6.55 cfs 0.350 af

Subcatchment16b: Area 16b Runoff Area=23,150 sf 0.00% Impervious Runoff Depth=4.82"
Flow Length=78' Tc=1.8 min CN=85 Runoff=4.47 cfs 0.214 af

Subcatchment16c: Area 16c Runoff Area=22,754 sf 0.00% Impervious Runoff Depth=4.60"
Flow Length=54' Tc=3.0 min CN=83 Runoff=4.18 cfs 0.200 af

Subcatchment16d: Area 16d Runoff Area=7,112 sf 0.00% Impervious Runoff Depth=4.60"
Flow Length=65' Tc=4.2 min CN=83 Runoff=1.26 cfs 0.063 af

Subcatchment16e: Area 16e Runoff Area=11,038 sf 0.00% Impervious Runoff Depth=4.50"
Flow Length=75' Tc=4.7 min CN=82 Runoff=1.88 cfs 0.095 af

Subcatchment16f: Area 16f Runoff Area=19,413 sf 0.00% Impervious Runoff Depth=4.60"
Flow Length=75' Tc=4.7 min CN=83 Runoff=3.37 cfs 0.171 af

Subcatchment17: Area 17 Runoff Area=18,834 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=140' Slope=0.2500 '/' Tc=6.0 min CN=79 Runoff=2.88 cfs 0.150 af

Subcatchment18: Area 18 Runoff Area=20,237 sf 0.00% Impervious Runoff Depth=4.28"
Flow Length=55' Slope=0.0714 '/' Tc=5.9 min CN=80 Runoff=3.17 cfs 0.166 af

Subcatchment19: Area 19 Runoff Area=5,416 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=141' Slope=0.2500 '/' Tc=6.0 min CN=79 Runoff=0.83 cfs 0.043 af

Subcatchment20: Area 20 Runoff Area=53,255 sf 0.00% Impervious Runoff Depth=4.28"
Flow Length=100' Slope=0.0050 '/' Tc=2.3 min CN=80 Runoff=9.34 cfs 0.436 af

Subcatchment21: Area 21 Runoff Area=7,329 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=62' Slope=0.0758 '/' Tc=6.4 min CN=79 Runoff=1.10 cfs 0.059 af

SubcatchmentP1: North Pond Runoff Area=342,674 sf 100.00% Impervious Runoff Depth=6.31"
Tc=0.0 min CN=98 Runoff=74.56 cfs 4.137 af

SubcatchmentP2: South Pond Runoff Area=3.099 ac 100.00% Impervious Runoff Depth=6.31"
Tc=0.0 min CN=98 Runoff=29.37 cfs 1.630 af

Reach NS1: North Swale 1 Avg. Flow Depth=0.54' Max Vel=4.27 fps Inflow=30.98 cfs 2.269 af
n=0.030 L=1,043.0' S=0.0209 '/' Capacity=302.62 cfs Outflow=27.37 cfs 2.269 af

Reach NS2: North Swale 2 Avg. Flow Depth=0.77' Max Vel=3.89 fps Inflow=38.55 cfs 3.272 af
n=0.030 L=381.0' S=0.0115 '/' Capacity=224.48 cfs Outflow=38.05 cfs 3.272 af

Reach NS3: North Swale 3 Avg. Flow Depth=0.71' Max Vel=4.82 fps Inflow=43.03 cfs 3.730 af
n=0.030 L=195.0' S=0.0193 '/' Capacity=290.78 cfs Outflow=42.94 cfs 3.730 af

Reach S1: Swale 1 Avg. Flow Depth=0.44' Max Vel=2.52 fps Inflow=9.46 cfs 0.492 af
n=0.030 L=423.0' S=0.0118 '/' Capacity=45.58 cfs Outflow=8.69 cfs 0.492 af

Reach S2: Swale 2 Avg. Flow Depth=0.38' Max Vel=2.40 fps Inflow=7.34 cfs 0.384 af
n=0.030 L=320.0' S=0.0125 '/' Capacity=46.88 cfs Outflow=6.93 cfs 0.384 af

Reach S3: Swale 3 Avg. Flow Depth=0.62' Max Vel=3.65 fps Inflow=15.56 cfs 0.876 af
n=0.030 L=68.7' S=0.0146 '/' Capacity=37.92 cfs Outflow=15.50 cfs 0.876 af

Reach S4: Swale 4 Avg. Flow Depth=0.18' Max Vel=0.86 fps Inflow=1.76 cfs 3.043 af
n=0.030 L=125.0' S=0.0032 '/' Capacity=123.75 cfs Outflow=1.70 cfs 3.042 af

Reach SS1: South Swale 1 Avg. Flow Depth=0.42' Max Vel=3.00 fps Inflow=15.12 cfs 1.140 af
n=0.030 L=686.0' S=0.0140 '/' Capacity=247.65 cfs Outflow=14.25 cfs 1.140 af

Reach SS2: South Swale 2 Avg. Flow Depth=0.50' Max Vel=3.42 fps Inflow=20.30 cfs 1.735 af
n=0.030 L=327.0' S=0.0146 '/' Capacity=253.11 cfs Outflow=20.14 cfs 1.735 af

Reach SS3: South Swale 3 Avg. Flow Depth=0.59' Max Vel=2.99 fps Inflow=21.38 cfs 1.982 af
n=0.030 L=320.0' S=0.0093 '/' Capacity=201.47 cfs Outflow=21.21 cfs 1.982 af

Reach SS4: South Swale 4 Avg. Flow Depth=0.35' Max Vel=5.57 fps Inflow=21.57 cfs 2.058 af
n=0.030 L=114.0' S=0.0605 '/' Capacity=514.50 cfs Outflow=21.56 cfs 2.058 af

Reach SS5: South Swale 5 Avg. Flow Depth=0.85' Max Vel=2.10 fps Inflow=23.33 cfs 5.240 af
n=0.030 L=140.0' S=0.0030 '/' Capacity=114.55 cfs Outflow=23.26 cfs 5.239 af

Reach SS6: South Swale 6 Avg. Flow Depth=0.94' Max Vel=2.22 fps Inflow=28.72 cfs 5.924 af
n=0.030 L=215.0' S=0.0030 '/' Capacity=114.10 cfs Outflow=27.71 cfs 5.922 af

Pond C1: Culvert C1a & b Peak Elev=689.43' Inflow=27.71 cfs 5.922 af
Outflow=27.71 cfs 5.922 af

Pond C2: C2 Peak Elev=692.47' Inflow=24.86 cfs 5.675 af
24.0" Round Culvert n=0.012 L=46.0' S=0.0030 '/' Outflow=24.86 cfs 5.675 af

Pond C3: C3 Peak Elev=701.99' Inflow=9.34 cfs 0.436 af
12.0" Round Culvert n=0.012 L=48.0' S=0.0146 '/' Outflow=9.34 cfs 0.436 af

Pond C4: C4 Peak Elev=702.74' Inflow=20.14 cfs 1.735 af
24.0" Round Culvert n=0.013 L=40.5' S=0.0121 '/' Outflow=20.14 cfs 1.735 af

Pond C5: C5 Peak Elev=710.06' Inflow=14.25 cfs 1.140 af
18.0" Round Culvert n=0.025 L=38.0' S=0.0034 '/' Outflow=14.25 cfs 1.140 af

Pond NP: North Pond Peak Elev=685.75' Storage=18.653 af Inflow=290.58 cfs 34.113 af
Primary=21.42 cfs 28.517 af Secondary=33.72 cfs 5.301 af Outflow=55.14 cfs 33.818 af

Pond SP: South Pond Peak Elev=691.03' Storage=674,066 cf Inflow=51.38 cfs 3.265 af
Primary=0.93 cfs 2.985 af Secondary=0.00 cfs 0.000 af Outflow=0.93 cfs 2.985 af

Link F1: Flume 1 Inflow=7.80 cfs 0.589 af
Primary=7.80 cfs 0.589 af

Link F2: Flume 2 Inflow=3.07 cfs 0.230 af
Primary=3.07 cfs 0.230 af

Link F3: Flume 3 Inflow=4.01 cfs 0.302 af
Primary=4.01 cfs 0.302 af

Link F4: Flume 4 Inflow=5.69 cfs 0.423 af
Primary=5.69 cfs 0.423 af

Total Runoff Area = 92.527 ac Runoff Volume = 34.397 af Average Runoff Depth = 4.46"
88.02% Pervious = 81.438 ac 11.98% Impervious = 11.088 ac

Summary for Subcatchment 1: Area 1

Runoff = 3.04 cfs @ 12.24 hrs, Volume= 0.228 af, Depth= 4.17"
Routed to Link F1 : Flume 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	28,521	79	
	28,521		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.5	106	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	141	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
15.8	347	Total			

Summary for Subcatchment 1_2: Phase 1 and 2

Runoff = 194.30 cfs @ 12.36 hrs, Volume= 18.230 af, Depth= 4.17"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	2,282,700	79	Closed Landfill
	2,282,700		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.0	100	0.0400	0.14		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.8	400	0.0400	1.40		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.2	2,976	0.0120	6.04	380.82	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=3.00' Z= 10.0 & 4.0 '/' Top.W=42.00' n= 0.035 Earth, dense weeds
25.0	3,476	Total			

Summary for Subcatchment 2: Area 2

Runoff = 3.07 cfs @ 12.24 hrs, Volume= 0.230 af, Depth= 4.17"
Routed to Link F2 : Flume 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	28,787	79	
	28,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.1	78	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	203	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	110	0.2500	20.09	10.95	**Pipe Channel,** 10.0" Round Area= 0.5 sf Perim= 2.6' r= 0.21' n= 0.013 Corrugated PE, smooth interior
15.8	491	Total			

Summary for Subcatchment 3: Area 3

Runoff = 4.76 cfs @ 12.24 hrs, Volume= 0.362 af, Depth= 4.17"
Routed to Link F1 : Flume 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	45,292	79	
	45,292		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.5	108	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	241	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
16.3	449	Total			

Summary for Subcatchment 4: Area 4

Runoff = 5.69 cfs @ 12.24 hrs, Volume= 0.423 af, Depth= 4.17"
Routed to Link F4 : Flume 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	52,914	79	
	52,914		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.1	83	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.9	173	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	119	0.2500	22.68	17.81	**Pipe Channel, Flume 4** 12.0" Round Area= 0.8 sf Perim= 3.1' r= 0.25' n= 0.013 Corrugated PE, smooth interior
15.6	475	Total			

Summary for Subcatchment 5: Area 5

Runoff = 4.01 cfs @ 12.24 hrs, Volume= 0.302 af, Depth= 4.17"
Routed to Link F3 : Flume 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	37,768	79	
	37,768		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.0	73	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	269	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Diversion Berm** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
15.9	442	Total			

Summary for Subcatchment 6: Area 6

Runoff = 9.46 cfs @ 12.13 hrs, Volume= 0.492 af, Depth= 4.17"
Routed to Reach S1 : Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	61,616	79	
	61,616		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.1	14	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
5.9	114	Total			

Summary for Subcatchment 7: Area 7

Runoff = 9.72 cfs @ 12.20 hrs, Volume= 0.653 af, Depth= 4.17"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	81,807	79	
	81,807		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.3	63	0.0300	0.11		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.6	37	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	100	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.4	200	Total			

Summary for Subcatchment 8: Area 8

Runoff = 7.18 cfs @ 12.22 hrs, Volume= 0.506 af, Depth= 4.17"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	62,504	79	
	858	96	Gravel surface, HSG C
	63,362	79	Weighted Average
	63,362		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.5	91	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	9	0.2500	0.18		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	98	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
13.8	198	Total			

Summary for Subcatchment 9: Area 9

Runoff = 7.34 cfs @ 12.13 hrs, Volume= 0.384 af, Depth= 4.17"
Routed to Reach S2 : Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	48,089	79	
	48,089		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.0	5	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	28	0.0800	1.98		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
6.0	133	Total			

Summary for Subcatchment 10: Area 10

Runoff = 10.44 cfs @ 12.12 hrs, Volume= 0.509 af, Depth= 4.17"
Routed to Pond SP : South Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	63,729	79	
	63,729		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.0	100	0.2500	0.42		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
0.1	19	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	19	0.2000	3.13		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
4.2	138	Total			

Summary for Subcatchment 11: Area 11

Runoff = 1.37 cfs @ 12.17 hrs, Volume= 0.084 af, Depth= 4.17"
Routed to Pond SP : South Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	10,561	79	
	10,561		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0	98	0.0610	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment 12a: Area 12a

Runoff = 11.03 cfs @ 12.22 hrs, Volume= 0.791 af, Depth= 4.17"
Routed to Reach SS1 : South Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	98,996	79	
	98,996		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	57	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	23	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.4	180	Total			

Summary for Subcatchment 12b: Area 12b

Runoff = 5.32 cfs @ 12.22 hrs, Volume= 0.381 af, Depth= 4.17"
Routed to Reach SS2 : South Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	47,328	79	
	358	96	Gravel surface, HSG C
	47,686	79	Weighted Average
	47,686		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.3	24	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.3	57	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	23	0.3333	4.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.2	204	Total			

Summary for Subcatchment 12c: Area 12c

Runoff = 0.94 cfs @ 12.12 hrs, Volume= 0.047 af, Depth= 4.17"
Routed to Reach SS3 : South Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	5,888	79	
	5,888		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0	19	0.0050	0.06		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"

Summary for Subcatchment 12d: Area 12d

Runoff = 0.23 cfs @ 12.16 hrs, Volume= 0.013 af, Depth= 4.17"
Routed to Reach SS4 : South Swale 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	1,651	79	
	1,651		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.5	23	0.0050	0.04		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment 12e: Area 12e

Runoff = 0.90 cfs @ 12.12 hrs, Volume= 0.045 af, Depth= 4.71"
Routed to Reach SS5 : South Swale 5

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	3,521	79	
	1,436	96	Gravel surface, HSG C
	4,957	84	Weighted Average
	4,957		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.3	9	0.0050	0.44		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
3.8	38	0.0400	0.17		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
4.1	47	Total			

Summary for Subcatchment 12f: Area 12f

Runoff = 1.50 cfs @ 12.13 hrs, Volume= 0.078 af, Depth= 4.50"
Routed to Reach SS6 : South Swale 6

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	7,374	79	
	1,657	96	Gravel surface, HSG C
	9,031	82	Weighted Average
	9,031		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	52	0.0788	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment 13: Area 13

Runoff = 19.29 cfs @ 12.23 hrs, Volume= 1.392 af, Depth= 4.17"
Routed to Reach NS1 : North Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	174,279	79	
	174,279		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	56	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	49	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.5	205	Total			

Summary for Subcatchment 14: Area 14

Runoff = 9.19 cfs @ 12.13 hrs, Volume= 0.478 af, Depth= 4.17"
Routed to Reach NS2 : North Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	59,877	79	
	59,877		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.1	25	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
5.9	125	Total			

Summary for Subcatchment 15a: Area 15a

Runoff = 18.14 cfs @ 12.11 hrs, Volume= 0.877 af, Depth= 4.60"
Routed to Reach NS1 : North Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	78,118	79	
	5,343	98	Paved roads w/curbs & sewers, HSG C
	16,153	96	Gravel surface, HSG C
	99,614	83	Weighted Average
	94,271		94.64% Pervious Area
	5,343		5.36% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	32	0.0050	0.57		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
2.4	26	0.1538	0.18		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
3.3	58	Total			

Summary for Subcatchment 15b: Area 15b

Runoff = 2.11 cfs @ 12.10 hrs, Volume= 0.102 af, Depth= 4.82"
Routed to Reach NS2 : North Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	7,026	79	
	4,030	96	Gravel surface, HSG C
	11,056	85	Weighted Average
	11,056		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	11	0.1176	1.62		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
2.3	22	0.1176	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.4	33	Total			

Summary for Subcatchment 15c: Area 15c

Runoff = 1.40 cfs @ 12.14 hrs, Volume= 0.078 af, Depth= 4.50"
Routed to Reach NS3 : North Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	7,178	79	
	1,854	96	Gravel surface, HSG C
	9,032	82	Weighted Average
	9,032		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	14	0.1250	1.74		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
4.4	50	0.1250	0.19		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.7	1,592	0.0167	9.92	610.36	**Trap/Vee/Rect Channel Flow,** Bot.W=10.00' D=3.00' Z= 4.0 & 3.0 '/' Top.W=31.00' n= 0.030 Earth, grassed & winding
7.2	1,656	Total			

Summary for Subcatchment 16a: Area 16a

Runoff = 6.55 cfs @ 12.13 hrs, Volume= 0.350 af, Depth= 4.93"
Routed to Reach SS1 : South Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	20,948	79	
	16,095	96	Gravel surface, HSG C
	37,043	86	Weighted Average
	37,043		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.7	13	0.0050	0.06		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
0.7	21	0.0050	0.52		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.2	16	0.3300	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
5.6	50	Total			

Summary for Subcatchment 16b: Area 16b

Runoff = 4.47 cfs @ 12.10 hrs, Volume= 0.214 af, Depth= 4.82"
Routed to Reach SS2 : South Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	14,694	79	
	8,456	96	Gravel surface, HSG C
	23,150	85	Weighted Average
	23,150		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.7	64	0.0450	1.57		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.1	14	0.3333	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.8	78	Total			

Summary for Subcatchment 16c: Area 16c

Runoff = 4.18 cfs @ 12.11 hrs, Volume= 0.200 af, Depth= 4.60"
Routed to Reach SS3 : South Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	17,622	79	
	5,132	96	Gravel surface, HSG C
	22,754	83	Weighted Average
	22,754		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.8	24	0.2500	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	7	0.1666	0.14		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.1	18	0.1667	2.05		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
0.3	5	0.3333	0.26		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
3.0	54	Total			

Summary for Subcatchment 16d: Area 16d

Runoff = 1.26 cfs @ 12.12 hrs, Volume= 0.063 af, Depth= 4.60"
Routed to Reach SS4 : South Swale 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	5,564	79	
	1,548	96	Gravel surface, HSG C
	7,112	83	Weighted Average
	7,112		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.7	38	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	14	0.0050	0.48		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.0	13	0.3300	0.21		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.2	65	Total			

Summary for Subcatchment 16e: Area 16e

Runoff = 1.88 cfs @ 12.12 hrs, Volume= 0.095 af, Depth= 4.50"
Routed to Reach SS5 : South Swale 5

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	8,772	79	
	2,266	96	Gravel surface, HSG C
	11,038	82	Weighted Average
	11,038		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.9	43	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	16	0.0050	0.49		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.3	16	0.2500	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.7	75	Total			

Summary for Subcatchment 16f: Area 16f

Runoff = 3.37 cfs @ 12.12 hrs, Volume= 0.171 af, Depth= 4.60"
Routed to Reach SS6 : South Swale 6

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	14,568	79	
	4,845	96	Gravel surface, HSG C
	19,413	83	Weighted Average
	19,413		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.9	43	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	16	0.0050	0.49		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.3	16	0.2500	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.7	75	Total			

Summary for Subcatchment 17: Area 17

Runoff = 2.88 cfs @ 12.13 hrs, Volume= 0.150 af, Depth= 4.17"
Routed to Reach NS3 : North Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	18,834	79	
	18,834		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.2	40	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
6.0	140	Total			

Summary for Subcatchment 18: Area 18

Runoff = 3.17 cfs @ 12.13 hrs, Volume= 0.166 af, Depth= 4.28"
Routed to Pond SP : South Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	19,430	79	
	807	96	Gravel surface, HSG C
	20,237	80	Weighted Average
	20,237		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.9	55	0.0714	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment 19: Area 19

Runoff = 0.83 cfs @ 12.13 hrs, Volume= 0.043 af, Depth= 4.17"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	5,416	79	
	5,416		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.2	41	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
6.0	141	Total			

Summary for Subcatchment 20: Area 20

Runoff = 9.34 cfs @ 12.10 hrs, Volume= 0.436 af, Depth= 4.28"
Routed to Pond C3 : C3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	50,854	79	
	2,401	96	Gravel surface, HSG C
	53,255	80	Weighted Average
	53,255		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.3	100	0.0050	0.71		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"

Summary for Subcatchment 21: Area 21

Runoff = 1.10 cfs @ 12.14 hrs, Volume= 0.059 af, Depth= 4.17"
Routed to Reach S4 : Swale 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	7,177	79	
	152	96	Gravel surface, HSG C
	7,329	79	Weighted Average
	7,329		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.4	62	0.0758	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"

Summary for Subcatchment P1: North Pond

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 74.56 cfs @ 12.09 hrs, Volume= 4.137 af, Depth= 6.31"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

Area (sf)	CN	Description
342,674	98	Water Surface
342,674		100.00% Impervious Area

Summary for Subcatchment P2: South Pond

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 29.37 cfs @ 12.09 hrs, Volume= 1.630 af, Depth= 6.31"
Routed to Pond SP : South Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

Area (ac)	CN	Description
3.099	98	Water Surface, HSG C
3.099		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0					**Direct Entry,**

Summary for Reach NS1: North Swale 1

Inflow Area = 6.288 ac, 1.95% Impervious, Inflow Depth = 4.33" for 100-yr event
Inflow = 30.98 cfs @ 12.12 hrs, Volume= 2.269 af
Outflow = 27.37 cfs @ 12.22 hrs, Volume= 2.269 af, Atten= 12%, Lag= 5.9 min
Routed to Reach NS2 : North Swale 2

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.27 fps, Min. Travel Time= 4.1 min
Avg. Velocity = 1.04 fps, Avg. Travel Time= 16.7 min

Peak Storage= 6,688 cf @ 12.15 hrs
Average Depth at Peak Storage= 0.54' , Surface Width= 13.78'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 302.62 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 1,043.0' Slope= 0.0209 '/'
Inlet Invert= 714.00', Outlet Invert= 692.16'

Summary for Reach NS2: North Swale 2

[62] Hint: Exceeded Reach NS1 OUTLET depth by 0.25' @ 12.23 hrs

Inflow Area = 9.131 ac, 1.34% Impervious, Inflow Depth = 4.30" for 100-yr event
Inflow = 38.55 cfs @ 12.21 hrs, Volume= 3.272 af
Outflow = 38.05 cfs @ 12.25 hrs, Volume= 3.272 af, Atten= 1%, Lag= 2.7 min
Routed to Reach NS3 : North Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.89 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 0.93 fps, Avg. Travel Time= 6.8 min

Peak Storage= 3,726 cf @ 12.22 hrs
Average Depth at Peak Storage= 0.77' , Surface Width= 15.39'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 224.48 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 381.0' Slope= 0.0115 '/'
Inlet Invert= 692.16', Outlet Invert= 687.77'

Summary for Reach NS3: North Swale 3

[61] Hint: Exceeded Reach NS2 outlet invert by 0.71' @ 12.25 hrs

Inflow Area = 10.431 ac, 1.18% Impervious, Inflow Depth = 4.29" for 100-yr event
Inflow = 43.03 cfs @ 12.25 hrs, Volume= 3.730 af
Outflow = 42.94 cfs @ 12.27 hrs, Volume= 3.730 af, Atten= 0%, Lag= 1.1 min
Routed to Pond NP : North Pond

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.82 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.16 fps, Avg. Travel Time= 2.8 min

Peak Storage= 1,736 cf @ 12.25 hrs
Average Depth at Peak Storage= 0.71' , Surface Width= 14.99'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 290.78 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 195.0' Slope= 0.0193 '/'
Inlet Invert= 687.77', Outlet Invert= 684.00'

‡

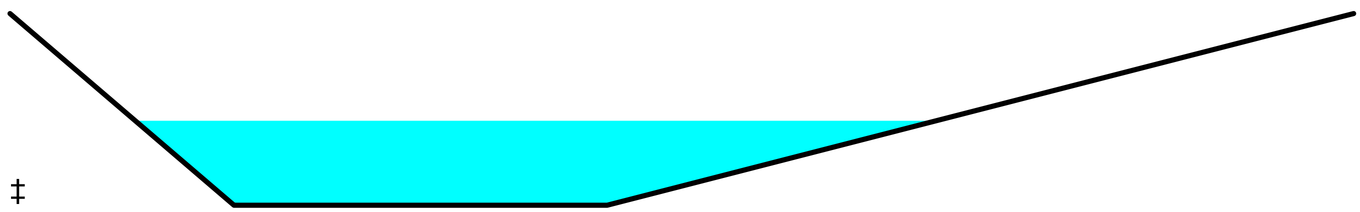
Summary for Reach S1: Swale 1

Inflow Area = 1.415 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 9.46 cfs @ 12.13 hrs, Volume= 0.492 af
Outflow = 8.69 cfs @ 12.20 hrs, Volume= 0.492 af, Atten= 8%, Lag= 4.3 min
Routed to Reach S3 : Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.52 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 0.62 fps, Avg. Travel Time= 11.4 min

Peak Storage= 1,463 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.44' , Surface Width= 10.72'
Bank-Full Depth= 1.00' Flow Area= 11.5 sf, Capacity= 45.58 cfs

5.00' x 1.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 3.0 10.0 '/' Top Width= 18.00'
Length= 423.0' Slope= 0.0118 '/'
Inlet Invert= 700.00', Outlet Invert= 695.00'



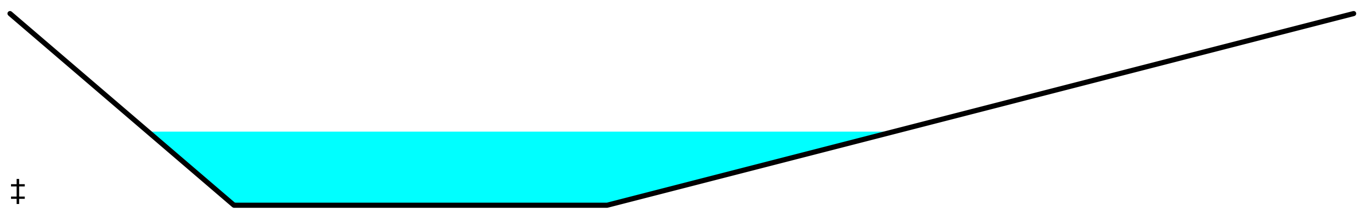
Summary for Reach S2: Swale 2

Inflow Area = 1.104 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 7.34 cfs @ 12.13 hrs, Volume= 0.384 af
Outflow = 6.93 cfs @ 12.19 hrs, Volume= 0.384 af, Atten= 6%, Lag= 3.5 min
Routed to Reach S3 : Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.40 fps, Min. Travel Time= 2.2 min
Avg. Velocity = 0.59 fps, Avg. Travel Time= 9.0 min

Peak Storage= 923 cf @ 12.15 hrs
Average Depth at Peak Storage= 0.38' , Surface Width= 10.00'
Bank-Full Depth= 1.00' Flow Area= 11.5 sf, Capacity= 46.88 cfs

5.00' x 1.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 3.0 10.0 '/' Top Width= 18.00'
Length= 320.0' Slope= 0.0125 '/'
Inlet Invert= 699.00', Outlet Invert= 695.00'



Summary for Reach S3: Swale 3

[62] Hint: Exceeded Reach S1 OUTLET depth by 0.23' @ 12.22 hrs
[62] Hint: Exceeded Reach S2 OUTLET depth by 0.29' @ 12.22 hrs

Inflow Area = 2.518 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 15.56 cfs @ 12.20 hrs, Volume= 0.876 af
Outflow = 15.50 cfs @ 12.21 hrs, Volume= 0.876 af, Atten= 0%, Lag= 0.5 min
Routed to Pond SP : South Pond

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.65 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 0.83 fps, Avg. Travel Time= 1.4 min

Peak Storage= 292 cf @ 12.20 hrs
Average Depth at Peak Storage= 0.62' , Surface Width= 8.72'
Bank-Full Depth= 1.00' Flow Area= 8.0 sf, Capacity= 37.92 cfs

5.00' x 1.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 3.0 '/' Top Width= 11.00'
Length= 68.7' Slope= 0.0146 '/'
Inlet Invert= 695.00', Outlet Invert= 694.00'

Summary for Reach S4: Swale 4

[79] Warning: Submerged Pond SP Primary device # 1 OUTLET by 0.18'

Inflow Area = 7.956 ac, 38.95% Impervious, Inflow Depth > 4.59" for 100-yr event
Inflow = 1.76 cfs @ 12.14 hrs, Volume= 3.043 af
Outflow = 1.70 cfs @ 12.20 hrs, Volume= 3.042 af, Atten= 3%, Lag= 3.7 min
Routed to Reach SS5 : South Swale 5

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 0.86 fps, Min. Travel Time= 2.4 min
Avg. Velocity = 0.47 fps, Avg. Travel Time= 4.5 min

Peak Storage= 246 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.18' , Surface Width= 11.47'
Bank-Full Depth= 2.00' Flow Area= 36.0 sf, Capacity= 123.75 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 26.00'
Length= 125.0' Slope= 0.0032 '/'
Inlet Invert= 689.50', Outlet Invert= 689.10'

Summary for Reach SS1: South Swale 1

Inflow Area = 3.123 ac, 0.00% Impervious, Inflow Depth = 4.38" for 100-yr event
Inflow = 15.12 cfs @ 12.16 hrs, Volume= 1.140 af
Outflow = 14.25 cfs @ 12.28 hrs, Volume= 1.140 af, Atten= 6%, Lag= 7.3 min
Routed to Pond C5 : C5

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.00 fps, Min. Travel Time= 3.8 min
Avg. Velocity = 0.73 fps, Avg. Travel Time= 15.6 min

Peak Storage= 3,263 cf @ 12.21 hrs
Average Depth at Peak Storage= 0.42' , Surface Width= 12.91'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 247.65 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 686.0' Slope= 0.0140 '/'
Inlet Invert= 714.00', Outlet Invert= 704.38'

Summary for Reach SS2: South Swale 2

[79] Warning: Submerged Pond C5 Primary device # 1 INLET by 0.37'

Inflow Area = 4.749 ac, 0.00% Impervious, Inflow Depth = 4.38" for 100-yr event
Inflow = 20.30 cfs @ 12.26 hrs, Volume= 1.735 af
Outflow = 20.14 cfs @ 12.30 hrs, Volume= 1.735 af, Atten= 1%, Lag= 2.7 min
Routed to Pond C4 : C4

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.42 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 0.85 fps, Avg. Travel Time= 6.4 min

Peak Storage= 1,925 cf @ 12.27 hrs
Average Depth at Peak Storage= 0.50' , Surface Width= 13.51'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 253.11 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 327.0' Slope= 0.0146 '/'
Inlet Invert= 704.25', Outlet Invert= 699.46'

Summary for Reach SS3: South Swale 3

[79] Warning: Submerged Pond C4 Primary device # 1 INLET by 0.10'

Inflow Area = 5.407 ac, 0.00% Impervious, Inflow Depth = 4.40" for 100-yr event
Inflow = 21.38 cfs @ 12.30 hrs, Volume= 1.982 af
Outflow = 21.21 cfs @ 12.35 hrs, Volume= 1.982 af, Atten= 1%, Lag= 3.0 min
Routed to Reach SS4 : South Swale 4

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.99 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 0.75 fps, Avg. Travel Time= 7.1 min

Peak Storage= 2,269 cf @ 12.32 hrs
Average Depth at Peak Storage= 0.59' , Surface Width= 14.12'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 201.47 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 320.0' Slope= 0.0093 '/'
Inlet Invert= 698.97', Outlet Invert= 696.00'

Summary for Reach SS4: South Swale 4

[61] Hint: Exceeded Reach SS3 outlet invert by 0.35' @ 12.35 hrs

Inflow Area = 5.608 ac, 0.00% Impervious, Inflow Depth = 4.40" for 100-yr event
Inflow = 21.57 cfs @ 12.35 hrs, Volume= 2.058 af
Outflow = 21.56 cfs @ 12.36 hrs, Volume= 2.058 af, Atten= 0%, Lag= 0.6 min
Routed to Reach SS5 : South Swale 5

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 5.57 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.46 fps, Avg. Travel Time= 1.3 min

Peak Storage= 441 cf @ 12.35 hrs
Average Depth at Peak Storage= 0.35' , Surface Width= 12.42'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 514.50 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 114.0' Slope= 0.0605 '/'
Inlet Invert= 696.00', Outlet Invert= 689.10'

‡

Summary for Reach SS5: South Swale 5

[63] Warning: Exceeded Reach S4 INLET depth by 0.31' @ 12.37 hrs
[62] Hint: Exceeded Reach SS4 OUTLET depth by 0.51' @ 12.38 hrs

Inflow Area = 13.931 ac, 22.25% Impervious, Inflow Depth > 4.51" for 100-yr event
Inflow = 23.33 cfs @ 12.35 hrs, Volume= 5.240 af
Outflow = 23.26 cfs @ 12.38 hrs, Volume= 5.239 af, Atten= 0%, Lag= 1.9 min
Routed to Pond C2 : C2

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.10 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 0.51 fps, Avg. Travel Time= 4.6 min

Peak Storage= 1,548 cf @ 12.36 hrs
Average Depth at Peak Storage= 0.85' , Surface Width= 15.96'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 114.55 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 140.0' Slope= 0.0030 '/'
Inlet Invert= 689.10', Outlet Invert= 688.68'

‡

Summary for Reach SS6: South Swale 6

[79] Warning: Submerged Pond C2 Primary device # 1 INLET by 0.80'

Inflow Area = 15.806 ac, 19.61% Impervious, Inflow Depth > 4.50" for 100-yr event
Inflow = 28.72 cfs @ 12.12 hrs, Volume= 5.924 af
Outflow = 27.71 cfs @ 12.16 hrs, Volume= 5.922 af, Atten= 4%, Lag= 2.6 min
Routed to Pond C1 : Culvert C1a & b

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.22 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 0.52 fps, Avg. Travel Time= 6.9 min

Peak Storage= 2,693 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.94' , Surface Width= 16.59'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 114.10 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 215.0' Slope= 0.0030 '/'
Inlet Invert= 688.54', Outlet Invert= 687.90'

‡

Summary for Pond C1: Culvert C1a & b

[62] Hint: Exceeded Reach SS6 OUTLET depth by 0.60' @ 12.16 hrs

Inflow Area = 15.806 ac, 19.61% Impervious, Inflow Depth > 4.50" for 100-yr event
Inflow = 27.71 cfs @ 12.16 hrs, Volume= 5.922 af
Outflow = 27.71 cfs @ 12.16 hrs, Volume= 5.922 af, Atten= 0%, Lag= 0.0 min
Primary = 27.71 cfs @ 12.16 hrs, Volume= 5.922 af
Routed to Pond NP : North Pond

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 689.43' @ 12.16 hrs
Flood Elev= 691.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	687.71'	**24.0" Round C1a** L= 341.7' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 687.71' / 683.12' S= 0.0134 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf
#2	Primary	687.47'	**24.0" Round C1b** L= 341.6' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 687.47' / 683.25' S= 0.0124 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf

Primary OutFlow Max=27.71 cfs @ 12.16 hrs HW=689.43' (Free Discharge)
├─**1=C1a** (Inlet Controls 12.82 cfs @ 4.46 fps)
└─**2=C1b** (Inlet Controls 14.89 cfs @ 4.76 fps)

Summary for Pond C2: C2

[63] Warning: Exceeded Reach SS5 INLET depth by 2.52' @ 12.38 hrs
[79] Warning: Submerged Pond C3 Primary device # 1 INLET by 0.76'

Inflow Area = 15.153 ac, 20.45% Impervious, Inflow Depth > 4.49" for 100-yr event
Inflow = 24.86 cfs @ 12.38 hrs, Volume= 5.675 af
Outflow = 24.86 cfs @ 12.38 hrs, Volume= 5.675 af, Atten= 0%, Lag= 0.0 min
Primary = 24.86 cfs @ 12.38 hrs, Volume= 5.675 af
Routed to Reach SS6 : South Swale 6

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 692.47' @ 12.38 hrs
Flood Elev= 694.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	688.68'	**24.0" Round Culvert** L= 46.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 688.68' / 688.54' S= 0.0030 '/' Cc= 0.900 n= 0.012 Steel, smooth, Flow Area= 3.14 sf

Primary OutFlow Max=24.85 cfs @ 12.38 hrs HW=692.47' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 24.85 cfs @ 7.91 fps)

Summary for Pond C3: C3

[58] Hint: Peaked 7.99' above defined flood level

Inflow Area = 1.223 ac, 0.00% Impervious, Inflow Depth = 4.28" for 100-yr event
Inflow = 9.34 cfs @ 12.10 hrs, Volume= 0.436 af
Outflow = 9.34 cfs @ 12.10 hrs, Volume= 0.436 af, Atten= 0%, Lag= 0.0 min
Primary = 9.34 cfs @ 12.10 hrs, Volume= 0.436 af
Routed to Pond C2 : C2

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 701.99' @ 12.10 hrs
Flood Elev= 694.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	691.71'	**12.0" Round Culvert** L= 48.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 691.71' / 691.01' S= 0.0146 '/' Cc= 0.900 n= 0.012 Steel, smooth, Flow Area= 0.79 sf

Primary OutFlow Max=9.33 cfs @ 12.10 hrs HW=701.97' (Free Discharge)
↑—**1=Culvert** (Inlet Controls 9.33 cfs @ 11.88 fps)

Summary for Pond C4: C4

[58] Hint: Peaked 0.74' above defined flood level
[62] Hint: Exceeded Reach SS2 OUTLET depth by 2.78' @ 12.30 hrs

Inflow Area = 4.749 ac, 0.00% Impervious, Inflow Depth = 4.38" for 100-yr event
Inflow = 20.14 cfs @ 12.30 hrs, Volume= 1.735 af
Outflow = 20.14 cfs @ 12.30 hrs, Volume= 1.735 af, Atten= 0%, Lag= 0.0 min
Primary = 20.14 cfs @ 12.30 hrs, Volume= 1.735 af
Routed to Reach SS3 : South Swale 3

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 702.74' @ 12.30 hrs
Flood Elev= 702.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	699.46'	**24.0" Round Culvert** L= 40.5' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 699.46' / 698.97' S= 0.0121 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 3.14 sf

Primary OutFlow Max=20.14 cfs @ 12.30 hrs HW=702.74' (Free Discharge)
└─**1=Culvert** (Inlet Controls 20.14 cfs @ 6.41 fps)

Summary for Pond C5: C5

[58] Hint: Peaked 2.06' above defined flood level
[62] Hint: Exceeded Reach SS1 OUTLET depth by 5.28' @ 12.28 hrs

Inflow Area = 3.123 ac, 0.00% Impervious, Inflow Depth = 4.38" for 100-yr event
Inflow = 14.25 cfs @ 12.28 hrs, Volume= 1.140 af
Outflow = 14.25 cfs @ 12.28 hrs, Volume= 1.140 af, Atten= 0%, Lag= 0.0 min
Primary = 14.25 cfs @ 12.28 hrs, Volume= 1.140 af
Routed to Reach SS2 : South Swale 2

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 710.06' @ 12.28 hrs
Flood Elev= 708.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	704.38'	**18.0" Round Culvert** L= 38.0' CMP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 704.38' / 704.25' S= 0.0034 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 1.77 sf

Primary OutFlow Max=14.24 cfs @ 12.28 hrs HW=710.06' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 14.24 cfs @ 8.06 fps)

Summary for Pond NP: North Pond

[62] Hint: Exceeded Reach NS3 OUTLET depth by 1.52' @ 13.34 hrs
[79] Warning: Submerged Pond C1 Primary device # 1 OUTLET by 2.63'
[79] Warning: Submerged Pond C1 Primary device # 2 OUTLET by 2.50'

Inflow Area = 92.527 ac, 11.98% Impervious, Inflow Depth > 4.42" for 100-yr event
Inflow = 290.58 cfs @ 12.29 hrs, Volume= 34.113 af
Outflow = 55.14 cfs @ 13.18 hrs, Volume= 33.818 af, Atten= 81%, Lag= 53.1 min
Primary = 21.42 cfs @ 13.18 hrs, Volume= 28.517 af
Secondary = 33.72 cfs @ 13.18 hrs, Volume= 5.301 af

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Starting Elev= 681.75' Surf.Area= 2.820 ac Storage= 0.808 af
Peak Elev= 685.75' @ 13.18 hrs Surf.Area= 5.899 ac Storage= 18.653 af (17.845 af above start)

Plug-Flow detention time= 504.5 min calculated for 33.007 af (97% of inflow)
Center-of-Mass det. time= 407.9 min (1,336.2 - 928.3)

Volume	Invert	Avail.Storage	Storage Description
#1	681.46'	20.170 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
681.46	2.750	0.000	0.000
682.00	2.880	1.520	1.520
684.00	4.860	7.740	9.260
686.00	6.050	10.910	20.170

Device	Routing	Invert	Outlet Devices
#1	Primary	681.50'	**24.0" Round Culvert** L= 50.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 681.50' / 681.00' S= 0.0100 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	681.75'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#3	Device 1	682.25'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#4	Device 1	682.75'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#5	Device 1	683.25'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#6	Device 1	684.00'	**36.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#7	Secondary	685.00'	**Custom Weir/Orifice, Cv= 2.62 (C= 3.28)** Head (feet) 0.00 0.50 1.00 Width (feet) 10.00 20.00 30.00

Primary OutFlow Max=21.42 cfs @ 13.18 hrs HW=685.75' (Free Discharge)
└─**1=Culvert** (Barrel Controls 21.42 cfs @ 6.82 fps)
  ├─**2=Orifice/Grate** (Passes < 7.32 cfs potential flow)
  ├─**3=Orifice/Grate** (Passes < 6.81 cfs potential flow)
  ├─**4=Orifice/Grate** (Passes < 6.27 cfs potential flow)
  ├─**5=Orifice/Grate** (Passes < 5.67 cfs potential flow)
  └─**6=Orifice/Grate** (Passes < 44.97 cfs potential flow)

Secondary OutFlow Max=33.69 cfs @ 13.18 hrs HW=685.75' (Free Discharge)
└─**7=Custom Weir/Orifice** (Weir Controls 33.69 cfs @ 2.59 fps)

Summary for Pond SP: South Pond

Inflow Area = 7.788 ac, 39.79% Impervious, Inflow Depth = 5.03" for 100-yr event
Inflow = 51.38 cfs @ 12.09 hrs, Volume= 3.265 af
Outflow = 0.93 cfs @ 16.80 hrs, Volume= 2.985 af, Atten= 98%, Lag= 283.1 min
Primary = 0.93 cfs @ 16.80 hrs, Volume= 2.985 af
Routed to Reach S4 : Swale 4
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Reach S4 : Swale 4

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Starting Elev= 690.00' Surf.Area= 104,799 sf Storage= 563,180 cf
Peak Elev= 691.03' @ 16.80 hrs Surf.Area= 110,704 sf Storage= 674,066 cf (110,886 cf above start)

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= 1,399.0 min (2,171.0 - 772.0)

Volume	Invert	Avail.Storage	Storage Description
#1	682.00'	1,159,218 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
682.00	4,661	0	0
683.00	34,274	19,468	19,468
684.00	54,009	44,142	63,609
685.00	67,049	60,529	124,138
686.00	76,841	71,945	196,083
687.00	84,846	80,844	276,927
688.00	92,571	88,709	365,635
689.00	98,860	95,716	461,351
690.00	104,799	101,830	563,180
691.00	110,544	107,672	670,852
692.00	116,064	113,304	784,156
693.00	121,865	118,965	903,120
694.00	127,659	124,762	1,027,882
695.00	135,013	131,336	1,159,218

Device	Routing	Invert	Outlet Devices
#1	Primary	690.00'	**12.0" Round Culvert** L= 50.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 690.00' / 689.50' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf
#2	Secondary	692.00'	**10.0' long x 50.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#3	Device 1	690.00'	**3.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#4	Device 1	691.00'	**3.0" Vert. Orifice/Grate X 6.00** C= 0.600 Limited to weir flow at low heads
#5	Device 1	692.00'	**36.0" Horiz. Orifice/Grate** C= 0.600

Limited to weir flow at low heads

Primary OutFlow Max=0.91 cfs @ 16.80 hrs HW=691.03' (Free Discharge)
└—**1=Culvert** (Passes 0.91 cfs of 2.75 cfs potential flow)
  ├—**3=Orifice/Grate** (Orifice Controls 0.90 cfs @ 4.58 fps)
  ├—**4=Orifice/Grate** (Orifice Controls 0.01 cfs @ 0.58 fps)
  └—**5=Orifice/Grate** (Controls 0.00 cfs)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=690.00' (Free Discharge)
└—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Summary for Link F1: Flume 1

Inflow Area = 1.695 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 7.80 cfs @ 12.24 hrs, Volume= 0.589 af
Primary = 7.80 cfs @ 12.24 hrs, Volume= 0.589 af, Atten= 0%, Lag= 0.0 min
Routed to Pond NP : North Pond

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F2: Flume 2

Inflow Area = 0.661 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 3.07 cfs @ 12.24 hrs, Volume= 0.230 af
Primary = 3.07 cfs @ 12.24 hrs, Volume= 0.230 af, Atten= 0%, Lag= 0.0 min
Routed to Reach NS3 : North Swale 3

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F3: Flume 3

Inflow Area = 0.867 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 4.01 cfs @ 12.24 hrs, Volume= 0.302 af
Primary = 4.01 cfs @ 12.24 hrs, Volume= 0.302 af, Atten= 0%, Lag= 0.0 min
Routed to Pond NP : North Pond

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

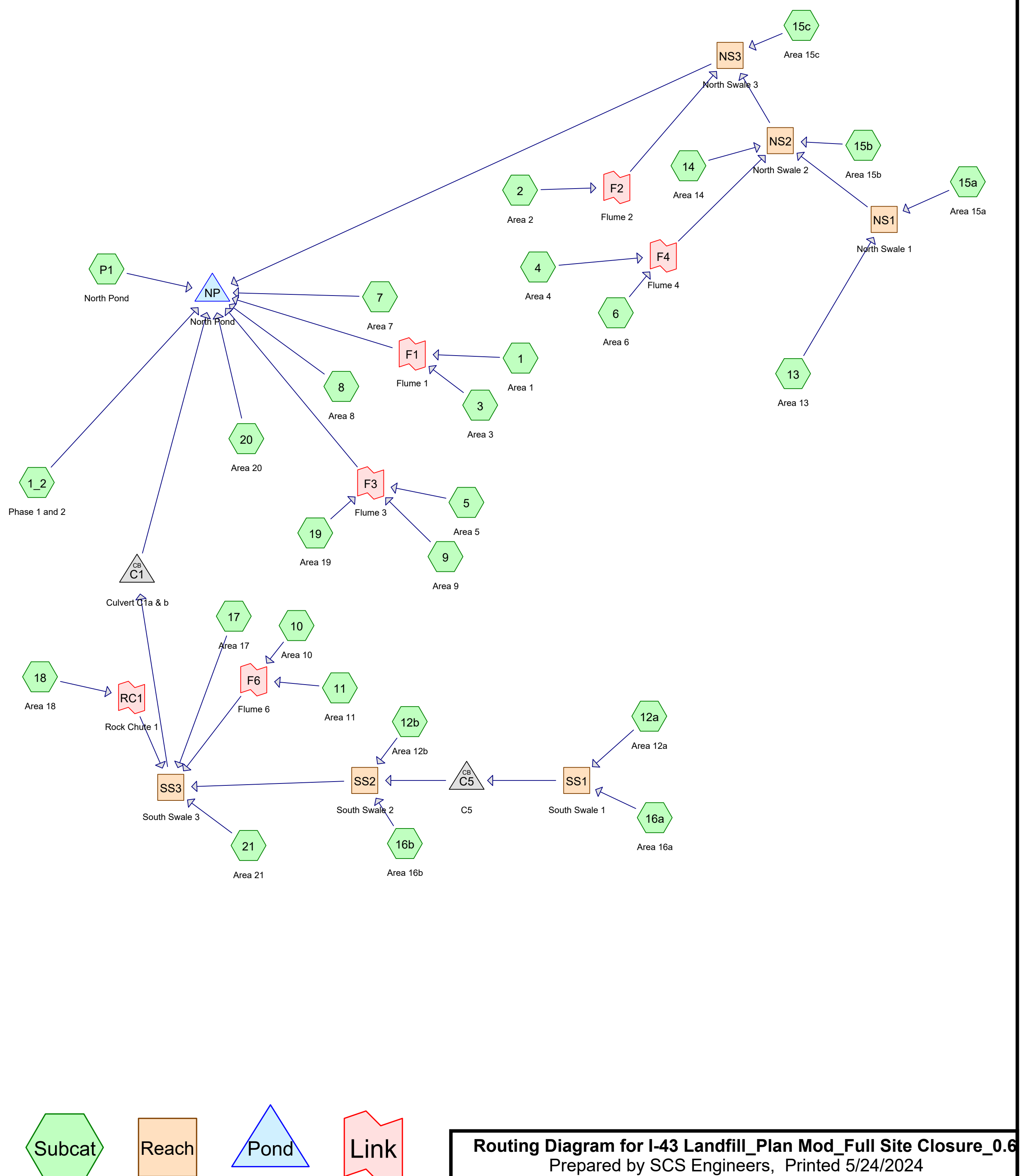
Summary for Link F4: Flume 4

Inflow Area = 1.215 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 5.69 cfs @ 12.24 hrs, Volume= 0.423 af
Primary = 5.69 cfs @ 12.24 hrs, Volume= 0.423 af, Atten= 0%, Lag= 0.0 min
Routed to Reach NS2 : North Swale 2

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Fully Developed Site Closure Conditions Hydrograph Generation

- 25-year, 24-hour Storm Event
- 100-year, 24-hour Storm Event



Routing Diagram for I-43 Landfill_Plan Mod_Full Site Closure_0.6
Prepared by SCS Engineers, Printed 5/24/2024
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Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	25-yr	MSE 24-hr	4	Default	24.00	1	4.80	2
2	100-yr	MSE 24-hr	4	Default	24.00	1	6.55	2

Time span=0.00-90.00 hrs, dt=0.01 hrs, 9001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1: Area 1 Runoff Area=28,521 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=347' Tc=15.8 min CN=79 Runoff=1.93 cfs 0.144 af

Subcatchment1_2: Phase 1 and 2 Runoff Area=2,282,700 sf 1.80% Impervious Runoff Depth=2.63"
Flow Length=3,476' Tc=25.5 min CN=79 Runoff=121.27 cfs 11.486 af

Subcatchment2: Area 2 Runoff Area=28,787 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=491' Tc=15.8 min CN=79 Runoff=1.95 cfs 0.145 af

Subcatchment3: Area 3 Runoff Area=45,296 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=494' Tc=16.4 min CN=79 Runoff=3.02 cfs 0.228 af

Subcatchment4: Area 4 Runoff Area=39,815 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=475' Tc=15.6 min CN=79 Runoff=2.72 cfs 0.200 af

Subcatchment5: Area 5 Runoff Area=62,799 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=442' Tc=15.9 min CN=79 Runoff=4.23 cfs 0.316 af

Subcatchment6: Area 6 Runoff Area=81,297 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=569' Tc=17.1 min CN=79 Runoff=5.29 cfs 0.409 af

Subcatchment7: Area 7 Runoff Area=81,807 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=200' Tc=12.4 min CN=79 Runoff=6.18 cfs 0.412 af

Subcatchment8: Area 8 Runoff Area=104,501 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=240' Tc=13.8 min CN=79 Runoff=7.52 cfs 0.526 af

Subcatchment9: Area 9 Runoff Area=63,901 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=630' Tc=17.3 min CN=79 Runoff=4.13 cfs 0.322 af

Subcatchment10: Area 10 Runoff Area=84,606 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=454' Tc=16.9 min CN=79 Runoff=5.54 cfs 0.426 af

Subcatchment11: Area 11 Runoff Area=29,415 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=223' Tc=15.1 min CN=79 Runoff=2.03 cfs 0.148 af

Subcatchment12a: Area 12a Runoff Area=98,996 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=180' Tc=14.4 min CN=79 Runoff=7.00 cfs 0.498 af

Subcatchment12b: Area 12b Runoff Area=89,691 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=204' Tc=14.2 min CN=79 Runoff=6.36 cfs 0.451 af

Subcatchment13: Area 13 Runoff Area=226,080 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=205' Tc=14.5 min CN=79 Runoff=15.89 cfs 1.138 af

Subcatchment14: Area 14 Runoff Area=59,877 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=125' Slope=0.2500 '/' Tc=5.9 min CN=79 Runoff=5.88 cfs 0.301 af

Subcatchment15a: Area 15a Runoff Area=99,614 sf 5.36% Impervious Runoff Depth=2.99"
Flow Length=58' Tc=3.3 min CN=83 Runoff=12.10 cfs 0.571 af

Subcatchment15b: Area 15b Runoff Area=11,056 sf 0.00% Impervious Runoff Depth=3.18"
Flow Length=33' Slope=0.1176 '/' Tc=2.4 min CN=85 Runoff=1.43 cfs 0.067 af

Subcatchment15c: Area 15c Runoff Area=9,032 sf 0.00% Impervious Runoff Depth=2.90"
Flow Length=1,656' Tc=7.2 min CN=82 Runoff=0.92 cfs 0.050 af

Subcatchment16a: Area 16a Runoff Area=37,043 sf 0.00% Impervious Runoff Depth=3.28"
Flow Length=50' Tc=5.6 min CN=86 Runoff=4.46 cfs 0.232 af

Subcatchment16b: Area 16b Runoff Area=32,470 sf 0.00% Impervious Runoff Depth=3.18"
Flow Length=78' Tc=1.8 min CN=85 Runoff=4.26 cfs 0.198 af

Subcatchment17: Area 17 Runoff Area=123,541 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=271' Tc=14.8 min CN=79 Runoff=8.63 cfs 0.622 af

Subcatchment18: Area 18 Runoff Area=13,884 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=303' Tc=5.1 min CN=79 Runoff=1.41 cfs 0.070 af

Subcatchment19: Area 19 Runoff Area=60,482 sf 0.00% Impervious Runoff Depth=2.63"
Flow Length=648' Tc=7.7 min CN=79 Runoff=5.50 cfs 0.304 af

Subcatchment20: Area 20 Runoff Area=2,125 sf 0.00% Impervious Runoff Depth=2.72"
Flow Length=31' Tc=5.5 min CN=80 Runoff=0.22 cfs 0.011 af

Subcatchment21: Area 21 Runoff Area=50,989 sf 0.00% Impervious Runoff Depth=2.72"
Flow Length=75' Tc=4.7 min CN=80 Runoff=5.42 cfs 0.265 af

SubcatchmentP1: North Pond Runoff Area=342,674 sf 36.61% Impervious Runoff Depth=3.28"
Tc=0.0 min CN=86 Runoff=46.44 cfs 2.151 af

Reach NS1: North Swale 1 Avg. Flow Depth=0.45' Max Vel=3.82 fps Inflow=22.44 cfs 1.708 af
n=0.030 L=1,043.0' S=0.0209 '/' Capacity=302.62 cfs Outflow=19.68 cfs 1.708 af

Reach NS2: North Swale 2 Avg. Flow Depth=0.68' Max Vel=3.61 fps Inflow=30.57 cfs 2.686 af
n=0.030 L=381.0' S=0.0115 '/' Capacity=224.48 cfs Outflow=30.24 cfs 2.686 af

Reach NS3: North Swale 3 Avg. Flow Depth=0.61' Max Vel=4.40 fps Inflow=32.49 cfs 2.881 af
n=0.030 L=195.0' S=0.0193 '/' Capacity=290.78 cfs Outflow=32.44 cfs 2.881 af

Reach SS1: South Swale 1 Avg. Flow Depth=0.32' Max Vel=2.56 fps Inflow=9.79 cfs 0.731 af
n=0.030 L=686.0' S=0.0140 '/' Capacity=247.65 cfs Outflow=9.07 cfs 0.731 af

Reach SS2: South Swale 2 Avg. Flow Depth=0.45' Max Vel=3.02 fps Inflow=15.95 cfs 1.380 af
n=0.030 L=481.0' S=0.0130 '/' Capacity=238.39 cfs Outflow=15.63 cfs 1.380 af

Reach SS3: South Swale 3 Avg. Flow Depth=0.65' Max Vel=3.98 fps Inflow=32.10 cfs 2.910 af
n=0.030 L=721.0' S=0.0147 '/' Capacity=253.69 cfs Outflow=31.65 cfs 2.910 af

Pond C1: Culvert C1a & b Peak Elev=689.68' Inflow=31.65 cfs 2.910 af
Outflow=31.65 cfs 2.910 af

Pond C5: C5 Peak Elev=707.50' Inflow=9.07 cfs 0.731 af
18.0" Round Culvert n=0.025 L=38.0' S=0.0034 '/' Outflow=9.07 cfs 0.731 af

Pond NP: North Pond Peak Elev=684.95' Storage=617,328 cf Inflow=213.22 cfs 21.690 af
Primary=18.09 cfs 21.672 af Secondary=0.00 cfs 0.000 af Outflow=18.09 cfs 21.672 af

Link F1: Flume 1 Inflow=4.94 cfs 0.371 af
Primary=4.94 cfs 0.371 af

Link F2: Flume 2 Inflow=1.95 cfs 0.145 af
Primary=1.95 cfs 0.145 af

Link F3: Flume 3 Inflow=12.17 cfs 0.942 af
Primary=12.17 cfs 0.942 af

Link F4: Flume 4 Inflow=7.99 cfs 0.609 af
Primary=7.99 cfs 0.609 af

Link F6: Flume 6 Inflow=7.54 cfs 0.574 af
Primary=7.54 cfs 0.574 af

Link RC1: Rock Chute 1 Inflow=1.41 cfs 0.070 af
Primary=1.41 cfs 0.070 af

Total Runoff Area = 96.212 ac Runoff Volume = 21.690 af Average Runoff Depth = 2.71"
95.90% Pervious = 92.267 ac 4.10% Impervious = 3.945 ac

Summary for Subcatchment 1: Area 1

Runoff = 1.93 cfs @ 12.24 hrs, Volume= 0.144 af, Depth= 2.63"
Routed to Link F1 : Flume 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	28,521	79	
	28,521		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.5	106	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	141	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
15.8	347	Total			

Summary for Subcatchment 1_2: Phase 1 and 2

Runoff = 121.27 cfs @ 12.38 hrs, Volume= 11.486 af, Depth= 2.63"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	2,241,655	79	Closed Landfill
	41,045	98	Paved parking, HSG C
	2,282,700	79	Weighted Average
	2,241,655		98.20% Pervious Area
	41,045		1.80% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.0	100	0.0400	0.14		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.8	400	0.0400	1.40		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.7	2,976	0.0120	5.70	256.59	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=3.00' Z= 10.0 & 0.0 '/' Top.W=30.00' n= 0.035 Earth, dense weeds
25.5	3,476	Total			

Summary for Subcatchment 2: Area 2

Runoff = 1.95 cfs @ 12.24 hrs, Volume= 0.145 af, Depth= 2.63"
Routed to Link F2 : Flume 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	28,787	79	
	28,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.1	78	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	203	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	110	0.2500	20.09	10.95	**Pipe Channel,** 10.0" Round Area= 0.5 sf Perim= 2.6' r= 0.21' n= 0.013 Corrugated PE, smooth interior
15.8	491	Total			

Summary for Subcatchment 3: Area 3

Runoff = 3.02 cfs @ 12.25 hrs, Volume= 0.228 af, Depth= 2.63"
Routed to Link F1 : Flume 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	45,296	79	
	45,296		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.3	94	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.6	300	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
16.4	494	Total			

Summary for Subcatchment 4: Area 4

Runoff = 2.72 cfs @ 12.24 hrs, Volume= 0.200 af, Depth= 2.63"
Routed to Link F4 : Flume 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	39,815	79	
	39,815		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.1	83	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.9	173	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	119	0.2500	22.68	17.81	**Pipe Channel, Flume 4** 12.0" Round Area= 0.8 sf Perim= 3.1' r= 0.25' n= 0.013 Corrugated PE, smooth interior
15.6	475	Total			

Summary for Subcatchment 5: Area 5

Runoff = 4.23 cfs @ 12.24 hrs, Volume= 0.316 af, Depth= 2.63"
Routed to Link F3 : Flume 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	62,799	79	
	62,799		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.0	73	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	269	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
15.9	442	Total			

Summary for Subcatchment 6: Area 6

Runoff = 5.29 cfs @ 12.26 hrs, Volume= 0.409 af, Depth= 2.63"
Routed to Link F4 : Flume 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	81,297	79	
	81,297		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.6	189	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.9	161	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	119	0.2500	22.68	17.81	**Pipe Channel, Flume 4** 12.0" Round Area= 0.8 sf Perim= 3.1' r= 0.25' n= 0.013 Corrugated PE, smooth interior
17.1	569	Total			

Summary for Subcatchment 7: Area 7

Runoff = 6.18 cfs @ 12.20 hrs, Volume= 0.412 af, Depth= 2.63"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	81,807	79	
	81,807		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.3	63	0.0300	0.11		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.6	37	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	100	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.4	200	Total			

Summary for Subcatchment 8: Area 8

Runoff = 7.52 cfs @ 12.22 hrs, Volume= 0.526 af, Depth= 2.63"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	104,501	79	
	104,501		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.7	93	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.4	4	0.2500	0.15		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.7	143	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
13.8	240	Total			

Summary for Subcatchment 9: Area 9

Runoff = 4.13 cfs @ 12.26 hrs, Volume= 0.322 af, Depth= 2.63"
Routed to Link F3 : Flume 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	63,901	79	
	63,901		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.4	99	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
2.4	431	0.0100	3.00	9.01	**Trap/Vee/Rect Channel Flow, Diversion Berm** Bot.W=0.00' D=1.00' Z= 2.0 & 4.0 '/' Top.W=6.00' n= 0.030 Short grass
17.3	630	Total			

Summary for Subcatchment 10: Area 10

Runoff = 5.54 cfs @ 12.26 hrs, Volume= 0.426 af, Depth= 2.63"
Routed to Link F6 : Flume 6

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	84,606	79	
	84,606		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.5	183	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.9	171	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Diversion Berm** Bot.W=0.00' D=1.00' Z= 33.0 & 4.0 '/' Top.W=37.00' n= 0.030 Earth, grassed & winding
16.9	454	Total			

Summary for Subcatchment 11: Area 11

Runoff = 2.03 cfs @ 12.23 hrs, Volume= 0.148 af, Depth= 2.63"
Routed to Link F6 : Flume 6

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	29,415	79	
	29,415		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.6	119	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.0	4	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.00' Z= 33.0 & 4.0 '/' Top.W=37.00' n= 0.030 Earth, grassed & winding
15.1	223	Total			

Summary for Subcatchment 12a: Area 12a

Runoff = 7.00 cfs @ 12.23 hrs, Volume= 0.498 af, Depth= 2.63"
Routed to Reach SS1 : South Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	98,996	79	
	0	96	Gravel surface, HSG C
	98,996	79	Weighted Average
	98,996		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	57	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	23	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.4	180	Total			

Summary for Subcatchment 12b: Area 12b

Runoff = 6.36 cfs @ 12.23 hrs, Volume= 0.451 af, Depth= 2.63"
Routed to Reach SS2 : South Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	89,333	79	
	358	96	Gravel surface, HSG C
	89,691	79	Weighted Average
	89,691		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.3	24	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.3	57	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	23	0.3333	4.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.2	204	Total			

Summary for Subcatchment 13: Area 13

Runoff = 15.89 cfs @ 12.23 hrs, Volume= 1.138 af, Depth= 2.63"
Routed to Reach NS1 : North Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	226,080	79	
	226,080		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	56	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	49	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.5	205	Total			

Summary for Subcatchment 14: Area 14

Runoff = 5.88 cfs @ 12.13 hrs, Volume= 0.301 af, Depth= 2.63"
Routed to Reach NS2 : North Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	59,877	79	
	59,877		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.1	25	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
5.9	125	Total			

Summary for Subcatchment 15a: Area 15a

Runoff = 12.10 cfs @ 12.11 hrs, Volume= 0.571 af, Depth= 2.99"
Routed to Reach NS1 : North Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	78,118	79	
	5,343	98	Paved roads w/curbs & sewers, HSG C
	16,153	96	Gravel surface, HSG C
	99,614	83	Weighted Average
	94,271		94.64% Pervious Area
	5,343		5.36% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	32	0.0050	0.57		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
2.4	26	0.1538	0.18		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
3.3	58	Total			

Summary for Subcatchment 15b: Area 15b

Runoff = 1.43 cfs @ 12.10 hrs, Volume= 0.067 af, Depth= 3.18"
Routed to Reach NS2 : North Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	7,026	79	
	4,030	96	Gravel surface, HSG C
	11,056	85	Weighted Average
	11,056		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	11	0.1176	1.62		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
2.3	22	0.1176	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.4	33	Total			

Summary for Subcatchment 15c: Area 15c

Runoff = 0.92 cfs @ 12.14 hrs, Volume= 0.050 af, Depth= 2.90"
Routed to Reach NS3 : North Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	7,178	79	
	1,854	96	Gravel surface, HSG C
	9,032	82	Weighted Average
	9,032		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	14	0.1250	1.74		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
4.4	50	0.1250	0.19		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.7	1,592	0.0167	9.92	610.36	**Trap/Vee/Rect Channel Flow,** Bot.W=10.00' D=3.00' Z= 4.0 & 3.0 '/' Top.W=31.00' n= 0.030 Earth, grassed & winding
7.2	1,656	Total			

Summary for Subcatchment 16a: Area 16a

Runoff = 4.46 cfs @ 12.13 hrs, Volume= 0.232 af, Depth= 3.28"
Routed to Reach SS1 : South Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	20,948	79	
	16,095	96	Gravel surface, HSG C
	37,043	86	Weighted Average
	37,043		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.7	13	0.0050	0.06		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
0.7	21	0.0050	0.52		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.2	16	0.3300	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
5.6	50	Total			

Summary for Subcatchment 16b: Area 16b

Runoff = 4.26 cfs @ 12.10 hrs, Volume= 0.198 af, Depth= 3.18"
Routed to Reach SS2 : South Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	21,666	79	
	10,804	96	Gravel surface, HSG C
	32,470	85	Weighted Average
	32,470		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.7	64	0.0450	1.57		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.1	14	0.3333	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.8	78	Total			

Summary for Subcatchment 17: Area 17

Runoff = 8.63 cfs @ 12.23 hrs, Volume= 0.622 af, Depth= 2.63"
Routed to Reach SS3 : South Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	123,541	79	
	123,541		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.7	48	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.6	123	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.8	271	Total			

Summary for Subcatchment 18: Area 18

Runoff = 1.41 cfs @ 12.13 hrs, Volume= 0.070 af, Depth= 2.63"
Routed to Link RC1 : Rock Chute 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	13,884	79	
	13,884		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.0	100	0.2500	0.42		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
0.0	3	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	200	0.0100	3.00	9.01	**Trap/Vee/Rect Channel Flow, Diversion Berm** Bot.W=0.00' D=1.00' Z= 2.0 & 4.0 '/' Top.W=6.00' n= 0.030 Earth, grassed & winding
5.1	303	Total			

Summary for Subcatchment 19: Area 19

Runoff = 5.50 cfs @ 12.15 hrs, Volume= 0.304 af, Depth= 2.63"
Routed to Link F3 : Flume 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	60,482	79	
	60,482		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.0	8	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.9	540	0.0100	4.77	57.18	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 2.0 & 4.0 '/' Top.W=12.00' n= 0.030 Earth, grassed & winding
7.7	648	Total			

Summary for Subcatchment 20: Area 20

Runoff = 0.22 cfs @ 12.13 hrs, Volume= 0.011 af, Depth= 2.72"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	1,965	79	
	160	96	Gravel surface, HSG C
	2,125	80	Weighted Average
	2,125		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.8	23	0.2500	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
3.7	8	0.0050	0.04		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
5.5	31	Total			

Summary for Subcatchment 21: Area 21

Runoff = 5.42 cfs @ 12.12 hrs, Volume= 0.265 af, Depth= 2.72"
Routed to Reach SS3 : South Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
*	49,452	79	
	1,537	96	Gravel surface, HSG C
	50,989	80	Weighted Average
	50,989		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.9	43	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	16	0.0050	0.49		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.3	16	0.2500	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.7	75	Total			

Summary for Subcatchment P1: North Pond

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 46.44 cfs @ 12.09 hrs, Volume= 2.151 af, Depth= 3.28"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 25-yr Rainfall=4.80"

	Area (sf)	CN	Description
	125,453	98	Water Surface
*	210,716	79	
	6,505	96	Gravel surface, HSG C
	342,674	86	Weighted Average
	217,221		63.39% Pervious Area
	125,453		36.61% Impervious Area

Summary for Reach NS1: North Swale 1

Inflow Area = 7.477 ac, 1.64% Impervious, Inflow Depth = 2.74" for 25-yr event
Inflow = 22.44 cfs @ 12.12 hrs, Volume= 1.708 af
Outflow = 19.68 cfs @ 12.31 hrs, Volume= 1.708 af, Atten= 12%, Lag= 11.1 min
Routed to Reach NS2 : North Swale 2

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.82 fps, Min. Travel Time= 4.6 min
Avg. Velocity = 0.97 fps, Avg. Travel Time= 17.8 min

Peak Storage= 5,375 cf @ 12.23 hrs
Average Depth at Peak Storage= 0.45' , Surface Width= 13.12'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 302.62 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 1,043.0' Slope= 0.0209 '/'
Inlet Invert= 714.00', Outlet Invert= 692.16'

Summary for Reach NS2: North Swale 2

[62] Hint: Exceeded Reach NS1 OUTLET depth by 0.26' @ 12.38 hrs

Inflow Area = 11.886 ac, 1.03% Impervious, Inflow Depth = 2.71" for 25-yr event
Inflow = 30.57 cfs @ 12.23 hrs, Volume= 2.686 af
Outflow = 30.24 cfs @ 12.29 hrs, Volume= 2.686 af, Atten= 1%, Lag= 3.3 min
Routed to Reach NS3 : North Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.61 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 0.89 fps, Avg. Travel Time= 7.1 min

Peak Storage= 3,188 cf @ 12.26 hrs
Average Depth at Peak Storage= 0.68' , Surface Width= 14.74'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 224.48 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 381.0' Slope= 0.0115 '/'
Inlet Invert= 692.16', Outlet Invert= 687.77'

‡

Summary for Reach NS3: North Swale 3

[61] Hint: Exceeded Reach NS2 outlet invert by 0.61' @ 12.29 hrs

Inflow Area = 12.754 ac, 0.96% Impervious, Inflow Depth = 2.71" for 25-yr event
Inflow = 32.49 cfs @ 12.28 hrs, Volume= 2.881 af
Outflow = 32.44 cfs @ 12.30 hrs, Volume= 2.881 af, Atten= 0%, Lag= 1.3 min
Routed to Pond NP : North Pond

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.40 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.09 fps, Avg. Travel Time= 3.0 min

Peak Storage= 1,437 cf @ 12.29 hrs
Average Depth at Peak Storage= 0.61' , Surface Width= 14.25'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 290.78 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 195.0' Slope= 0.0193 '/'
Inlet Invert= 687.77', Outlet Invert= 684.00'

Summary for Reach SS1: South Swale 1

Inflow Area = 3.123 ac, 0.00% Impervious, Inflow Depth = 2.81" for 25-yr event
Inflow = 9.79 cfs @ 12.15 hrs, Volume= 0.731 af
Outflow = 9.07 cfs @ 12.30 hrs, Volume= 0.731 af, Atten= 7%, Lag= 8.6 min
Routed to Pond C5 : C5

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.56 fps, Min. Travel Time= 4.5 min
Avg. Velocity = 0.66 fps, Avg. Travel Time= 17.4 min

Peak Storage= 2,434 cf @ 12.22 hrs
Average Depth at Peak Storage= 0.32' , Surface Width= 12.23'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 247.65 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 686.0' Slope= 0.0140 '/'
Inlet Invert= 714.00', Outlet Invert= 704.38'

Summary for Reach SS2: South Swale 2

[79] Warning: Submerged Pond C5 Primary device # 1 INLET by 0.32'

Inflow Area = 5.927 ac, 0.00% Impervious, Inflow Depth = 2.79" for 25-yr event
Inflow = 15.95 cfs @ 12.26 hrs, Volume= 1.380 af
Outflow = 15.63 cfs @ 12.34 hrs, Volume= 1.380 af, Atten= 2%, Lag= 4.5 min
Routed to Reach SS3 : South Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.02 fps, Min. Travel Time= 2.7 min
Avg. Velocity = 0.77 fps, Avg. Travel Time= 10.4 min

Peak Storage= 2,492 cf @ 12.29 hrs
Average Depth at Peak Storage= 0.45' , Surface Width= 13.14'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 238.39 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 481.0' Slope= 0.0130 '/'
Inlet Invert= 704.25', Outlet Invert= 698.00'

‡

Summary for Reach SS3: South Swale 3

[62] Hint: Exceeded Reach SS2 OUTLET depth by 0.21' @ 12.18 hrs

Inflow Area = 12.870 ac, 0.00% Impervious, Inflow Depth = 2.71" for 25-yr event
Inflow = 32.10 cfs @ 12.28 hrs, Volume= 2.910 af
Outflow = 31.65 cfs @ 12.36 hrs, Volume= 2.910 af, Atten= 1%, Lag= 4.8 min
Routed to Pond C1 : Culvert C1a & b

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.98 fps, Min. Travel Time= 3.0 min
Avg. Velocity = 0.99 fps, Avg. Travel Time= 12.1 min

Peak Storage= 5,728 cf @ 12.31 hrs
Average Depth at Peak Storage= 0.65' , Surface Width= 14.53'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 253.69 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 721.0' Slope= 0.0147 '/'
Inlet Invert= 698.00', Outlet Invert= 687.39'

Summary for Pond C1: Culvert C1a & b

[62] Hint: Exceeded Reach SS3 OUTLET depth by 1.66' @ 12.37 hrs

Inflow Area = 12.870 ac, 0.00% Impervious, Inflow Depth = 2.71" for 25-yr event
Inflow = 31.65 cfs @ 12.36 hrs, Volume= 2.910 af
Outflow = 31.65 cfs @ 12.36 hrs, Volume= 2.910 af, Atten= 0%, Lag= 0.0 min
Primary = 31.65 cfs @ 12.36 hrs, Volume= 2.910 af
Routed to Pond NP : North Pond

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 689.68' @ 12.36 hrs
Flood Elev= 691.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	687.71'	**24.0" Round C1a** L= 341.7' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 687.71' / 683.12' S= 0.0134 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf
#2	Primary	687.47'	**24.0" Round C1b** L= 341.6' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 687.47' / 683.25' S= 0.0124 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf

Primary OutFlow Max=31.65 cfs @ 12.36 hrs HW=689.68' (Free Discharge)
├─**1=C1a** (Inlet Controls 14.99 cfs @ 4.78 fps)
└─**2=C1b** (Inlet Controls 16.66 cfs @ 5.30 fps)

Summary for Pond C5: C5

[62] Hint: Exceeded Reach SS1 OUTLET depth by 2.81' @ 12.30 hrs

Inflow Area = 3.123 ac, 0.00% Impervious, Inflow Depth = 2.81" for 25-yr event
Inflow = 9.07 cfs @ 12.30 hrs, Volume= 0.731 af
Outflow = 9.07 cfs @ 12.30 hrs, Volume= 0.731 af, Atten= 0%, Lag= 0.0 min
Primary = 9.07 cfs @ 12.30 hrs, Volume= 0.731 af
Routed to Reach SS2 : South Swale 2

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 707.50' @ 12.30 hrs
Flood Elev= 708.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	704.38'	**18.0" Round Culvert** L= 38.0' CMP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 704.38' / 704.25' S= 0.0034 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 1.77 sf

Primary OutFlow Max=9.07 cfs @ 12.30 hrs HW=707.50' (Free Discharge)
└─**1=Culvert** (Barrel Controls 9.07 cfs @ 5.13 fps)

Summary for Pond NP: North Pond

[62] Hint: Exceeded Reach NS3 OUTLET depth by 0.83' @ 14.16 hrs
[79] Warning: Submerged Pond C1 Primary device # 1 OUTLET by 1.83'
[79] Warning: Submerged Pond C1 Primary device # 2 OUTLET by 1.70'

Inflow Area = 96.212 ac, 4.10% Impervious, Inflow Depth = 2.71" for 25-yr event
Inflow = 213.22 cfs @ 12.33 hrs, Volume= 21.690 af
Outflow = 18.09 cfs @ 13.97 hrs, Volume= 21.672 af, Atten= 92%, Lag= 98.4 min
Primary = 18.09 cfs @ 13.97 hrs, Volume= 21.672 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Starting Elev= 681.75' Surf.Area= 122,831 sf Storage= 35,180 cf
Peak Elev= 684.95' @ 13.97 hrs Surf.Area= 236,450 sf Storage= 617,328 cf (582,148 cf above start)
Flood Elev= 886.00' Surf.Area= 263,538 sf Storage= 878,611 cf (843,431 cf above start)

Plug-Flow detention time= 527.6 min calculated for 20.862 af (96% of inflow)
Center-of-Mass det. time= 484.9 min (1,311.4 - 826.5)

Volume	Invert	Avail.Storage	Storage Description
#1	681.46'	878,611 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
681.46	119,790	0	0
682.00	125,453	66,216	66,216
684.00	211,702	337,155	403,371
686.00	263,538	475,240	878,611

Device	Routing	Invert	Outlet Devices
#1	Primary	681.50'	**24.0" Round Culvert** L= 50.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 681.50' / 681.00' S= 0.0100 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	681.75'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#3	Device 1	682.25'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#4	Device 1	682.75'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#5	Device 1	683.25'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#6	Device 1	684.00'	**36.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#7	Secondary	685.00'	**Custom Weir/Orifice, Cv= 2.62 (C= 3.28)** Head (feet) 0.00 0.50 1.00 Width (feet) 10.00 20.00 30.00

Primary OutFlow Max=18.07 cfs @ 13.97 hrs HW=684.95' (Free Discharge)
└─**1=Culvert** (Barrel Controls 18.07 cfs @ 5.75 fps)
  ├─**2=Orifice/Grate** (Passes < 6.50 cfs potential flow)
  ├─**3=Orifice/Grate** (Passes < 5.93 cfs potential flow)
  ├─**4=Orifice/Grate** (Passes < 5.29 cfs potential flow)
  ├─**5=Orifice/Grate** (Passes < 4.56 cfs potential flow)
  └─**6=Orifice/Grate** (Passes < 28.76 cfs potential flow)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=681.75' (Free Discharge)
└─**7=Custom Weir/Orifice** (Controls 0.00 cfs)

Summary for Link F1: Flume 1

Inflow Area = 1.695 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 4.94 cfs @ 12.25 hrs, Volume= 0.371 af
Primary = 4.94 cfs @ 12.25 hrs, Volume= 0.371 af, Atten= 0%, Lag= 0.0 min
Routed to Pond NP : North Pond

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F2: Flume 2

Inflow Area = 0.661 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 1.95 cfs @ 12.24 hrs, Volume= 0.145 af
Primary = 1.95 cfs @ 12.24 hrs, Volume= 0.145 af, Atten= 0%, Lag= 0.0 min
Routed to Reach NS3 : North Swale 3

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F3: Flume 3

Inflow Area = 4.297 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 12.17 cfs @ 12.19 hrs, Volume= 0.942 af
Primary = 12.17 cfs @ 12.19 hrs, Volume= 0.942 af, Atten= 0%, Lag= 0.0 min
Routed to Pond NP : North Pond

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F4: Flume 4

Inflow Area = 2.780 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 7.99 cfs @ 12.25 hrs, Volume= 0.609 af
Primary = 7.99 cfs @ 12.25 hrs, Volume= 0.609 af, Atten= 0%, Lag= 0.0 min
Routed to Reach NS2 : North Swale 2

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F6: Flume 6

Inflow Area = 2.618 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 7.54 cfs @ 12.25 hrs, Volume= 0.574 af
Primary = 7.54 cfs @ 12.25 hrs, Volume= 0.574 af, Atten= 0%, Lag= 0.0 min
Routed to Reach SS3 : South Swale 3

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link RC1: Rock Chute 1

Inflow Area = 0.319 ac, 0.00% Impervious, Inflow Depth = 2.63" for 25-yr event
Inflow = 1.41 cfs @ 12.13 hrs, Volume= 0.070 af
Primary = 1.41 cfs @ 12.13 hrs, Volume= 0.070 af, Atten= 0%, Lag= 0.0 min
Routed to Reach SS3 : South Swale 3

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Time span=0.00-90.00 hrs, dt=0.01 hrs, 9001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1: Area 1 Runoff Area=28,521 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=347' Tc=15.8 min CN=79 Runoff=3.04 cfs 0.228 af

Subcatchment1_2: Phase 1 and 2 Runoff Area=2,282,700 sf 1.80% Impervious Runoff Depth=4.17"
Flow Length=3,476' Tc=25.5 min CN=79 Runoff=191.41 cfs 18.230 af

Subcatchment2: Area 2 Runoff Area=28,787 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=491' Tc=15.8 min CN=79 Runoff=3.07 cfs 0.230 af

Subcatchment3: Area 3 Runoff Area=45,296 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=494' Tc=16.4 min CN=79 Runoff=4.75 cfs 0.362 af

Subcatchment4: Area 4 Runoff Area=39,815 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=475' Tc=15.6 min CN=79 Runoff=4.28 cfs 0.318 af

Subcatchment5: Area 5 Runoff Area=62,799 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=442' Tc=15.9 min CN=79 Runoff=6.66 cfs 0.502 af

Subcatchment6: Area 6 Runoff Area=81,297 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=569' Tc=17.1 min CN=79 Runoff=8.34 cfs 0.649 af

Subcatchment7: Area 7 Runoff Area=81,807 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=200' Tc=12.4 min CN=79 Runoff=9.72 cfs 0.653 af

Subcatchment8: Area 8 Runoff Area=104,501 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=240' Tc=13.8 min CN=79 Runoff=11.84 cfs 0.835 af

Subcatchment9: Area 9 Runoff Area=63,901 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=630' Tc=17.3 min CN=79 Runoff=6.52 cfs 0.510 af

Subcatchment10: Area 10 Runoff Area=84,606 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=454' Tc=16.9 min CN=79 Runoff=8.74 cfs 0.676 af

Subcatchment11: Area 11 Runoff Area=29,415 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=223' Tc=15.1 min CN=79 Runoff=3.20 cfs 0.235 af

Subcatchment12a: Area 12a Runoff Area=98,996 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=180' Tc=14.4 min CN=79 Runoff=11.03 cfs 0.791 af

Subcatchment12b: Area 12b Runoff Area=89,691 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=204' Tc=14.2 min CN=79 Runoff=10.01 cfs 0.716 af

Subcatchment13: Area 13 Runoff Area=226,080 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=205' Tc=14.5 min CN=79 Runoff=25.02 cfs 1.806 af

Subcatchment14: Area 14 Runoff Area=59,877 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=125' Slope=0.2500 '/' Tc=5.9 min CN=79 Runoff=9.19 cfs 0.478 af

Subcatchment15a: Area 15a Runoff Area=99,614 sf 5.36% Impervious Runoff Depth=4.60"
Flow Length=58' Tc=3.3 min CN=83 Runoff=18.14 cfs 0.877 af

Subcatchment15b: Area 15b Runoff Area=11,056 sf 0.00% Impervious Runoff Depth=4.82"
Flow Length=33' Slope=0.1176 '/' Tc=2.4 min CN=85 Runoff=2.11 cfs 0.102 af

Subcatchment15c: Area 15c Runoff Area=9,032 sf 0.00% Impervious Runoff Depth=4.50"
Flow Length=1,656' Tc=7.2 min CN=82 Runoff=1.40 cfs 0.078 af

Subcatchment16a: Area 16a Runoff Area=37,043 sf 0.00% Impervious Runoff Depth=4.93"
Flow Length=50' Tc=5.6 min CN=86 Runoff=6.55 cfs 0.350 af

Subcatchment16b: Area 16b Runoff Area=32,470 sf 0.00% Impervious Runoff Depth=4.82"
Flow Length=78' Tc=1.8 min CN=85 Runoff=6.26 cfs 0.300 af

Subcatchment17: Area 17 Runoff Area=123,541 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=271' Tc=14.8 min CN=79 Runoff=13.60 cfs 0.987 af

Subcatchment18: Area 18 Runoff Area=13,884 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=303' Tc=5.1 min CN=79 Runoff=2.20 cfs 0.111 af

Subcatchment19: Area 19 Runoff Area=60,482 sf 0.00% Impervious Runoff Depth=4.17"
Flow Length=648' Tc=7.7 min CN=79 Runoff=8.62 cfs 0.483 af

Subcatchment20: Area 20 Runoff Area=2,125 sf 0.00% Impervious Runoff Depth=4.28"
Flow Length=31' Tc=5.5 min CN=80 Runoff=0.34 cfs 0.017 af

Subcatchment21: Area 21 Runoff Area=50,989 sf 0.00% Impervious Runoff Depth=4.28"
Flow Length=75' Tc=4.7 min CN=80 Runoff=8.37 cfs 0.418 af

SubcatchmentP1: North Pond Runoff Area=342,674 sf 36.61% Impervious Runoff Depth=4.93"
Tc=0.0 min CN=86 Runoff=67.48 cfs 3.235 af

Reach NS1: North Swale 1 Avg. Flow Depth=0.58' Max Vel=4.46 fps Inflow=34.91 cfs 2.683 af
n=0.030 L=1,043.0' S=0.0209 '/' Capacity=302.62 cfs Outflow=31.25 cfs 2.683 af

Reach NS2: North Swale 2 Avg. Flow Depth=0.88' Max Vel=4.20 fps Inflow=48.82 cfs 4.230 af
n=0.030 L=381.0' S=0.0115 '/' Capacity=224.48 cfs Outflow=48.36 cfs 4.230 af

Reach NS3: North Swale 3 Avg. Flow Depth=0.79' Max Vel=5.13 fps Inflow=52.05 cfs 4.538 af
n=0.030 L=195.0' S=0.0193 '/' Capacity=290.78 cfs Outflow=51.98 cfs 4.538 af

Reach SS1: South Swale 1 Avg. Flow Depth=0.42' Max Vel=3.00 fps Inflow=15.12 cfs 1.140 af
n=0.030 L=686.0' S=0.0140 '/' Capacity=247.65 cfs Outflow=14.25 cfs 1.140 af

Reach SS2: South Swale 2 Avg. Flow Depth=0.59' Max Vel=3.53 fps Inflow=25.27 cfs 2.156 af
n=0.030 L=481.0' S=0.0130 '/' Capacity=238.39 cfs Outflow=24.90 cfs 2.156 af

Reach SS3: South Swale 3 Avg. Flow Depth=0.85' Max Vel=4.65 fps Inflow=51.87 cfs 4.582 af
n=0.030 L=721.0' S=0.0147 '/' Capacity=253.69 cfs Outflow=51.15 cfs 4.582 af

Pond C1: Culvert C1a & b Peak Elev=691.45' Inflow=51.15 cfs 4.582 af
Outflow=51.15 cfs 4.582 af

Pond C5: C5 Peak Elev=710.06' Inflow=14.25 cfs 1.140 af
18.0" Round Culvert n=0.025 L=38.0' S=0.0034 '/' Outflow=14.25 cfs 1.140 af

Pond NP: North Pond Peak Elev=685.89' Storage=850,819 cf Inflow=337.29 cfs 34.174 af
Primary=21.98 cfs 26.485 af Secondary=49.59 cfs 7.668 af Outflow=71.57 cfs 34.153 af

Link F1: Flume 1 Inflow=7.79 cfs 0.590 af
Primary=7.79 cfs 0.590 af

Link F2: Flume 2 Inflow=3.07 cfs 0.230 af
Primary=3.07 cfs 0.230 af

Link F3: Flume 3 Inflow=19.25 cfs 1.495 af
Primary=19.25 cfs 1.495 af

Link F4: Flume 4 Inflow=12.59 cfs 0.967 af
Primary=12.59 cfs 0.967 af

Link F6: Flume 6 Inflow=11.89 cfs 0.911 af
Primary=11.89 cfs 0.911 af

Link RC1: Rock Chute 1 Inflow=2.20 cfs 0.111 af
Primary=2.20 cfs 0.111 af

Total Runoff Area = 96.212 ac Runoff Volume = 34.174 af Average Runoff Depth = 4.26"
95.90% Pervious = 92.267 ac 4.10% Impervious = 3.945 ac

Summary for Subcatchment 1: Area 1

Runoff = 3.04 cfs @ 12.24 hrs, Volume= 0.228 af, Depth= 4.17"
Routed to Link F1 : Flume 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	28,521	79	
	28,521		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.5	106	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	141	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
15.8	347	Total			

Summary for Subcatchment 1_2: Phase 1 and 2

Runoff = 191.41 cfs @ 12.36 hrs, Volume= 18.230 af, Depth= 4.17"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	2,241,655	79	Closed Landfill
	41,045	98	Paved parking, HSG C
	2,282,700	79	Weighted Average
	2,241,655		98.20% Pervious Area
	41,045		1.80% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.0	100	0.0400	0.14		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.8	400	0.0400	1.40		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.7	2,976	0.0120	5.70	256.59	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=3.00' Z= 10.0 & 0.0 '/' Top.W=30.00' n= 0.035 Earth, dense weeds
25.5	3,476	Total			

Summary for Subcatchment 2: Area 2

Runoff = 3.07 cfs @ 12.24 hrs, Volume= 0.230 af, Depth= 4.17"
Routed to Link F2 : Flume 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	28,787	79	
	28,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.1	78	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	203	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	110	0.2500	20.09	10.95	**Pipe Channel,** 10.0" Round Area= 0.5 sf Perim= 2.6' r= 0.21' n= 0.013 Corrugated PE, smooth interior
15.8	491	Total			

Summary for Subcatchment 3: Area 3

Runoff = 4.75 cfs @ 12.25 hrs, Volume= 0.362 af, Depth= 4.17"
Routed to Link F1 : Flume 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	45,296	79	
	45,296		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.3	94	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.6	300	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
16.4	494	Total			

Summary for Subcatchment 4: Area 4

Runoff = 4.28 cfs @ 12.24 hrs, Volume= 0.318 af, Depth= 4.17"
Routed to Link F4 : Flume 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	39,815	79	
	39,815		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.1	83	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.9	173	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	119	0.2500	22.68	17.81	**Pipe Channel, Flume 4** 12.0" Round Area= 0.8 sf Perim= 3.1' r= 0.25' n= 0.013 Corrugated PE, smooth interior
15.6	475	Total			

Summary for Subcatchment 5: Area 5

Runoff = 6.66 cfs @ 12.24 hrs, Volume= 0.502 af, Depth= 4.17"
Routed to Link F3 : Flume 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	62,799	79	
	62,799		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.0	73	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	269	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
15.9	442	Total			

Summary for Subcatchment 6: Area 6

Runoff = 8.34 cfs @ 12.26 hrs, Volume= 0.649 af, Depth= 4.17"
Routed to Link F4 : Flume 4

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	81,297	79	
	81,297		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.6	189	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.9	161	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Intermediate Swale** Bot.W=0.00' D=1.00' Z= 4.0 & 33.0 '/' Top.W=37.00' n= 0.030 Short grass
0.1	119	0.2500	22.68	17.81	**Pipe Channel, Flume 4** 12.0" Round Area= 0.8 sf Perim= 3.1' r= 0.25' n= 0.013 Corrugated PE, smooth interior
17.1	569	Total			

Summary for Subcatchment 7: Area 7

Runoff = 9.72 cfs @ 12.20 hrs, Volume= 0.653 af, Depth= 4.17"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	81,807	79	
	81,807		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.3	63	0.0300	0.11		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.6	37	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	100	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.4	200	Total			

Summary for Subcatchment 8: Area 8

Runoff = 11.84 cfs @ 12.22 hrs, Volume= 0.835 af, Depth= 4.17"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	104,501	79	
	104,501		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.7	93	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.4	4	0.2500	0.15		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.7	143	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
13.8	240	Total			

Summary for Subcatchment 9: Area 9

Runoff = 6.52 cfs @ 12.26 hrs, Volume= 0.510 af, Depth= 4.17"
Routed to Link F3 : Flume 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	63,901	79	
	63,901		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.4	99	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
2.4	431	0.0100	3.00	9.01	**Trap/Vee/Rect Channel Flow, Diversion Berm** Bot.W=0.00' D=1.00' Z= 2.0 & 4.0 '/' Top.W=6.00' n= 0.030 Short grass
17.3	630	Total			

Summary for Subcatchment 10: Area 10

Runoff = 8.74 cfs @ 12.26 hrs, Volume= 0.676 af, Depth= 4.17"
Routed to Link F6 : Flume 6

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	84,606	79	
	84,606		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.5	183	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.9	171	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow, Diversion Berm** Bot.W=0.00' D=1.00' Z= 33.0 & 4.0 '/' Top.W=37.00' n= 0.030 Earth, grassed & winding
16.9	454	Total			

Summary for Subcatchment 11: Area 11

Runoff = 3.20 cfs @ 12.23 hrs, Volume= 0.235 af, Depth= 4.17"
Routed to Link F6 : Flume 6

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	29,415	79	
	29,415		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.6	119	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.0	4	0.0100	3.11	57.58	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.00' Z= 33.0 & 4.0 '/' Top.W=37.00' n= 0.030 Earth, grassed & winding
15.1	223	Total			

Summary for Subcatchment 12a: Area 12a

Runoff = 11.03 cfs @ 12.22 hrs, Volume= 0.791 af, Depth= 4.17"
Routed to Reach SS1 : South Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	98,996	79	
	0	96	Gravel surface, HSG C
	98,996	79	Weighted Average
	98,996		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	57	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	23	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.4	180	Total			

Summary for Subcatchment 12b: Area 12b

Runoff = 10.01 cfs @ 12.22 hrs, Volume= 0.716 af, Depth= 4.17"
Routed to Reach SS2 : South Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	89,333	79	
	358	96	Gravel surface, HSG C
	89,691	79	Weighted Average
	89,691		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.3	24	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.3	57	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	23	0.3333	4.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.2	204	Total			

Summary for Subcatchment 13: Area 13

Runoff = 25.02 cfs @ 12.23 hrs, Volume= 1.806 af, Depth= 4.17"
Routed to Reach NS1 : North Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	226,080	79	
	226,080		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.8	56	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	49	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.5	205	Total			

Summary for Subcatchment 14: Area 14

Runoff = 9.19 cfs @ 12.13 hrs, Volume= 0.478 af, Depth= 4.17"
Routed to Reach NS2 : North Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	59,877	79	
	59,877		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.1	25	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
5.9	125	Total			

Summary for Subcatchment 15a: Area 15a

Runoff = 18.14 cfs @ 12.11 hrs, Volume= 0.877 af, Depth= 4.60"
Routed to Reach NS1 : North Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	78,118	79	
	5,343	98	Paved roads w/curbs & sewers, HSG C
	16,153	96	Gravel surface, HSG C
	99,614	83	Weighted Average
	94,271		94.64% Pervious Area
	5,343		5.36% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	32	0.0050	0.57		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
2.4	26	0.1538	0.18		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
3.3	58	Total			

Summary for Subcatchment 15b: Area 15b

Runoff = 2.11 cfs @ 12.10 hrs, Volume= 0.102 af, Depth= 4.82"
Routed to Reach NS2 : North Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	7,026	79	
	4,030	96	Gravel surface, HSG C
	11,056	85	Weighted Average
	11,056		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	11	0.1176	1.62		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
2.3	22	0.1176	0.16		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.4	33	Total			

Summary for Subcatchment 15c: Area 15c

Runoff = 1.40 cfs @ 12.14 hrs, Volume= 0.078 af, Depth= 4.50"
Routed to Reach NS3 : North Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	7,178	79	
	1,854	96	Gravel surface, HSG C
	9,032	82	Weighted Average
	9,032		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	14	0.1250	1.74		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
4.4	50	0.1250	0.19		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
2.7	1,592	0.0167	9.92	610.36	**Trap/Vee/Rect Channel Flow,** Bot.W=10.00' D=3.00' Z= 4.0 & 3.0 '/' Top.W=31.00' n= 0.030 Earth, grassed & winding
7.2	1,656	Total			

Summary for Subcatchment 16a: Area 16a

Runoff = 6.55 cfs @ 12.13 hrs, Volume= 0.350 af, Depth= 4.93"
Routed to Reach SS1 : South Swale 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	20,948	79	
	16,095	96	Gravel surface, HSG C
	37,043	86	Weighted Average
	37,043		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.7	13	0.0050	0.06		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
0.7	21	0.0050	0.52		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.2	16	0.3300	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
5.6	50	Total			

Summary for Subcatchment 16b: Area 16b

Runoff = 6.26 cfs @ 12.10 hrs, Volume= 0.300 af, Depth= 4.82"
Routed to Reach SS2 : South Swale 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	21,666	79	
	10,804	96	Gravel surface, HSG C
	32,470	85	Weighted Average
	32,470		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.7	64	0.0450	1.57		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.1	14	0.3333	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
1.8	78	Total			

Summary for Subcatchment 17: Area 17

Runoff = 13.60 cfs @ 12.23 hrs, Volume= 0.987 af, Depth= 4.17"
Routed to Reach SS3 : South Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	123,541	79	
	123,541		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.5	100	0.0300	0.12		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.7	48	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.6	123	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
14.8	271	Total			

Summary for Subcatchment 18: Area 18

Runoff = 2.20 cfs @ 12.12 hrs, Volume= 0.111 af, Depth= 4.17"
Routed to Link RC1 : Rock Chute 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	13,884	79	
	13,884		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.0	100	0.2500	0.42		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.59"
0.0	3	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	200	0.0100	3.00	9.01	**Trap/Vee/Rect Channel Flow, Diversion Berm** Bot.W=0.00' D=1.00' Z= 2.0 & 4.0 '/' Top.W=6.00' n= 0.030 Earth, grassed & winding
5.1	303	Total			

Summary for Subcatchment 19: Area 19

Runoff = 8.62 cfs @ 12.15 hrs, Volume= 0.483 af, Depth= 4.17"
Routed to Link F3 : Flume 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	60,482	79	
	60,482		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	100	0.2500	0.29		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.0	8	0.2500	3.50		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.9	540	0.0100	4.77	57.18	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 2.0 & 4.0 '/' Top.W=12.00' n= 0.030 Earth, grassed & winding
7.7	648	Total			

Summary for Subcatchment 20: Area 20

Runoff = 0.34 cfs @ 12.13 hrs, Volume= 0.017 af, Depth= 4.28"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	1,965	79	
	160	96	Gravel surface, HSG C
	2,125	80	Weighted Average
	2,125		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.8	23	0.2500	0.22		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
3.7	8	0.0050	0.04		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
5.5	31	Total			

Summary for Subcatchment 21: Area 21

Runoff = 8.37 cfs @ 12.12 hrs, Volume= 0.418 af, Depth= 4.28"
Routed to Reach SS3 : South Swale 3

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
*	49,452	79	
	1,537	96	Gravel surface, HSG C
	50,989	80	Weighted Average
	50,989		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.9	43	0.2500	0.24		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
0.5	16	0.0050	0.49		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.59"
1.3	16	0.2500	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.59"
4.7	75	Total			

Summary for Subcatchment P1: North Pond

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 67.48 cfs @ 12.09 hrs, Volume= 3.235 af, Depth= 4.93"
Routed to Pond NP : North Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
MSE 24-hr 4 100-yr Rainfall=6.55"

	Area (sf)	CN	Description
	125,453	98	Water Surface
*	210,716	79	
	6,505	96	Gravel surface, HSG C
	342,674	86	Weighted Average
	217,221		63.39% Pervious Area
	125,453		36.61% Impervious Area

Summary for Reach NS1: North Swale 1

Inflow Area = 7.477 ac, 1.64% Impervious, Inflow Depth = 4.31" for 100-yr event
Inflow = 34.91 cfs @ 12.12 hrs, Volume= 2.683 af
Outflow = 31.25 cfs @ 12.22 hrs, Volume= 2.683 af, Atten= 10%, Lag= 6.1 min
Routed to Reach NS2 : North Swale 2

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.46 fps, Min. Travel Time= 3.9 min
Avg. Velocity = 1.10 fps, Avg. Travel Time= 15.9 min

Peak Storage= 7,302 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.58' , Surface Width= 14.07'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 302.62 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 1,043.0' Slope= 0.0209 '/'
Inlet Invert= 714.00', Outlet Invert= 692.16'

‡

Summary for Reach NS2: North Swale 2

[62] Hint: Exceeded Reach NS1 OUTLET depth by 0.32' @ 12.36 hrs

Inflow Area = 11.886 ac, 1.03% Impervious, Inflow Depth = 4.27" for 100-yr event
Inflow = 48.82 cfs @ 12.22 hrs, Volume= 4.230 af
Outflow = 48.36 cfs @ 12.26 hrs, Volume= 4.230 af, Atten= 1%, Lag= 2.8 min
Routed to Reach NS3 : North Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.20 fps, Min. Travel Time= 1.5 min
Avg. Velocity = 1.01 fps, Avg. Travel Time= 6.3 min

Peak Storage= 4,390 cf @ 12.23 hrs
Average Depth at Peak Storage= 0.88' , Surface Width= 16.17'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 224.48 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 381.0' Slope= 0.0115 '/'
Inlet Invert= 692.16', Outlet Invert= 687.77'

‡

Summary for Reach NS3: North Swale 3

[61] Hint: Exceeded Reach NS2 outlet invert by 0.79' @ 12.27 hrs

Inflow Area = 12.754 ac, 0.96% Impervious, Inflow Depth = 4.27" for 100-yr event
Inflow = 52.05 cfs @ 12.26 hrs, Volume= 4.538 af
Outflow = 51.98 cfs @ 12.28 hrs, Volume= 4.538 af, Atten= 0%, Lag= 1.1 min
Routed to Pond NP : North Pond

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 5.13 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 1.23 fps, Avg. Travel Time= 2.6 min

Peak Storage= 1,977 cf @ 12.27 hrs
Average Depth at Peak Storage= 0.79' , Surface Width= 15.55'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 290.78 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 195.0' Slope= 0.0193 '/'
Inlet Invert= 687.77', Outlet Invert= 684.00'

Summary for Reach SS1: South Swale 1

Inflow Area = 3.123 ac, 0.00% Impervious, Inflow Depth = 4.38" for 100-yr event
Inflow = 15.12 cfs @ 12.16 hrs, Volume= 1.140 af
Outflow = 14.25 cfs @ 12.28 hrs, Volume= 1.140 af, Atten= 6%, Lag= 7.3 min
Routed to Pond C5 : C5

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.00 fps, Min. Travel Time= 3.8 min
Avg. Velocity = 0.73 fps, Avg. Travel Time= 15.6 min

Peak Storage= 3,263 cf @ 12.21 hrs
Average Depth at Peak Storage= 0.42' , Surface Width= 12.91'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 247.65 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 686.0' Slope= 0.0140 '/'
Inlet Invert= 714.00', Outlet Invert= 704.38'

Summary for Reach SS2: South Swale 2

[79] Warning: Submerged Pond C5 Primary device # 1 INLET by 0.46'

Inflow Area = 5.927 ac, 0.00% Impervious, Inflow Depth = 4.37" for 100-yr event
Inflow = 25.27 cfs @ 12.25 hrs, Volume= 2.156 af
Outflow = 24.90 cfs @ 12.31 hrs, Volume= 2.156 af, Atten= 1%, Lag= 3.9 min
Routed to Reach SS3 : South Swale 3

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.53 fps, Min. Travel Time= 2.3 min
Avg. Velocity = 0.87 fps, Avg. Travel Time= 9.3 min

Peak Storage= 3,393 cf @ 12.27 hrs
Average Depth at Peak Storage= 0.59' , Surface Width= 14.10'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 238.39 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 481.0' Slope= 0.0130 '/'
Inlet Invert= 704.25', Outlet Invert= 698.00'

Summary for Reach SS3: South Swale 3

[62] Hint: Exceeded Reach SS2 OUTLET depth by 0.27' @ 12.17 hrs

Inflow Area = 12.870 ac, 0.00% Impervious, Inflow Depth = 4.27" for 100-yr event
Inflow = 51.87 cfs @ 12.26 hrs, Volume= 4.582 af
Outflow = 51.15 cfs @ 12.33 hrs, Volume= 4.582 af, Atten= 1%, Lag= 4.2 min
Routed to Pond C1 : Culvert C1a & b

Routing by Stor-Ind+Trans method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.65 fps, Min. Travel Time= 2.6 min
Avg. Velocity = 1.13 fps, Avg. Travel Time= 10.7 min

Peak Storage= 7,937 cf @ 12.29 hrs
Average Depth at Peak Storage= 0.85' , Surface Width= 15.94'
Bank-Full Depth= 2.00' Flow Area= 34.0 sf, Capacity= 253.69 cfs

10.00' x 2.00' deep channel, n= 0.030 Earth, dense weeds
Side Slope Z-value= 4.0 3.0 '/' Top Width= 24.00'
Length= 721.0' Slope= 0.0147 '/'
Inlet Invert= 698.00', Outlet Invert= 687.39'

Summary for Pond C1: Culvert C1a & b

[58] Hint: Peaked 0.45' above defined flood level
[62] Hint: Exceeded Reach SS3 OUTLET depth by 3.23' @ 12.34 hrs

Inflow Area = 12.870 ac, 0.00% Impervious, Inflow Depth = 4.27" for 100-yr event
Inflow = 51.15 cfs @ 12.33 hrs, Volume= 4.582 af
Outflow = 51.15 cfs @ 12.33 hrs, Volume= 4.582 af, Atten= 0%, Lag= 0.0 min
Primary = 51.15 cfs @ 12.33 hrs, Volume= 4.582 af
Routed to Pond NP : North Pond

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 691.45' @ 12.33 hrs
Flood Elev= 691.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	687.71'	**24.0" Round C1a** L= 341.7' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 687.71' / 683.12' S= 0.0134 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf
#2	Primary	687.47'	**24.0" Round C1b** L= 341.6' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 687.47' / 683.25' S= 0.0124 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf

Primary OutFlow Max=51.13 cfs @ 12.33 hrs HW=691.45' (Free Discharge)
1=C1a (Inlet Controls 25.03 cfs @ 7.97 fps)
2=C1b (Inlet Controls 26.10 cfs @ 8.31 fps)

Summary for Pond C5: C5

[58] Hint: Peaked 2.06' above defined flood level
[62] Hint: Exceeded Reach SS1 OUTLET depth by 5.28' @ 12.28 hrs

Inflow Area = 3.123 ac, 0.00% Impervious, Inflow Depth = 4.38" for 100-yr event
Inflow = 14.25 cfs @ 12.28 hrs, Volume= 1.140 af
Outflow = 14.25 cfs @ 12.28 hrs, Volume= 1.140 af, Atten= 0%, Lag= 0.0 min
Primary = 14.25 cfs @ 12.28 hrs, Volume= 1.140 af
Routed to Reach SS2 : South Swale 2

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Peak Elev= 710.06' @ 12.28 hrs
Flood Elev= 708.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	704.38'	**18.0" Round Culvert** L= 38.0' CMP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 704.38' / 704.25' S= 0.0034 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 1.77 sf

Primary OutFlow Max=14.24 cfs @ 12.28 hrs HW=710.06' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 14.24 cfs @ 8.06 fps)

Summary for Pond NP: North Pond

[62] Hint: Exceeded Reach NS3 OUTLET depth by 1.62' @ 13.17 hrs
[79] Warning: Submerged Pond C1 Primary device # 1 OUTLET by 2.77'
[79] Warning: Submerged Pond C1 Primary device # 2 OUTLET by 2.64'

Inflow Area = 96.212 ac, 4.10% Impervious, Inflow Depth = 4.26" for 100-yr event
Inflow = 337.29 cfs @ 12.33 hrs, Volume= 34.174 af
Outflow = 71.57 cfs @ 13.04 hrs, Volume= 34.153 af, Atten= 79%, Lag= 42.9 min
Primary = 21.98 cfs @ 13.04 hrs, Volume= 26.485 af
Secondary = 49.59 cfs @ 13.04 hrs, Volume= 7.668 af

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs
Starting Elev= 681.75' Surf.Area= 122,831 sf Storage= 35,180 cf
Peak Elev= 685.89' @ 13.04 hrs Surf.Area= 260,790 sf Storage= 850,819 cf (815,638 cf above start)
Flood Elev= 886.00' Surf.Area= 263,538 sf Storage= 878,611 cf (843,431 cf above start)

Plug-Flow detention time= 423.6 min calculated for 33.345 af (98% of inflow)
Center-of-Mass det. time= 397.2 min (1,212.5 - 815.3)

Volume	Invert	Avail.Storage	Storage Description
#1	681.46'	878,611 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
681.46	119,790	0	0
682.00	125,453	66,216	66,216
684.00	211,702	337,155	403,371
686.00	263,538	475,240	878,611

Device	Routing	Invert	Outlet Devices
#1	Primary	681.50'	**24.0" Round Culvert** L= 50.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 681.50' / 681.00' S= 0.0100 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	681.75'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#3	Device 1	682.25'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#4	Device 1	682.75'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#5	Device 1	683.25'	**6.0" Vert. Orifice/Grate X 4.00** C= 0.600 Limited to weir flow at low heads
#6	Device 1	684.00'	**36.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#7	Secondary	685.00'	**Custom Weir/Orifice, Cv= 2.62 (C= 3.28)** Head (feet) 0.00 0.50 1.00 Width (feet) 10.00 20.00 30.00

Primary OutFlow Max=21.99 cfs @ 13.04 hrs HW=685.89' (Free Discharge)
└─**1=Culvert** (Barrel Controls 21.99 cfs @ 7.00 fps)
  ├─**2=Orifice/Grate** (Passes < 7.46 cfs potential flow)
  ├─**3=Orifice/Grate** (Passes < 6.97 cfs potential flow)
  ├─**4=Orifice/Grate** (Passes < 6.43 cfs potential flow)
  ├─**5=Orifice/Grate** (Passes < 5.85 cfs potential flow)
  └─**6=Orifice/Grate** (Passes < 46.84 cfs potential flow)

Secondary OutFlow Max=47.48 cfs @ 13.04 hrs HW=685.89' (Free Discharge)
└─**7=Custom Weir/Orifice** (Weir Controls 47.48 cfs @ 2.80 fps)

Summary for Link F1: Flume 1

Inflow Area = 1.695 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 7.79 cfs @ 12.24 hrs, Volume= 0.590 af
Primary = 7.79 cfs @ 12.24 hrs, Volume= 0.590 af, Atten= 0%, Lag= 0.0 min
Routed to Pond NP : North Pond

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F2: Flume 2

Inflow Area = 0.661 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 3.07 cfs @ 12.24 hrs, Volume= 0.230 af
Primary = 3.07 cfs @ 12.24 hrs, Volume= 0.230 af, Atten= 0%, Lag= 0.0 min
Routed to Reach NS3 : North Swale 3

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F3: Flume 3

Inflow Area = 4.297 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 19.25 cfs @ 12.18 hrs, Volume= 1.495 af
Primary = 19.25 cfs @ 12.18 hrs, Volume= 1.495 af, Atten= 0%, Lag= 0.0 min
Routed to Pond NP : North Pond

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F4: Flume 4

Inflow Area = 2.780 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 12.59 cfs @ 12.25 hrs, Volume= 0.967 af
Primary = 12.59 cfs @ 12.25 hrs, Volume= 0.967 af, Atten= 0%, Lag= 0.0 min
Routed to Reach NS2 : North Swale 2

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link F6: Flume 6

Inflow Area = 2.618 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 11.89 cfs @ 12.25 hrs, Volume= 0.911 af
Primary = 11.89 cfs @ 12.25 hrs, Volume= 0.911 af, Atten= 0%, Lag= 0.0 min
Routed to Reach SS3 : South Swale 3

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Summary for Link RC1: Rock Chute 1

Inflow Area = 0.319 ac, 0.00% Impervious, Inflow Depth = 4.17" for 100-yr event
Inflow = 2.20 cfs @ 12.12 hrs, Volume= 0.111 af
Primary = 2.20 cfs @ 12.12 hrs, Volume= 0.111 af, Atten= 0%, Lag= 0.0 min
Routed to Reach SS3 : South Swale 3

Primary outflow = Inflow, Time Span= 0.00-90.00 hrs, dt= 0.01 hrs

Diversion Berm Sizing and Spacing

SCS ENGINEERS

		Sheet No.	1 of 6
		Calc. No.	
		Rev. No.	
Job No. 25222259	Job: I-43 Plan Mod Addendum	By: RJG	Date: 2/27/24
Client: WPL	Subject: Intermediate Diversion Berm Spacing	Chk'd: SJL	Date: 4/5/24

Universal Soil Loss Equation (USLE) Calculation

Purpose/Approach:

Use USLE to properly space diversion berms/swales along the 3% slope of the final cover and a 4:1 to maintain average annual soil loss along the final cover to 3 tons/acre or less. Also check average slope.

References:

1. Figure 7.2 Rainfall factors for use with the universal soil loss equation, Sheet 2
2. Table 5.1. Soil Erodibility Factor K_{fact}, Sheet 3
3. Table 10. Factor C for permanent pasture, range, and idle land, Sheet 4
4. Table of P-factors per land cover, Sheet 5

Assumptions:

A = 3 tons/acre

R = 98 see pg. 2

K = 0.33 see pg. 3 for silt loam assuming 4% organic matter

C = 0.0065 see pg. 4

P = 1.0 see pg. 5 for Dense vegetation

Calculations: USLE Equation: A = R * K * LS * C * P

where: A = Average annual soil loss, ton/acre

R = Rainfall and runoff erosivity index

K = Soil erodibility factor, tons/acre

LS = Slope length and steepness factor

C = Cover management factor

P = Practice factor

$$\text{or} \quad LS = \frac{A}{R \times K \times C \times P} = \frac{3}{98 \times 0.33 \times 0.0065 \times 1.0}$$

$$= 14.27$$

From the LS Values Table (Sheet 5), based on the final cover slopes, the slope distance is between as shown below. Use linear interpolation between the LS values to determine the slope length for each slope. Then check average slope.

Slope Length @	200	ft	LS=	13.34
Slope Length @	250	ft	LS=	14.91

Conclusion:

The distance between the intermediate berms/swales on the final cover 4:1 slope cannot exceed 230 ft. The 3% slope and the average slope 10% can not be computed from the graphs since the LS value would require a slope greater than 1000 feet. No intermediate/swale is required for the final cover.

SCS ENGINEERS

		Sheet No.	2 of 7
		Calc. No.	
		Rev. No.	
Job No. 25222159	Job: I-43 Plan Mod Addendum	By: RJG	Date: 2/27/24
Client: WPL	Subject: Intermediate Diversion Berm Spacing	Chk'd: SJL	Date: 4/5/24

Calculations (Continued):

Slope length for the calculate LS factor for 4:1 = 230 ft
Slope length for the calculate LS factor for 3% = <1,000 ft

Determine average slope along longest flow length. From the drawings the longest slope is
130 ft @ 4:1 slope and 280 ft @ 3% slope
Total Length = 410 ft
Average slope = (Slope1 * Length1 + Slope2 * Length2)/Total Length = 0.1 = ~10%

At 10% the calculated LS value gives a slope greater than 1000 ft, which exceeds
the longest potential flow path of the proposed intermediate and final closure design.

SCS ENGINEERS

		Sheet No.	3 of 7
		Calc. No.	
		Rev. No.	
Job No. 25222259	Job: I-43 Plan Mod Addendum	By: RJG	Date: 2/27/24
Client: WPL	Subject: Intermediate Diversion Berm Spacing	Chk'd: SJL	Date: 4/5/24

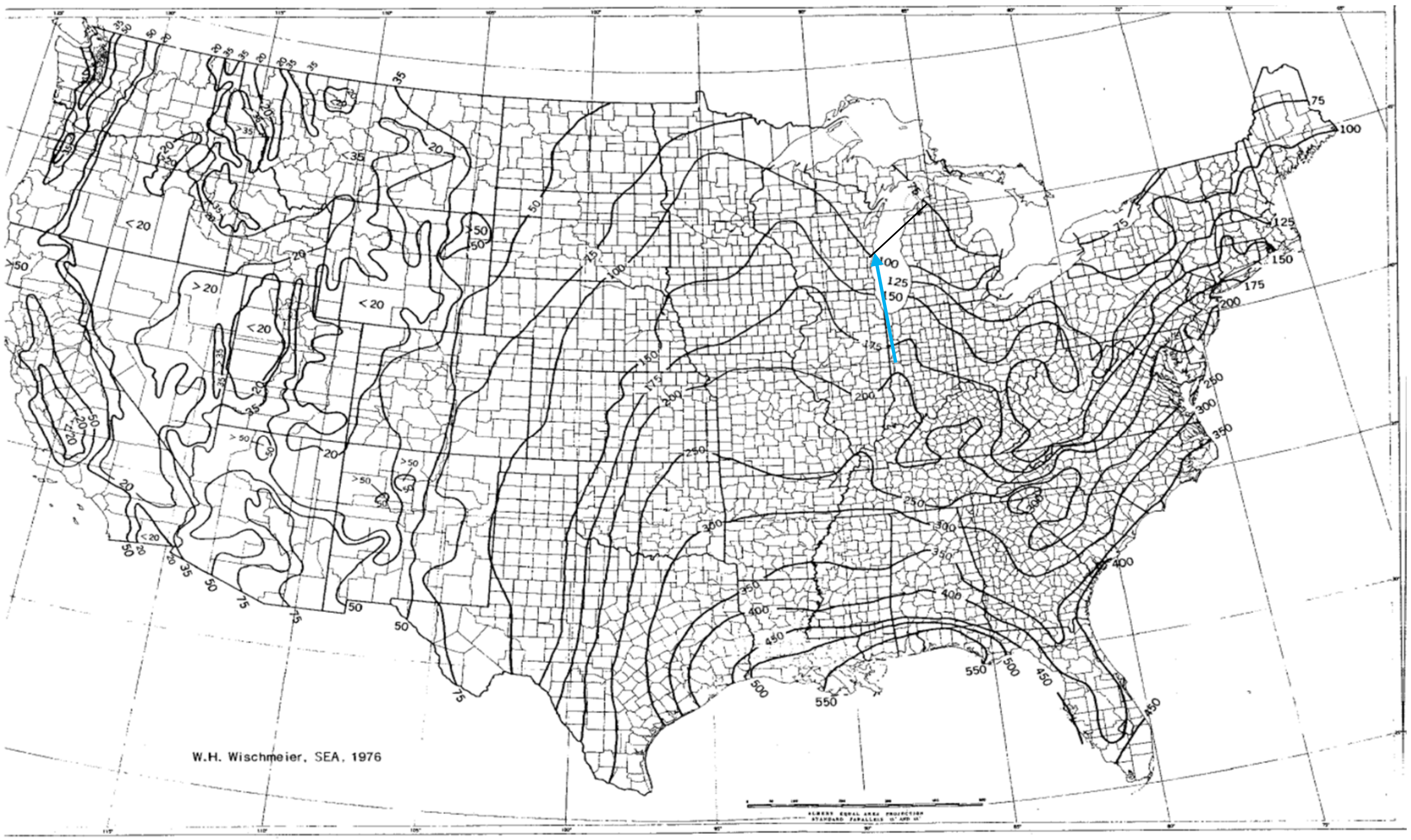


FIGURE 1.—Average annual values of the rainfall erosion index.

Source: "Predicting Rainfall Erosion Losses," USDA Agriculture Handbook Number 537, 1978.

Table 5.10. Soil Erodibility Factor K_{fact} (after Stewart et al. 1975)[a]

	P_{om}(%)		
Textural Class	<0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very finesand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy finesand	0.24	0.20	0.16
Loamy veryfine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandyloam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clayloam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clayloam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13-0.2	

(a) The values shown are estimated averages of broad ranges of specific soil values. When a texture is near the border line of two texture classes, use the average of the two K_{fact} values. In addition, the values shown are commensurate with the English units used in the cited reference (and as used in the source-term module input files). To obtain analagous values in the metric units used in this report, the above values should be multiplied by 1.292.

Assuming an organic content (P_{om}) of 4% to be conservative, typically range for topsoil is 4% and 8%.

K = 0.33

TABLE 10.—*Factor* **C** *for permanent pasture, range, and idle land*[1]

Vegetative canopy: Type and height[2]	Vegetative canopy: Percent cover[3]	Cover that contacts the soil surface: Type[4]	Percent ground cover: 0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

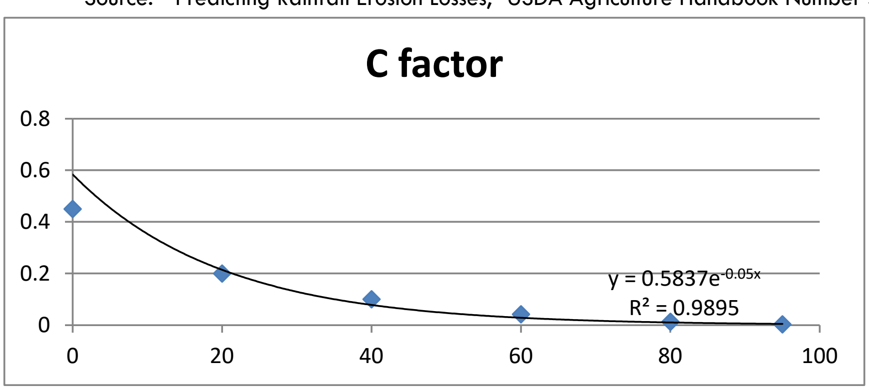
[1] The listed C values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.
W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

Source: "Predicting Rainfall Erosion Losses," USDA Agriculture Handbook Number 537, 1978.



90	% Cover
=	0.0065

S. no.	Land use/land cover classes	*P* values
1	Dense vegetation	1
2	Sparse vegetation	0.8
3	Built- up	1
4	Water bodies	1
5	Scrub land	1
6	Agricultural cropland	0.5
7	Fallow land	0.9
8	Bare soil/barren land	1

Source: USDA Handbook No. 282 (1981)

P factor for different land cover types

TABLE 5.5 LS Values* (10)

Slope ratio	Slope gradient s, %	LS values for following slope lengths l, ft (m): 10 (3.0)	20 (6.1)	30 (9.1)	40 (12.2)	50 (15.2)	60 (18.3)	70 (21.3)	80 (24.4)	90 (27.4)	100 (30.5)
	0.5	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10
100:1	1	0.08	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12
	2	0.10	0.12	0.14	0.15	0.16	0.17	0.18	0.19	0.19	0.20
	3	0.14	0.18	0.20	0.22	0.23	0.25	0.26	0.27	0.28	0.29
	4	0.16	0.21	0.25	0.28	0.30	0.33	0.35	0.37	0.38	0.40
20:1	5	0.17	0.24	0.29	0.34	0.38	0.41	0.45	0.48	0.51	0.53
	6	0.21	0.30	0.37	0.43	0.48	0.52	0.56	0.60	0.64	0.67
	7	0.26	0.37	0.45	0.52	0.58	0.64	0.69	0.74	0.78	0.82
12½:1	8	0.31	0.44	0.54	0.63	0.70	0.77	0.83	0.89	0.94	0.99
	9	0.37	0.52	0.64	0.74	0.83	0.91	0.98	1.05	1.11	1.17
10:1	10	0.43	0.61	0.75	0.87	0.97	1.06	1.15	1.22	1.30	1.37
	11	0.50	0.71	0.86	1.00	1.12	1.22	1.32	1.41	1.50	1.58
8:1	12.5	0.61	0.86	1.05	1.22	1.36	1.49	1.61	1.72	1.82	1.92
	15	0.81	1.14	1.40	1.62	1.81	1.98	2.14	2.29	2.43	2.56
6:1	16.7	0.96	1.36	1.67	1.92	2.15	2.36	2.54	2.72	2.88	3.04
5:1	20	1.29	1.82	2.23	2.58	2.88	3.16	3.41	3.65	3.87	4.08
4½:1	22	1.51	2.13	2.61	3.02	3.37	3.69	3.99	4.27	4.53	4.77
→ 4:1	25	1.86	2.63	3.23	3.73	4.16	4.56	4.93	5.27	5.59	5.89
	30	2.51	3.56	4.36	5.03	5.62	6.16	6.65	7.11	7.54	7.95
3:1	33.3	2.98	4.22	5.17	5.96	6.67	7.30	7.89	8.43	8.95	9.43
	35	3.23	4.57	5.60	6.46	7.23	7.92	8.55	9.14	9.70	10.22
2½:1	40	4.00	5.66	6.93	8.00	8.95	9.80	10.59	11.32	12.00	12.65
	45	4.81	6.80	8.33	9.61	10.75	11.77	12.72	13.60	14.42	15.20
2:1	50	5.64	7.97	9.76	11.27	12.60	13.81	14.91	15.94	16.91	17.82
	55	6.48	9.16	11.22	12.96	14.48	15.87	17.14	18.32	19.43	20.48
1¾:1	57	6.82	9.64	11.80	13.63	15.24	16.69	18.03	19.28	20.45	21.55
	60	7.32	10.35	12.68	14.64	16.37	17.93	19.37	20.71	21.96	23.15
1½:1	66.7	8.44	11.93	14.61	16.88	18.87	20.67	22.32	23.87	25.31	26.68
	70	8.98	12.70	15.55	17.96	20.08	21.99	23.75	25.39	26.93	28.39
	75	9.78	13.83	16.94	19.56	21.87	23.95	25.87	27.66	29.34	30.92
1¼:1	80	10.55	14.93	18.28	21.11	23.60	25.85	27.93	29.85	31.66	33.38
	85	11.30	15.98	19.58	22.61	25.27	27.69	29.90	31.97	33.91	35.74
	90	12.02	17.00	20.82	24.04	26.88	29.44	31.80	34.00	36.06	38.01
	95	12.71	17.97	22.01	25.41	28.41	31.12	33.62	35.94	38.12	40.18
1:1	100	13.36	18.89	23.14	26.72	29.87	32.72	35.34	37.78	40.08	42.24

Slope ratio	Slope gradient s, %	LS values for following slope lengths l, ft (m): 150 (46)	200 (61)	250 (76)	300 (91)	350 (107)	400 (122)	450 (137)	500 (152)	600 (183)	700 (213)	800 (244)	900 (274)	1000 (305)
	0.5	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15
100:1	1	0.14	0.14	0.15	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.20
	2	0.23	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.36	0.37	0.39	0.40
	3	0.32	0.35	0.38	0.40	0.42	0.43	0.45	0.46	0.49	0.51	0.54	0.55	0.57
	4	0.47	0.53	0.58	0.62	0.66	0.70	0.73	0.76	0.82	0.87	0.92	0.96	1.00
20:1	5	0.66	0.76	0.85	0.93	1.00	1.07	1.13	1.20	1.31	1.42	1.51	1.60	1.69
	6	0.82	0.95	1.06	1.16	1.26	1.34	1.43	1.50	1.65	1.78	1.90	2.02	2.13
	7	1.01	1.17	1.30	1.43	1.54	1.65	1.75	1.84	2.02	2.18	2.33	2.47	2.61
12½:1	8	1.21	1.40	1.57	1.72	1.85	1.98	2.10	2.22	2.43	2.62	2.80	2.97	3.13
	9	1.44	1.66	1.85	2.03	2.19	2.35	2.49	2.62	2.87	3.10	3.32	3.52	3.71
10:1	10	1.68	1.94	2.16	2.37	2.56	2.74	2.90	3.06	3.35	3.62	3.87	4.11	4.33
	11	1.93	2.23	2.50	2.74	2.95	3.16	3.35	3.53	3.87	4.18	4.47	4.74	4.99
8:1	12.5	2.35	2.72	3.04	3.33	3.59	3.84	4.08	4.30	4.71	5.08	5.43	5.76	6.08
	15	3.13	3.62	4.05	4.43	4.79	5.12	5.43	5.72	6.27	6.77	7.24	7.68	8.09
6:1	16.7	3.72	4.30	4.81	5.27	5.69	6.08	6.45	6.80	7.45	8.04	8.60	9.12	9.62
5:1	20	5.00	5.77	6.45	7.06	7.63	8.16	8.65	9.12	9.99	10.79	11.54	12.24	12.90
4½:1	22	5.84	6.75	7.54	8.26	8.92	9.54	10.12	10.67	11.68	12.62	13.49	14.31	15.08
→ 4:1	25	7.21	8.33	9.31	10.20	11.02	11.78	12.49	13.17	14.43	15.58	16.66	17.67	18.63
	30	9.74	11.25	12.57	13.77	14.88	15.91	16.87	17.78	19.48	21.04	22.49	23.86	25.15
3:1	33.3	11.55	13.34	14.91	16.33	17.64	18.86	20.00	21.09	23.10	24.95	26.67	28.29	29.82
	35	12.52	14.46	16.16	17.70	19.12	20.44	21.68	22.86	25.04	27.04	28.91	30.67	32.32
2½:1	40	15.50	17.89	20.01	21.91	23.67	25.30	26.84	28.29	30.99	33.48	35.79	37.96	40.01
	45	18.62	21.50	24.03	26.33	28.44	30.40	32.24	33.99	37.23	40.22	42.99	45.60	48.07
2:1	50	21.83	25.21	28.18	30.87	33.34	35.65	37.81	39.85	43.66	47.16	50.41	53.47	56.36
	55	25.09	28.97	32.39	35.48	38.32	40.97	43.45	45.80	50.18	54.20	57.94	61.45	64.78
1¾:1	57	26.40	30.48	34.08	37.33	40.32	43.10	45.72	48.19	52.79	57.02	60.96	64.66	68.15
	60	28.35	32.74	36.60	40.10	43.31	46.30	49.11	51.77	56.71	61.25	65.48	69.45	73.21
1½:1	66.7	32.68	37.74	42.19	46.22	49.92	53.37	56.60	59.66	65.36	70.60	75.47	80.05	84.38
	70	34.77	40.15	44.89	49.17	53.11	56.78	60.23	63.48	69.54	75.12	80.30	85.17	89.78
	75	37.87	43.73	48.89	53.56	57.85	61.85	65.60	69.15	75.75	81.82	87.46	92.77	97.79
1¼:1	80	40.88	47.20	52.77	57.81	62.44	66.75	70.80	74.63	81.76	88.31	94.41	100.13	105.55
	85	43.78	50.55	56.51	61.91	66.87	71.48	75.82	79.92	87.55	94.57	101.09	107.23	113.03
	90	46.55	53.76	60.10	65.84	71.11	76.02	80.63	84.99	93.11	100.57	107.51	114.03	120.20
	95	49.21	56.82	63.53	69.59	75.17	80.36	85.23	89.84	98.42	106.30	113.64	120.54	127.06
1:1	100	51.74	59.74	66.79	73.17	79.03	84.49	89.61	94.46	103.48	111.77	119.48	126.73	133.59

*Calculated from

$$LS = \left(\frac{65.41 \times s^2}{s^2 + 10{,}000} + \frac{4.56 \times s}{\sqrt{s^2 + 10{,}000}} + 0.065\right)\left(\frac{l}{72.5}\right)^m$$

LS = topographic factor
l = slope length, ft (m × 0.3048)
s = slope steepness,
m = exponent dependent upon slope steep
(0.2 for slopes < 1%, 0.3 for slopes 1
0.4 for slopes 3.5 to 4.5%, and
0.5 for slopes > 5%)

FROM "EROSION & SEDIMENT CONTROL HANDBOOK," Goldman, Jackson, + Bursztynsky, 1986

Source: Erosion and Sediment Control Handbook," Goldman, Jackson, & Bursztynsky, 1986.

SCS ENGINEERS

		Sheet No: 1/3	
		Calc. No.	
		Rev. No.	
Job No. 25222259.00	Job: I-43 Plan Mod Addendum	By: RJG	Date: 4/5/24
Client: WPL	Subject: Diversion Berm Sizing	Chk'd: SJL	Date: 5/23/24

Purpose:

To size the diversion berm to accommodate the 25-year, 24-hour storm event.

References:

1. WisDOT Facilities Development Manual Chapter 13, Section 30-15, Grass Lined Channels.
2. Design of Roadside Channels with Flexible Linings, HEC-15, USDOT FHWA.
3. HydroCAD Report_I-43_CWS Liner Conversion.pdf
4. HydroCAD Report_I-43_Fully Developed Site Closure.pdf

Approach:

Use HydroCAD to determine the 25-year, 24-hour peak flow to each diversion berm drainage area. Use Grass Lined Channel Design WisDOT Spreadsheet, FDM 13-30 Attachment 15.2 (from Reference #1) to size the diversion berms. The WisDOT spreadsheet incorporates the design guidelines and equations described in "Design of Roadside Channels with Flexible Linings", HEC-15, USDOT FHWA (Reference #2).

Confirm the diversion berm swale is stable and has enough capacity for the design flow rate.

Assumptions:

1. Assume the channel geometry is a v-notch swale with one sideslope at either 4:1 (final cover slope) or 3% and the other sideslope at 2:1.
2. Assume 1.0% slope along the flow path of the diversion berm.
3. Assume the following parameters per Section 15.2 - Grass Lining Properties from Reference #1:
   Vegetation Retardance Class = C
   Vegetation Condition = Good
   Vegetation Growth Form = Turf
4. Assume Cohesive soil type with ASTM Soil Class SC and a Plasticity Index (PI) of 16.
5. Existing diversion berms are not evaluated because they will accept the same or less drainage area for the two closure options compared to when they were constructed.

Calculations:

Diversion berm flow rates:

Contact Water Swale Liner Conversion		Fully Developed Site Closure		
Drainage Area	Flowrate (cfs)	Drainage Area	Flowrate (cfs)	
Area 1	*1.93*	*Area 1*	*1.93*	
Area 3	*3.02*	*Area 3*	*3.02*	
Area 5	*2.54*	*Area 5*	*4.23*	
		Area 6	*5.29*	
		Area 9	*4.13*	4:1 cover
		Area 10	*5.54*	
		Area 11	*2.03*	
		Area 18	*1.41*	4:1 cover
		Area 19	*5.50*	4:1 cover

Size the diversion berm on the 3% cover based on a flow rate of: 5.54 cfs

Size the diversion berms on the 4:1 cover based on a flow rate of: 5.50 cfs

Use the WisDOT Grass Swale Design Spreadsheet to determine the flow depth, velocity and shear stress in the swale.

Results:

The calculated flow depth on the 3% final cover diversion berm is 0.65 feet with a flow velocity of 0.74 fps.
The diversion berm is stable at the design flow rate. The design diversion berm depth of 2 feet maintains at least 0.5 ft of during the 25-year, 24-hour storm event. Based on the shear stress o 0.41 lb/sf, install a Class 1, Type B channel erosion mat.

The calculated flow depth on the 4:1 final cover diversion berm is 1.19 feet with a flow velocity of 1.29 fps.
The diversion berm is stable at the design flow rate. The design diversion berm depth of 2.0 feet maintains at least 0.5 ft of during the 25-year, 24-hour storm event. Based on the shear stress o 0.74 lb/sf, install a Class 1, Type B channel erosion mat.

Channel/Ditch Geometry		
Channel Slope, S_o (ft/ft)	**0.01**	**0.01**
Channel Bottom Width, B (ft)	**0**	**0**
Channel Side Slope, z_1	**2**	**2**
Channel Side Slope, z_2	**33.33**	**4**
Flow Depth, d (ft) Solve iteratively	**0.65**	**1.19**
Safety Factor, SF	**1.0**	**1.0**
Vegetation/Soil Parameters		
Vegetation Retardance Class	**C**	**C**
Vegetation Condition	**good**	**good**
Vegetation Growth Form	**turf**	**turf**
Soil Type	**cohesive**	**cohesive**
D_{75} (in) (Set at 0.00 for cohesive soils)		
ASTM Soil Class	**SC**	**SC**
Plasticity Index, PI	**16**	**16**
Results Summary		
Design Q (ft^3/s)	**5.5**	**5.5**
Calculated Q (ft^3/s)	5.4	5.6
Difference Between Design & Calc. Flow (%)	-1.6%	1.7%
Stable (Yes or No)	**YES**	**YES**
Channel Parameters		
Vegetation Height, h (ft)	0.67	0.67
Grass Roughness Coefficient, C_n	0.238	0.238
Cover Factor, C_f	0.90	0.90
Noncohesive Soil		
Soil Grain Roughness, n_s	0.016	0.016
Permissible Soil Shear Stress, τ_p (lb/ft^2)	N/A	N/A
Cohesive Soil		
Porosity, e	0.35	0.35
Soil Coefficient 1, c_1	1.0700	1.0700
Soil Coefficient 2, c_2	14.30	14.30
Soil Coefficient 3, c_3	47.700	47.700
Soil Coefficient 4, c_4	1.42	1.42
Soil Coefficient 5, c_5	-0.61	-0.61
Soil Coefficient 6, c_6	0.00010	0.00010
Permissible Soil Shear Stress, τ_p (lb/ft^2)	0.080	0.080
Total Permissible Shear Stress, τ_p (lb/ft^2)	0.080	0.080
Cross Sectional Area, A (ft^2)	7.463	4.248
Wetted Perimeter, P (ft)	23.13	7.57
Hydraulic Radius, R (ft)	0.323	0.561
Top Width, T (ft)	22.96	7.14
Hydraulic Depth, D (ft)	0.325	0.595
Froude Number (Q design)	0.226	0.301
Channel Shear Stress, τ_o (lb/ft^2)	0.20	0.35
Actual Sheer Stress, τ_d (lb/ft^2)	0.41	0.74
Mannings n	0.096	0.077
Average Velocity, V (ft/s)	0.74	1.29
Calculated Flow, Q (ft^3/s)	5.4	5.6
Difference Between Design & Calc. Flow (%)	-1.6%	1.7%
Effective Shear on Soil Surface, τ_e (lb/ft^2)	0.001	0.003
Total Permissible Shear on Veg., $\tau_{p,veg}$ (lb/ft^2)	28.84	18.56
Stable (Y or N)	YES	YES

Source: Grass Lined Channel Design WisDOT Spreadsheet, FDM 13-30 Attachment 15.2

To differentiate applications WisDOT organizes erosion mats into three classes of mats, which are further broken down into various Types.

A. **Class I**: A short-term duration (minimum of 6 months), light duty, organic ECRM with plastic or biodegradable netting.

   1. **Type A** – Only suitable for slope applications, not channel applications.

   2. **Type B** – Double netted product for use in channels where the calculated (design) shear stress is 1.5 lbs/ft^2 or less.

B. **Class II**: A long-term duration (three years or greater), organic ECRM.

   1. **Type A** – Jute fiber only for use in channels to reinforce sod.

   2. **Type B** – For use in channels where the calculated (design) shear stress is 2.0 lbs/ft^2 or less. Made with plastic or biodegradable mat.

   3. **Type C** – A woven mat of 100% organic material for use in channels where the calculated (design) shear stress is 2.0 lbs/ft^2 or less. Applicable for use in environmentally sensitive areas where plastic netting is inappropriate.

C. **Class III**: A permanent 100% synthetic ECRM or TRM. Class I, Type B erosion mat or Class II, Type B or C erosion mat must be placed over a soil filled TRM.

   1. **Type A** – An ECRM for use in channels where the calculated (design) shear stress of 2.0 lbs/ft^2 or less.

   2. **Type B** – A TRM for use in channels where the calculated (design) shear stress of 2.0 lbs/ft^2 or less.

   3. **Type C** – A TRM for use in channels where the calculated (design) shear stress of 3.5 lbs/ft^2 or less.

   4. **Type D** – A TRM for use in channels where the calculated (design) shear stress of 5.0 lbs/ft^2 or less.

Swale Sizing

SCS ENGINEERS

		Sheet No: 1/2	
		Calc. No.	
		Rev. No.	
Job No.: 25222259.00	Job: I-43 Plan Mod Addendum	By: RJG	Date: 5/22/24
Client: WPL	Subject: Perimeter Swale Sizing	Chk'd: SJL	Date: 5/23/24

Purpose:

To size the perimeter swale to accommodate the 25-year, 24-hour storm event.

References:

1. WisDOT Facilities Development Manual Chapter 13, Section 30-15 - Grass Lined Channels.
2. Design of Roadside Channels with Flexible Linings, HEC-15, USDOT FHWA.
3. HydroCAD Report_I-43_CWS Liner Conversion.pdf
4. HydroCAD Report_I-43_Fully Developed Site Closure.pdf

Approach:

Use HydroCAD to determine the 25-year, 24-hour peak flow rate for the perimeter swale. Use Grass Lined Channel Design WisDOT Spreadsheet, FDM 13-30 Attachment 15.2 (from Reference #1) to size the perimeter swale for each design swale cross section. The WisDOT spreadsheet incorporates the design guidelines and equations described in "Design of Roadside Channels with Flexible Linings", HEC-15, USDOT FHWA (Reference #2).

Confirm the swale is stable and has enough capacity for the design flow rate.

Assumptions:

1. Assume the channel sideslopes are as shown on drawings.
2. Assume slope along the flowpath of the swale as shown on drawings.
3. Assume the following parameters per Section 15.2 - Grass Lining Properties from Reference #1:
   Vegetation Retardance Class = C
   Vegetation Condition = Good
   Vegetation Growth Form = Turf
4. Assume Cohesive soil type with ASTM Soil Class SC and a Plasticity Index (PI) of 16.

Calculations:

See Page 2, 3 and 4

Results:

The North and South perimeter swales can handle the flow rate without overtopping based on the average slope and as individual sections.

The proposed swales are designed to handle the 25-year, 24-hour storm peak discharge.

Based on the shear stress of each proposed swale install a Class 1, Type B channel erosion mat and where a swale is regraded.

Calculations (Continued):

Contact Water Swale Liner Conversion:

Size proposed Swale 1 in Area 6 based on a flow rate of:	6.05	cfs from Node S1 from Reference 1.
Size proposed Swale 2 in Area 9 based on a flow rate of:	4.70	cfs from Node S2 from Reference 1.
Size proposed Swale 3 based on a flow rate of:	9.78	cfs from Node S3 from Reference 1.
Size proposed Swale 4 based on a flow rate of:	1.20	cfs from Node S4 from Reference 1.
Confirm Size of South Swale 1 based on a flow rate of:	9.79	cfs from Node SS1 from Reference 1.
Confirm Size of South Swale 2 based on a flow rate of:	12.82	cfs from Node SS2 from Reference 1.
Confirm Size of South Swale 3 based on a flow rate of:	13.51	cfs from Node SS3 from Reference 1.
Confirm Size of South Swale 4 based on a flow rate of:	13.56	cfs from Node SS4 from Reference 1.
Size regraded South Swale 5 based on a flow rate of:	14.75	cfs from Node SS5 from Reference 1.
Size regraded South Swale 6 based on a flow rate of:	17.37	cfs from Node SS6 from Reference 1.
Average South Swale flow rate:	17.37	cfs from Node SS6 from Reference 1.
Confirm Size of North Swale 1 based on a flow rate of:	20.02	cfs from Node NS1 from Reference 1.
Confirm Size of North Swale 2 based on a flow rate of:	24.00	cfs from Node NS2 from Reference 1.
Confirm Size of North Swale 3 based on a flow rate of:	26.58	cfs from Node NS3 from Reference 1.
Average North Swale flow rate:	26.58	cfs from Node NS3 from Reference 1.

Fully Developed Site Closure:

Confirm Size of North Swale 1 based on a flow rate of:	22.44	cfs from Node NS1 from Reference 2.
Confirm Size of North Swale 2 based on a flow rate of:	30.57	cfs from Node NS2 from Reference 2.
Confirm Size of North Swale 3 based on a flow rate of:	32.49	cfs from Node NS3 from Reference 2.
Confirm Size of South Swale 1 based on a flow rate of:	9.79	cfs from Node SS1 from Reference 2.
Confirm Size of South Swale 2 based on a flow rate of:	15.95	cfs from Node SS2 from Reference 2.
Confirm Size of South Swale 3 based on a flow rate of:	32.10	cfs from Node SS3 from Reference 2.

Use the WisDOT Grass Swale Design Spreadsheet (Sheet 2) to determine the flow depth, velocity and shear stress in the swale.

Contact Water Swale Liner Conversion

Channel/Ditch Geometry	***Swale 1***	***Swale 2***	***Swale 3***	***Swale 4***	***SS1***	***SS2***	***SS3***	***SS4***	***SS5***	***SS6***	***South Swale (average)***	***NS1***	***NS2***	***NS3***	***North Swale (averag***
Channel Slope, S_o (ft/ft)	**0.0118**	**0.0125**	**0.0146**	**0.0032**	**0.014**	**0.0146**	**0.0093**	**0.0605**	**0.003**	**0.003**	**0.014**	**0.0209**	**0.0115**	**0.0193**	**0.01852996**
Channel Bottom Width, B (ft)	**5**	**5**	**5**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Channel Side Slope, z_1	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Channel Side Slope, z_2	**10**	**10**	**3**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Flow Depth (ft)	**0.61**	**0.53**	**0.74**	**0.38**	**0.56**	**0.62**	**0.77**	**0.35**	**1.28**	**1.38**	**0.72**	**0.65**	**0.92**	**0.78**	**0.79**
Safety Factor	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Vegetation/Soil Parameters															
Vegetation Retardance Class	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**
Vegetation Condition	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**
Vegetation Growth Form	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**
Soil Type	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**
D_{75} (in) (Set at 0.00 for cohesive soils)															
ASTM Soil Class	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**
Plasticity Index, PI	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**
Results Summary															
Design Q (ft^3/s)	**6.1**	**4.7**	**9.8**	**1.2**	**9.8**	**12.8**	**13.5**	**13.6**	**14.8**	**17.4**	**17.4**	**20.0**	**24.0**	**26.6**	**26.6**
Calculated Q (ft^3/s)	6.1	4.7	9.7	1.2	9.8	12.9	13.5	13.5	14.6	17.3	17.5	19.7	23.8	26.6	26.7
Difference Between Design & Calc. Flow (%)	1.1%	-1.0%	-1.2%	-1.5%	0.5%	0.7%	0.1%	-0.5%	-1.3%	-0.5%	0.9%	-1.7%	-0.7%	0.0%	0.3%
Stable (Yes or No)	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Channel Parameters															
Vegetation Height, h (ft)	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Grass Roughness Coefficient, C_n	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238
Cover Factor, C_f	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Noncohesive Soil															
Soil Grain Roughness, n_s	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Permissible Soil Shear Stress, τ_p (lb/ft^2)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cohesive Soil															
Porosity, e	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Soil Coefficient 1, c_1	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700
Soil Coefficient 2, c_2	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30
Soil Coefficient 3, c_3	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700
Soil Coefficient 4, c_4	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Soil Coefficient 5, c_5	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
Soil Coefficient 6, c_6	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Permissible Soil Shear Stress, τ_p (lb/ft^2)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Total Permissible Shear Stress, τ_p (lb/ft^2)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Cross Sectional Area, A (ft^2)	5.469	4.476	5.343	4.378	6.628	7.545	9.775	3.867	18.534	20.465	9.014	7.979	12.162	9.929	10.084
Wetted Perimeter, P (ft)	13.06	12.00	9.68	13.13	14.04	14.52	15.61	12.51	19.33	20.05	15.25	14.74	16.70	15.68	15.76
Hydraulic Radius, R (ft)	0.419	0.373	0.552	0.333	0.472	0.520	0.626	0.309	0.959	1.021	0.591	0.541	0.728	0.633	0.640
Top Width, T (ft)	12.93	11.89	9.44	13.04	13.89	14.34	15.39	12.42	18.96	19.66	15.04	14.55	16.44	15.46	15.53
Hydraulic Depth, D (ft)	0.423	0.376	0.566	0.336	0.477	0.526	0.635	0.311	0.978	1.041	0.599	0.548	0.740	0.642	0.649
Froude Number (Q design)	0.303	0.299	0.424	0.082	0.379	0.416	0.306	1.102	0.140	0.146	0.442	0.587	0.401	0.589	0.578
Channel Shear Stress τ_o (lb/ft^2)	0.31	0.29	0.50	0.07	0.41	0.47	0.36	1.17	0.18	0.19	0.53	0.71	0.52	0.76	0.74
Actual Sheer Stress τ_d (lb/ft^2)	0.45	0.41	0.67	0.08	0.48	0.56	0.45	1.30	0.24	0.26	0.65	0.85	0.66	0.94	0.91
Mannings n	0.081	0.083	0.067	0.150	0.072	0.068	0.076	0.048	0.101	0.098	0.065	0.058	0.066	0.057	0.057
Average Velocity, V (ft/s)	1.11	1.05	1.83	0.27	1.48	1.70	1.38	3.51	0.80	0.85	1.93	2.51	1.97	2.68	2.64
Calculated Flow, Q (ft^3/s)	6.1	4.7	9.7	1.2	9.8	12.9	13.5	13.5	14.6	17.3	17.5	19.7	23.8	26.6	26.7
Difference Between Design & Calc. Flow (%)	1.1%	-1.0%	-1.2%	-1.5%	0.5%	0.7%	0.1%	-0.5%	-1.3%	-0.5%	0.9%	-1.7%	-0.7%	0.0%	0.3%
Effective Shear on Soil Surface, τ_e (lb/ft^2)	0.002	0.002	0.004	0.000	0.002	0.003	0.002	0.014	0.001	0.001	0.004	0.006	0.004	0.007	0.007
Total Permissible Shear on Veg., $\tau_{p\,veg}$ (lb/ft^2)	20.53	21.56	14.05	70.42	16.22	14.47	18.08	7.21	31.93	30.06	13.22	10.53	13.63	10.17	10.17
Stable (Y or N)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Source: Grass Lined Channel Design WisDOT Spreadsheet, FDM 13-30 Attachment 15.2

Fully Developed Site Closure

Channel/Ditch Geometry	***SS1***	***SS2***	***SS3***	***NS1***	***NS2***	***NS3***
Channel Slope, S_o (ft/ft)	**0.014**	**0.013**	**0.0147**	**0.0209**	**0.0115**	**0.0193**
Channel Bottom Width, B (ft)	**10**	**10**	**10**	**10**	**10**	**10**
Channel Side Slope, z_1	**4**	**4**	**4**	**4**	**4**	**4**
Channel Side Slope, z_2	**3**	**3**	**3**	**3**	**3**	**3**
Flow Depth (ft)	**0.56**	**0.72**	**0.95**	**0.69**	**1.03**	**0.85**
Safety Factor	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Vegetation/Soil Parameters						
Vegetation Retardance Class	**C**	**C**	**C**	**C**	**C**	**C**
Vegetation Condition	**good**	**good**	**good**	**good**	**good**	**good**
Vegetation Growth Form	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**
Soil Type	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**
D_{75} (in) (Set at 0.00 for cohesive soils)						
ASTM Soil Class	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**
Plasticity Index, PI	**16**	**16**	**16**	**16**	**16**	**16**
Results Summary						
Design Q (ft^3/s)	**9.8**	**16.0**	**32.1**	**22.4**	**30.6**	**32.5**
Calculated Q (ft^3/s)	9.8	15.9	31.9	22.3	30.6	32.1
Difference Between Design & Calc. Flow (%)	0.5%	-0.5%	-0.5%	-0.8%	0.2%	-1.1%
Stable (Yes or No)	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Channel Parameters						
Vegetation Height, h (ft)	0.67	0.67	0.67	0.67	0.67	0.67
Grass Roughness Coefficient, C_n	0.238	0.238	0.238	0.238	0.238	0.238
Cover Factor, C_f	0.90	0.90	0.90	0.90	0.90	0.90
Noncohesive Soil						
Soil Grain Roughness, n_s	0.016	0.016	0.016	0.016	0.016	0.016
Permissible Soil Shear Stress, τ_p (lb/ft^2)	N/A	N/A	N/A	N/A	N/A	N/A
Cohesive Soil						
Porosity, e	0.35	0.35	0.35	0.35	0.35	0.35
Soil Coefficient 1, c_1	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700
Soil Coefficient 2, c_2	14.30	14.30	14.30	14.30	14.30	14.30
Soil Coefficient 3, c_3	47.700	47.700	47.700	47.700	47.700	47.700
Soil Coefficient 4, c_4	1.42	1.42	1.42	1.42	1.42	1.42
Soil Coefficient 5, c_5	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
Soil Coefficient 6, c_6	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Permissible Soil Shear Stress, τ_p (lb/ft^2)	0.080	0.080	0.080	0.080	0.080	0.080
Total Permissible Shear Stress, τ_p (lb/ft^2)	0.080	0.080	0.080	0.080	0.080	0.080
Cross Sectional Area, A (ft^2)	6.628	9.014	12.659	8.566	14.013	11.029
Wetted Perimeter, P (ft)	14.04	15.25	16.92	15.03	17.50	16.19
Hydraulic Radius, R (ft)	0.472	0.591	0.748	0.570	0.801	0.681
Top Width, T (ft)	13.89	15.04	16.65	14.83	17.21	15.95
Hydraulic Depth, D (ft)	0.477	0.599	0.760	0.578	0.814	0.691
Froude Number (Q design)	0.379	0.401	0.510	0.602	0.427	0.617
Channel Shear Stress, τ_o (lb/ft^2)	0.41	0.48	0.69	0.74	0.57	0.82
Actual Sheer Stress, τ_d (lb/ft^2)	0.48	0.58	0.87	0.90	0.74	1.02
Mannings n	0.072	0.068	0.059	0.057	0.063	0.055
Average Velocity, V (ft/s)	1.48	1.77	2.54	2.62	2.18	2.95
Calculated Flow, Q (ft^3/s)	9.8	15.9	31.9	22.3	30.6	32.1
Difference Between Design & Calc. Flow (%)	0.5%	-0.5%	-0.5%	-0.8%	0.2%	-1.1%
Effective Shear on Soil Surface, τ_e (lb/ft^2)	0.002	0.003	0.006	0.007	0.005	0.009
Total Permissible Shear on Veg., $\tau_{p,veg}$ (lb/ft^2)	16.22	14.47	10.89	10.17	12.42	9.47
Stable (Y or N)	YES	YES	YES	YES	YES	YES

Source: Grass Lined Channel Design WisDOT Spreadsheet, FDM 13-30 Attachment 15.2

To differentiate applications WisDOT organizes erosion mats into three classes of mats, which are further broken down into various Types.

A. **Class I**: A short-term duration (minimum of 6 months), light duty, organic ECRM with plastic or biodegradable netting.

1. **Type A** – Only suitable for slope applications, not channel applications.
2. **Type B** – Double netted product for use in channels where the calculated (design) shear stress is 1.5 lbs/ft^2 or less.

B. **Class II**: A long-term duration (three years or greater), organic ECRM.

1. **Type A** – Jute fiber only for use in channels to reinforce sod.
2. **Type B** – For use in channels where the calculated (design) shear stress is 2.0 lbs/ft^2 or less. Made with plastic or biodegradable mat.
3. **Type C** – A woven mat of 100% organic material for use in channels where the calculated (design) shear stress is 2.0 lbs/ft^2 or less. Applicable

for use in environmentally sensitive areas where plastic netting is inappropriate.

C. **Class III**: A permanent 100% synthetic ECRM or TRM. Class I, Type B erosion mat or Class II, Type B or C erosion mat must be placed over a soil filled TRM.

1. **Type A** – An ECRM for use in channels where the calculated (design) shear stress of 2.0 lbs/ft^2 or less.
2. **Type B** – A TRM for use in channels where the calculated (design) shear stress of 2.0 lbs/ft^2 or less.
3. **Type C** – A TRM for use in channels where the calculated (design) shear stress of 3.5 lbs/ft^2 or less.
4. **Type D** – A TRM for use in channels where the calculated (design) shear stress of 5.0 lbs/ft^2 or less.

Rock Chute Sizing

Purpose:

To size the rock chute to accommodate the 25-year, 24-hour storm event.

References:

1. WisDOT Facilities Development Manual Chapter 13, Section 30-30 - Rock Riprap Lined Chutes.
2. HydroCAD Report_I-43_Fully Developed Site Closure.pdf

Approach:

Use HydroCAD to determine the 25-year, 24-hour peak flow rate for the perimeter swale. Use WisDOT Rock Chute Data Spreadsheet, FDM 13-30-30 Attachment 30.1 (from Reference #1) to design the rock chute. The WisDOT spreadsheet was developed using a design procedure developed by NRCS and modified by WisDOT to account for WisDOT specific riprap sizes and design requirements.

Confirm the swale is stable and has enough capacity for the design flow rate.

Assumptions:

1. Assume the channel is a diversion berm that is 0 ft wide with sideslopes of 2H:1V and 4H:1V.
2. Assume 1.0 % slope along the flowpath of the chute.
3. Assume 4H:1V slope for calculation.

Calculations:

Chute flow rates:

Size the chute based on a flow rate of 1.41 cfs.

Use the WisDOT Rock Chute Data Spreadsheet (Sheet 2) to determine the flow depth, riprap size and apron dimensions.

Results:

A rock chute designed as summarized on Sheet 3 and the project plan set will accommodate the runoff from a 25-year, 24-hour storm event in a stable manner. Use light riprap per table below.

Table 25.1 Typical Particle Sizes of Native Sands at 75 Percent Passing (D_{75})

Riprap Type	D50 (inches)	D50 (feet)	Riprap Thickness (in)	Geotextile Type
Select Crushed Material	2.2	0.18	5	Type R
Light Riprap	10	0.83	12	Type R
Medium Riprap	12.5	1.04	18	Type HR
Heavy Riprap	16	1.33	24	Type HR
Extra-Heavy Riprap	20	1.67	30	Type HR

Rock Chute Design Data

(Version WI-April-2005, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)
Revised for WisDOT 9/2010

Project:	I-43 Plan Mod Add.	**County:**	Sheboygan
Designer:	RJG	**Checked by:**	SJL
Date:	April 4, 2024	**Date:**	04/05/24

Input Geometry:

Upstream Channel		Chute			Downstream Channel	
Bottom Width =	0.0 ft.	Bottom Width =	4.0 ft.		Bottom Width =	4.0 ft.
Side slopes =	4.0 (m:1)	Factor of safety =	1.20 (SF)	1.2 Min	Side slopes =	4.0 (m:1)
Mannings n value =	0.030	Side slopes =	3.0 (z:1)	2.0:1 max.	Mannings n value =	0.030
Bed slope =	0.0100 ft./ft.	Bed slope =	0.2500 ft./ft	3.0:1 max.	Bed slope =	0.0050 ft./ft.
Note: Use procedures 13-30-15 or 13-30-25 for upstream and downstream Mannings n		Freeboard =	1.0 ft.			
		Outlet apron depth, d =	1.0 ft.		Base flow =	0.0 cfs

Flow and Elevation Data:

Apron elev. --- Inlet = 698.0 ft. ------- Outlet 690.0 ft. --- (H_{drop} = 7 ft.)

Degree of angularity = 1
1 --> 50% angular, 50% rounded
2 --> 100 % rounded

Q_{high} = Runoff from design storm
Q_5 = Runoff from a 5-year,24-hour storm

Q_{high} = 1.4 cfs — High flow storm through chute → Tw (ft.) = **Program**
Q_{low} = 1.4 cfs — Low flow storm through chute → Tw (ft.) = **Program**

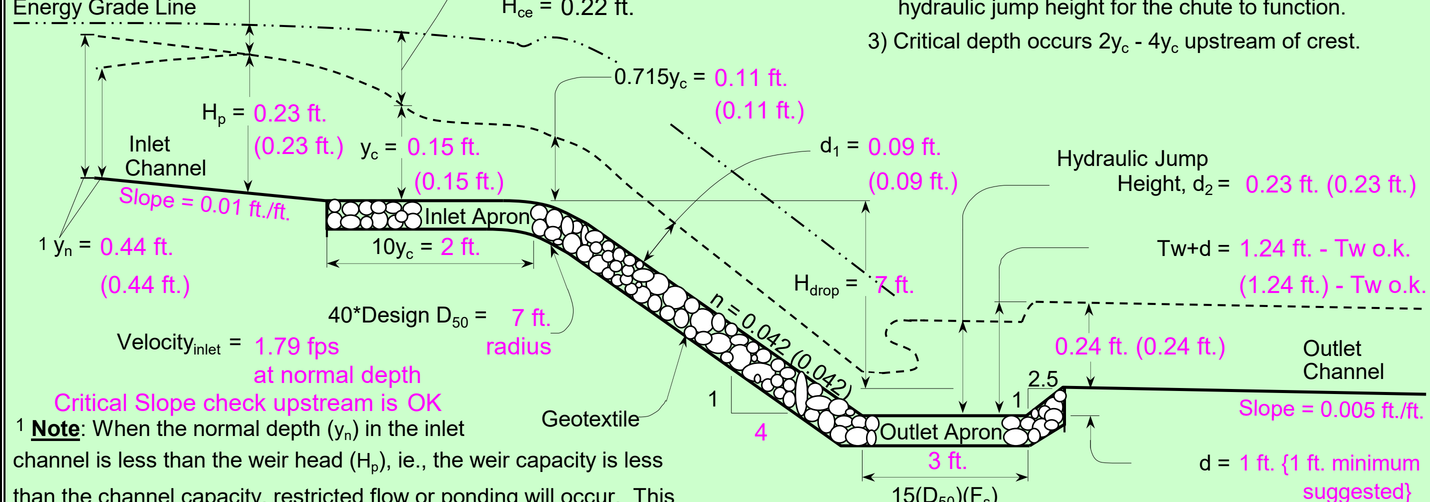
Note: The total required capacity is routed through the chute (principal spillway) or in combination with an auxiliary spillway.

Input tailwater (Tw):

Profile and Cross Section (Output):

Starting Station = 3+00.0

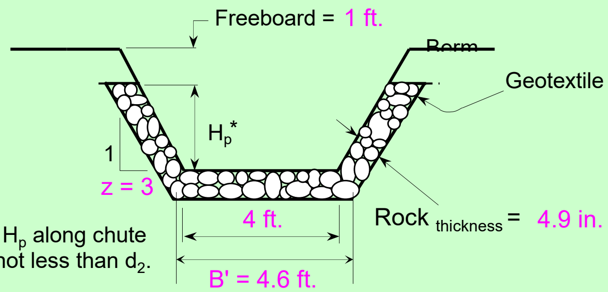
Notes:
1) Output given as **High Flow (Low Flow)** values.
2) Tailwater depth plus d must be at or above the hydraulic jump height for the chute to function.
3) Critical depth occurs $2y_c$ - $4y_c$ upstream of crest.



[1] **Note**: When the normal depth (y_n) in the inlet channel is less than the weir head (H_p), ie., the weir capacity is less than the channel capacity, restricted flow or ponding will occur. This reduces velocity and prevents erosion upstream of the inlet apron.

Profile Along Centerline of Chute

Typical Cross Section



* Use H_p along chute but not less than d_2.

	0.33 cfs/ft.	Equivalent unit discharge
SF =	1.20	Factor of safety (multiplier)
d_1 =	0.09 ft.	Normal depth in chute
n-value =	0.042	Manning's roughness coefficient
$D_{50}(SF)$ =	2.4 in.	Minimum Design D_{50}*
$2(D_{50})(SF)$ =	4.9 in.	Rock chute thickness
Tw + d =	1.24 ft.	Tailwater above outlet apron
d_2 =	0.23 ft.	Hydraulic jump height
***** The outlet**	**will**	**function adequately**

High Flow Storm Information

Existing Culverts

		Sheet No:	1 of 16
		Calc. No.	
		Rev. No.	
Job No. 25222259.00	Job: I-43 Plan Mod Addendum	By: RJG	Date: 5/22/24
Client: WPL	Subject: Culvert Sizing	Chk'd: SJL	Date: 5/23/24

Purpose:

To size the post closure culverts to accommodate the 25-year, 24-hour storm event.

References:

1. HY-8 7.40 Computer Model
2. HydroCAD Report_I-43_CWS Liner Conversion.pdf and HydroCAD Report_I-43_Fully Developed Site Closure.pdf
3. Sheet 1 - Storm Water - Contact Water Swale Liner Conversion
4. Sheet 2 - Storm Water - Fully Developed Site Closure

Approach:

1. Create culvert crossing in HY-8 and input data from Reference #2, #3, and #4.
2. Adjust diameter size and number of culverts in model until design flow does not over top berm/road crossing.

Assumptions:

1. Assume the tailwater channel data is a based on discharge swale or rock chute geometry (Reference #2).
2. Culverts are circular, PE Pipe with smooth interior, and with square edge with headwall.
3. Culvert elevations, lengths, and slopes based on Sheet 1 (Reference #3) and Sheet 2 (Reference #4).
4. Roadway data for crossing based on Sheet 1 (Reference #3) and Sheet 2 (Reference #4).
5. Discharge flows from HydroCAD report (Refence #2).

Calculations:

See attached HY-8 Model output reports for C1 through C5.

Results:

The existing culverts are adequately designed to accommodate the flows from the 25-year, 24-hour storm event for the Contact Water Swale Liner Conversion and Fully Developed Site Closure conditions.

HY-8 Culvert Analysis Report – Fully Developed Site

Culvert Data: Culvert C1 a & b

Site Data - Culvert C1 a & b
Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 687.47 ft
Outlet Station: 341.60 ft
Outlet Elevation: 683.25 ft
Number of Barrels: 2
Culvert Data Summary - Culvert C1 a & b
Barrel Shape: Circular
Barrel Diameter: 2.00 ft
Barrel Material: Smooth HDPE
Embedment: 0.00 in
Barrel Manning's n: 0.0120
Culvert Type: Straight
Inlet Configuration: Square Edge with Headwall (Ke=0.5)
Inlet Depression: None
Culvert Barrel Data
Culvert Barrel Type Straight Culvert
Inlet Elevation (invert): 687.47 ft,
Outlet Elevation (invert): 683.25 ft
Culvert Length: 341.63 ft,
Culvert Slope: 0.0124
Tailwater Channel Data - Fully Developed Site Closure
Tailwater Channel Option: Trapezoidal Channel
Bottom Width: 10.00 ft
Side Slope (H:V): 3.50 (_:1)
Channel Slope: 0.0130
Channel Manning's n: 0.0270
Roadway Data for Crossing: CWS Liner Conversion
Roadway Profile Shape: Constant Roadway Elevation
Crest Length: 100.00 ft
Crest Elevation: 691.00 ft
Roadway Surface: Gravel
Roadway Top Width: 50.00 ft
Crossing Discharge Data
Discharge Selection Method: Specify Minimum, Design, and Maximum Flow
Minimum Flow: 31.65 cfs
Design Flow: 31.65 cfs
Maximum Flow: 51.15 cfs

Table 1 - Summary of Culvert Flows at Crossing: Fully Developed Site Closure

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert C1 a & b Discharge (cfs)	Roadway Discharge (cfs)	Iterations
689.82	31.65	31.65	0.00	1 25-yr Storm
689.94	33.60	33.60	0.00	1
690.07	35.55	35.55	0.00	1
690.21	37.50	37.50	0.00	1
690.36	39.45	39.45	0.00	1
690.51	41.40	41.40	0.00	1
690.68	43.35	43.35	0.00	1
690.85	45.30	45.30	0.00	1
691.01	47.25	47.03	0.13	30
691.04	49.20	47.35	1.77	7
691.06	51.15	47.57	3.54	6
691.00	46.96	46.96	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert C1 a & b

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
31.65 cfs	31.65 cfs	689.82	2.35	0.0*	5-S2n	1.09	1.43	1.09	0.63	9.01	4.10
33.60 cfs	33.60 cfs	689.94	2.47	0.0*	5-S2n	1.13	1.48	1.13	0.65	9.14	4.18
35.55 cfs	35.55 cfs	690.07	2.60	0.072	5-S2n	1.18	1.52	1.18	0.67	9.25	4.26
37.50 cfs	37.50 cfs	690.21	2.74	0.377	5-S2n	1.22	1.56	1.22	0.70	9.36	4.34
39.45 cfs	39.45 cfs	690.36	2.89	0.697	5-S2n	1.26	1.60	1.26	0.72	9.46	4.41
41.40 cfs	41.40 cfs	690.51	3.04	1.030	5-S2n	1.30	1.63	1.30	0.74	9.56	4.48
43.35 cfs	43.35 cfs	690.68	3.21	1.378	5-S2n	1.35	1.66	1.35	0.75	9.64	4.54
45.30 cfs	45.30 cfs	690.85	3.38	1.740	5-S2n	1.39	1.70	1.39	0.77	9.71	4.61
47.25 cfs	47.03 cfs	691.01	3.54	2.072	5-S2n	1.43	1.72	1.43	0.79	9.77	4.67
49.20 cfs	47.35 cfs	691.04	3.57	2.136	5-S2n	1.44	1.73	1.44	0.81	9.78	4.73
51.15 cfs	47.57 cfs	691.06	3.59	2.180	5-S2n	1.44	1.73	1.45	0.83	9.77	4.79

* Full Flow Headwater elevation is below inlet invert.

Culvert Data: Culvert C5

Site Data - Culvert C5

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 704.38 ft
Outlet Station: 38.05 ft
Outlet Elevation: 704.25 ft
Number of Barrels: 1

Culvert Data Summary - Culvert C5

Barrel Shape: Circular
Barrel Diameter: 1.50 ft
Barrel Material: Smooth HDPE
Embedment: 0.00 in
Barrel Manning's n: 0.0120
Culvert Type: Straight
Inlet Configuration: Thin Edge Projecting
Inlet Depression: None

Culvert Barrel Data

Culvert Barrel Type Straight Culvert
Inlet Elevation (invert): 704.38 ft,
  Outlet Elevation (invert): 704.25 ft
Culvert Length: 38.06 ft,
  Culvert Slope: 0.0035

Tailwater Channel Data - Fully Developed Site Closure

Tailwater Channel Option: Trapezoidal Channel
Bottom Width: 10.00 ft
Side Slope (H:V): 3.50 (_:1)
Channel Slope: 0.0128
Channel Manning's n: 0.0300
Channel Invert Elevation: 704.25 ft

Roadway Data for Crossing: Fully Developed Site Closure

Roadway Profile Shape: Constant Roadway Elevation
Crest Length: 25.00 ft
Crest Elevation: 708.00 ft
Roadway Surface: Gravel
Roadway Top Width: 25.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow
Minimum Flow: 9.07 cfs
Design Flow: 9.07 cfs
Maximum Flow: 14.25 cfs

Table 1 - Summary of Culvert Flows at Crossing: Fully Developed Site Closure

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert C5 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
706.76	9.07	9.07	0.00	1
706.92	9.59	9.59	0.00	1
707.09	10.11	10.11	0.00	1
707.27	10.62	10.62	0.00	1
707.46	11.14	11.14	0.00	1
707.67	11.66	11.66	0.00	1
707.88	12.18	12.18	0.00	1
708.02	12.70	12.49	0.18	19
708.05	13.21	12.55	0.65	7
708.07	13.73	12.60	1.13	6
708.09	14.25	12.64	1.60	5
708.00	12.44	12.44	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert C5

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
9.07 cfs	9.07 cfs	706.76	2.38	2.227	7-M2c	1.50	1.16	1.16	0.33	6.16	2.48
9.59 cfs	9.59 cfs	706.92	2.54	2.345	7-M2c	1.50	1.20	1.20	0.34	6.35	2.53
10.11 cfs	10.11 cfs	707.09	2.71	2.484	7-M2c	1.50	1.22	1.22	0.35	6.54	2.58
10.62 cfs	10.62 cfs	707.27	2.89	2.642	7-M2c	1.50	1.25	1.25	0.36	6.74	2.63
11.14 cfs	11.14 cfs	707.46	3.08	2.793	7-M2c	1.50	1.28	1.28	0.37	6.95	2.67
11.66 cfs	11.66 cfs	707.67	3.29	2.959	7-M2c	1.50	1.30	1.30	0.38	7.17	2.71
12.18 cfs	12.18 cfs	707.88	3.50	3.124	7-M2c	1.50	1.32	1.32	0.39	7.39	2.75
12.70 cfs	12.49 cfs	708.02	3.64	3.226	7-M2c	1.50	1.33	1.33	0.40	7.53	2.79
13.21 cfs	12.55 cfs	708.05	3.67	3.242	7-M2c	1.50	1.34	1.34	0.41	7.55	2.83
13.73 cfs	12.60 cfs	708.07	3.69	3.257	7-M2c	1.50	1.34	1.34	0.42	7.57	2.87
14.25 cfs	12.64 cfs	708.09	3.71	3.270	7-M2c	1.50	1.34	1.34	0.43	7.59	2.91

Culverts – Contact Water Swale Liner Conversion

Culvert Data: Culvert C1 a & b CWS Liner Conversion

Site Data - Culvert C1 a & b

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 687.47 ft
Outlet Station: 341.60 ft
Outlet Elevation: 683.25 ft
Number of Barrels: 2

Culvert Data Summary - Culvert C1 a & b

Barrel Shape: Circular
Barrel Diameter: 2.00 ft
Barrel Material: Smooth HDPE
Embedment: 0.00 in
Barrel Manning's n: 0.0120
Culvert Type: Straight
Inlet Configuration: Square Edge with Headwall (Ke=0.5)
Inlet Depression: None

Tailwater Channel Data - Fully Developed Site Closure

Tailwater Channel Option: Trapezoidal Channel
Bottom Width: 10.00 ft
Side Slope (H:V): 3.50 (_:1)
Channel Slope: 0.0130
Channel Manning's n: 0.0270

Roadway Data for Crossing: CWS Liner Conversion

Roadway Profile Shape: Constant Roadway Elevation
Crest Length: 100.00 ft
Crest Elevation: 691.00 ft
Roadway Surface: Gravel
Roadway Top Width: 50.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow
Minimum Flow: 16.57 cfs
Design Flow: 16.57 cfs
Maximum Flow: 27.70 cfs

Table 1 - Summary of Culvert Flows at Crossing: CWS Liner Conversion

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert C1 a & b Discharge (cfs)	Roadway Discharge (cfs)	Iterations
688.98	16.57	16.57	0.00	1
689.04	17.68	17.68	0.00	1
689.10	18.80	18.80	0.00	1
689.16	19.91	19.91	0.00	1
689.22	21.02	21.02	0.00	1
689.28	22.13	22.13	0.00	1
689.34	23.25	23.25	0.00	1
689.40	24.36	24.36	0.00	1
689.46	25.47	25.47	0.00	1
689.52	26.59	26.59	0.00	1
689.58	27.70	27.70	0.00	1
691.00	46.97	46.97	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert C1 a & b

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
16.57 cfs	16.57 cfs	688.98	1.51	0.0*	1-S2n	0.76	1.03	0.76	0.44	7.62	3.30
17.68 cfs	17.68 cfs	689.04	1.57	0.0*	1-S2n	0.78	1.06	0.78	0.45	7.76	3.37
18.80 cfs	18.80 cfs	689.10	1.63	0.0*	1-S2n	0.81	1.10	0.81	0.47	7.89	3.45
19.91 cfs	19.91 cfs	689.16	1.69	0.0*	1-S2n	0.84	1.13	0.84	0.48	8.01	3.51
21.02 cfs	21.02 cfs	689.22	1.75	0.0*	1-S2n	0.86	1.16	0.86	0.50	8.12	3.58
22.13 cfs	22.13 cfs	689.28	1.81	0.0*	1-S2n	0.89	1.19	0.89	0.51	8.23	3.64
23.25 cfs	23.25 cfs	689.34	1.87	0.0*	1-S2n	0.91	1.22	0.91	0.53	8.34	3.70
24.36 cfs	24.36 cfs	689.40	1.93	0.0*	1-S2n	0.94	1.25	0.94	0.54	8.44	3.76
25.47 cfs	25.47 cfs	689.46	1.99	0.0*	1-S2n	0.96	1.28	0.96	0.56	8.54	3.82
26.59 cfs	26.59 cfs	689.52	2.05	0.0*	5-S2n	0.98	1.31	0.98	0.57	8.63	3.87
27.70 cfs	27.70 cfs	689.58	2.11	0.0*	5-S2n	1.01	1.34	1.01	0.59	8.72	3.93

* Full Flow Headwater elevation is below inlet invert.

Culvert Data: Culvert C2

Site Data - Culvert C2

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 688.68 ft
Outlet Station: 46.00 ft
Outlet Elevation: 688.54 ft
Number of Barrels: 1

Culvert Data Summary - Culvert C2

Barrel Shape: Circular
Barrel Diameter: 2.00 ft
Barrel Material: Smooth HDPE
Embedment: 0.00 in
Barrel Manning's n: 0.0120
Culvert Type: Straight
Inlet Configuration: Thin Edge Projecting
Inlet Depression: None

Culvert Barrel Data

Culvert Barrel Type Straight Culvert
Inlet Elevation (invert): 688.68 ft,
Outlet Elevation (invert): 688.54 ft
Culvert Length: 46.00 ft,
Culvert Slope: 0.0030

Tailwater Channel Data - CWS Liner Conversion

Tailwater Channel Option: Trapezoidal Channel
Bottom Width: 10.00 ft
Side Slope (H:V): 3.50 (_:1)
Channel Slope: 0.0030
Channel Manning's n: 0.0300
Channel Invert Elevation: 688.54 ft

Roadway Data for Crossing: CWS Liner Conversion

Roadway Profile Shape: Constant Roadway Elevation
Crest Length: 27.00 ft
Crest Elevation: 694.00 ft
Roadway Surface: Gravel
Roadway Top Width: 25.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow
Minimum Flow: 15.73 cfs
Design Flow: 15.73 cfs
Maximum Flow: 24.86 cfs

Table 1 - Summary of Culvert Flows at Crossing: CWS Liner Conversion

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert C2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
691.33	15.73	15.73	0.00	1
691.48	16.64	16.64	0.00	1
691.65	17.56	17.56	0.00	1
691.82	18.47	18.47	0.00	1
692.00	19.38	19.38	0.00	1
692.19	20.30	20.30	0.00	1
692.39	21.21	21.21	0.00	1
692.61	22.12	22.12	0.00	1
692.83	23.03	23.03	0.00	1
693.07	23.95	23.95	0.00	1
693.31	24.86	24.86	0.00	1
694.00	27.20	27.20	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert C2

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
15.73 cfs	15.73 cfs	691.33	2.65	2.600	7-M2c	2.00	1.43	1.43	0.68	6.55	1.86
16.64 cfs	16.64 cfs	691.48	2.80	2.710	7-M2c	2.00	1.47	1.47	0.71	6.72	1.89
17.56 cfs	17.56 cfs	691.65	2.97	2.824	7-M2c	2.00	1.51	1.51	0.73	6.90	1.92
18.47 cfs	18.47 cfs	691.82	3.14	2.944	7-M2c	2.00	1.55	1.55	0.75	7.08	1.95
19.38 cfs	19.38 cfs	692.00	3.32	3.071	7-M2c	2.00	1.58	1.58	0.77	7.27	1.99
20.30 cfs	20.30 cfs	692.19	3.51	3.208	7-M2c	2.00	1.62	1.62	0.79	7.46	2.01
21.21 cfs	21.21 cfs	692.39	3.71	3.375	7-M2c	2.00	1.65	1.65	0.81	7.66	2.04
22.12 cfs	22.12 cfs	692.61	3.93	3.536	7-M2c	2.00	1.68	1.68	0.83	7.86	2.07
23.03 cfs	23.03 cfs	692.83	4.15	3.717	7-M2c	2.00	1.71	1.71	0.85	8.06	2.10
23.95 cfs	23.95 cfs	693.07	4.39	3.893	7-M2c	2.00	1.73	1.73	0.87	8.28	2.12
24.86 cfs	24.86 cfs	693.31	4.63	4.075	7-M2c	2.00	1.76	1.76	0.88	8.50	2.15

Culvert Data: Culvert C3

Site Data - Culvert C3

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 691.71 ft
Outlet Station: 48.00 ft
Outlet Elevation: 691.01 ft
Number of Barrels: 1

Culvert Data Summary - Culvert C3

Barrel Shape: Circular
Barrel Diameter: 12.00 ft
Barrel Material: Smooth HDPE
Embedment: 0.00 in
Barrel Manning's n: 0.0120
Culvert Type: Straight
Inlet Configuration: Thin Edge Projecting
Inlet Depression: None

Culvert Barrel Data

Culvert Barrel Type Straight Culvert
Inlet Elevation (invert): 691.71 ft,
Outlet Elevation (invert): 691.01 ft
Culvert Length: 48.01 ft,
Culvert Slope: 0.0146

Tailwater Channel Data - CWS Liner Conversion

Tailwater Channel Option: Trapezoidal Channel
Bottom Width: 10.00 ft
Side Slope (H:V): 3.50 (_:1)
Channel Slope: 0.0030
Channel Manning's n: 0.0300
Channel Invert Elevation: 691.01 ft

Roadway Data for Crossing: CWS Liner Conversion

Roadway Profile Shape: Constant Roadway Elevation
Crest Length: 25.00 ft
Crest Elevation: 702.00 ft
Roadway Surface: Gravel
Roadway Top Width: 25.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow
Minimum Flow: 6.08 cfs
Design Flow: 6.08 cfs
Maximum Flow: 9.34 cfs

Table 1 - Summary of Culvert Flows at Crossing: CWS Liner Conversion

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert C3 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
692.47	6.08	6.08	0.00	1
692.49	6.41	6.41	0.00	1
692.51	6.73	6.73	0.00	1
692.53	7.06	7.06	0.00	1
692.55	7.38	7.38	0.00	1
692.57	7.71	7.71	0.00	1
692.60	8.04	8.04	0.00	1
692.61	8.36	8.36	0.00	1
692.63	8.69	8.69	0.00	1
692.64	9.01	9.01	0.00	1
692.66	9.34	9.34	0.00	1
702.00	809.83	809.83	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert C3

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
6.08 cfs	6.08 cfs	692.47	0.76	0.0*	1-S2n	0.35	0.54	0.38	0.40	5.51	1.35
6.41 cfs	6.41 cfs	692.49	0.78	0.0*	1-S2n	0.36	0.55	0.39	0.41	5.56	1.37
6.73 cfs	6.73 cfs	692.51	0.80	0.0*	1-S2n	0.37	0.56	0.40	0.42	5.63	1.40
7.06 cfs	7.06 cfs	692.53	0.82	0.0*	1-S2n	0.37	0.58	0.41	0.43	5.70	1.42
7.38 cfs	7.38 cfs	692.55	0.84	0.0*	1-S2n	0.38	0.59	0.42	0.44	5.78	1.44
7.71 cfs	7.71 cfs	692.57	0.86	0.0*	1-S2n	0.39	0.60	0.42	0.45	5.84	1.46
8.04 cfs	8.04 cfs	692.60	0.89	0.0*	1-S2n	0.40	0.62	0.43	0.47	5.92	1.48
8.36 cfs	8.36 cfs	692.61	0.90	0.0*	1-S2n	0.40	0.63	0.44	0.48	5.97	1.50
8.69 cfs	8.69 cfs	692.63	0.92	0.0*	1-S2n	0.41	0.64	0.45	0.49	6.06	1.52
9.01 cfs	9.01 cfs	692.64	0.93	0.0*	1-S2n	0.42	0.65	0.46	0.50	6.10	1.54
9.34 cfs	9.34 cfs	692.66	0.95	0.0*	1-S2n	0.43	0.66	0.47	0.51	6.18	1.56

* Full Flow Headwater elevation is below inlet invert.

Culvert Data: Culvert C4

Site Data - Culvert C4

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 699.46 ft
Outlet Station: 40.55 ft
Outlet Elevation: 698.97 ft
Number of Barrels: 1

Culvert Data Summary - Culvert C4

Barrel Shape: Circular
Barrel Diameter: 2.00 ft
Barrel Material: Smooth HDPE
Embedment: 0.00 in
Barrel Manning's n: 0.0120
Culvert Type: Straight
Inlet Configuration: Thin Edge Projecting
Inlet Depression: None

Culvert Barrel Data

Culvert Barrel Type Straight Culvert
Inlet Elevation (invert): 699.46 ft,
Outlet Elevation (invert): 698.97 ft
Culvert Length: 40.55 ft,
Culvert Slope: 0.0122

Tailwater Channel Data - CWS Liner Conversion

Tailwater Channel Option: Trapezoidal Channel
Bottom Width: 10.00 ft
Side Slope (H:V): 3.50 (_:1)
Channel Slope: 0.0128
Channel Manning's n: 0.0300
Channel Invert Elevation: 698.97 ft

Roadway Data for Crossing: CWS Liner Conversion

Roadway Profile Shape: Constant Roadway Elevation
Crest Length: 25.00 ft
Crest Elevation: 702.00 ft
Roadway Surface: Gravel
Roadway Top Width: 25.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow
Minimum Flow: 12.71 cfs
Design Flow: 12.71 cfs
Maximum Flow: 20.14 cfs

Table 1 - Summary of Culvert Flows at Crossing: CWS Liner Conversion

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert C4 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
701.64	12.71	12.71	0.00	1
701.75	13.45	13.45	0.00	1
701.86	14.20	14.20	0.00	1
701.97	14.94	14.94	0.00	1
702.03	15.68	15.31	0.36	10
702.06	16.43	15.48	0.92	6
702.08	17.17	15.63	1.53	6
702.10	17.91	15.75	2.14	5
702.12	18.65	15.87	2.78	5
702.14	19.40	15.97	3.42	5
702.16	20.14	16.07	4.05	4
702.00	15.11	15.11	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert C4

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
12.71 cfs	12.71 cfs	701.64	2.18	1.380	5-S2n	0.96	1.28	1.02	0.40	7.89	2.80
13.45 cfs	13.45 cfs	701.75	2.29	1.490	5-S2n	1.00	1.32	1.06	0.41	8.00	2.85
14.20 cfs	14.20 cfs	701.86	2.40	1.602	5-S2n	1.03	1.36	1.09	0.43	8.11	2.91
14.94 cfs	14.94 cfs	701.97	2.51	1.717	5-S2n	1.06	1.39	1.12	0.44	8.21	2.96
15.68 cfs	15.31 cfs	702.03	2.57	1.775	5-S2n	1.08	1.41	1.14	0.45	8.26	3.01
16.43 cfs	15.48 cfs	702.06	2.60	1.802	5-S2n	1.08	1.42	1.15	0.46	8.29	3.05
17.17 cfs	15.63 cfs	702.08	2.62	1.826	5-S2n	1.09	1.42	1.16	0.47	8.31	3.10
17.91 cfs	15.75 cfs	702.10	2.64	1.846	5-S2n	1.10	1.43	1.16	0.49	8.32	3.15
18.65 cfs	15.87 cfs	702.12	2.66	1.865	5-S2n	1.10	1.44	1.17	0.50	8.34	3.19
19.40 cfs	15.97 cfs	702.14	2.68	1.882	5-S2n	1.10	1.44	1.17	0.51	8.35	3.23
20.14 cfs	16.07 cfs	702.16	2.70	1.898	5-S2n	1.11	1.45	1.18	0.52	8.37	3.27

Culvert Data: Culvert C5

Site Data - Culvert C5

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 704.38 ft
Outlet Station: 38.05 ft
Outlet Elevation: 704.25 ft
Number of Barrels: 1

Culvert Data Summary - Culvert C5

Barrel Shape: Circular
Barrel Diameter: 1.50 ft
Barrel Material: Smooth HDPE
Embedment: 0.00 in
Barrel Manning's n: 0.0120
Culvert Type: Straight
Inlet Configuration: Thin Edge Projecting
Inlet Depression: None

Culvert Barrel Data

Culvert Barrel Type Straight Culvert
Inlet Elevation (invert): 704.38 ft,
Outlet Elevation (invert): 704.25 ft
Culvert Length: 38.06 ft,
Culvert Slope: 0.0035

Tailwater Channel Data - CWS Liner Conversion

Tailwater Channel Option: Trapezoidal Channel
Bottom Width: 10.00 ft
Side Slope (H:V): 3.50 (_:1)
Channel Slope: 0.0128
Channel Manning's n: 0.0300
Channel Invert Elevation: 704.25 ft

Roadway Data for Crossing: CWS Liner Conversion

Roadway Profile Shape: Constant Roadway Elevation
Crest Length: 25.00 ft
Crest Elevation: 708.00 ft
Roadway Surface: Gravel
Roadway Top Width: 25.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow
Minimum Flow: 9.07 cfs
Design Flow: 9.07 cfs
Maximum Flow: 14.25 cfs

Table 1 - Summary of Culvert Flows at Crossing: CWS Liner Conversion

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert C5 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
706.76	9.07	9.07	0.00	1
706.92	9.59	9.59	0.00	1
707.09	10.11	10.11	0.00	1
707.27	10.62	10.62	0.00	1
707.46	11.14	11.14	0.00	1
707.67	11.66	11.66	0.00	1
707.88	12.18	12.18	0.00	1
708.02	12.70	12.49	0.18	19
708.05	13.21	12.55	0.65	7
708.07	13.73	12.60	1.13	6
708.09	14.25	12.64	1.60	5
708.00	12.44	12.44	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert C5

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
9.07 cfs	9.07 cfs	706.76	2.38	2.227	7-M2c	1.50	1.16	1.16	0.33	6.16	2.48
9.59 cfs	9.59 cfs	706.92	2.54	2.345	7-M2c	1.50	1.20	1.20	0.34	6.35	2.53
10.11 cfs	10.11 cfs	707.09	2.71	2.484	7-M2c	1.50	1.22	1.22	0.35	6.54	2.58
10.62 cfs	10.62 cfs	707.27	2.89	2.642	7-M2c	1.50	1.25	1.25	0.36	6.74	2.63
11.14 cfs	11.14 cfs	707.46	3.08	2.793	7-M2c	1.50	1.28	1.28	0.37	6.95	2.67
11.66 cfs	11.66 cfs	707.67	3.29	2.959	7-M2c	1.50	1.30	1.30	0.38	7.17	2.71
12.18 cfs	12.18 cfs	707.88	3.50	3.124	7-M2c	1.50	1.32	1.32	0.39	7.39	2.75
12.70 cfs	12.49 cfs	708.02	3.64	3.226	7-M2c	1.50	1.33	1.33	0.40	7.53	2.79
13.21 cfs	12.55 cfs	708.05	3.67	3.242	7-M2c	1.50	1.34	1.34	0.41	7.55	2.83
13.73 cfs	12.60 cfs	708.07	3.69	3.257	7-M2c	1.50	1.34	1.34	0.42	7.57	2.87
14.25 cfs	12.64 cfs	708.09	3.71	3.270	7-M2c	1.50	1.34	1.34	0.43	7.59	2.91

Downslope Flume and Energy Dissipator Sizing

SCS ENGINEERS

		Sheet No:	1/3
		Calc. No.	
		Rev. No.	
Job No. 25222259.00	Job: I-43 - Plan Mod Addendum	By: RJG	Date: 04/5/24
Client: WPL	Subject: Downslope Pipe and Inlet Sizing	Chk'd: SJL	Date: 4/5/24

Purpose:

To size the downslope pipe and inlet to accommodate the 25-year, 24-hour storm event.

References:

1. HydroCAD Report_I-43_Fully Developed Site Closure.pdf

Approach:

Use the orifice equation to size the downslope pipe inlet. Size the inlet for the largest diversion berm flow rate and apply that inlet size to all downslope pipe inlets. Confirm the head (h) acting on the orifice will not overtop the diversion berm depth of 2.0 ft.

Use Manning's equation to size the downslope pipe based on the largest diversion berm flow rate. Confirm the pipe has capacity for the design flow under open channel flow conditions.

Assumptions:

1. Orifice coefficient = 0.63
2. Assume the orifice head (h) acts on the centerline of the inlet pipe.
3. Manning's n = 0.013 from HydroCAD report
4. Size flumes under the vegetated cover condition.
5. The peak flow rate at each flume is experienced in the Full Closure condition of the site.
6. Flume 1 and 4 were not evaluated because they were designed and constructed based on a larger drainage area with a higher flow rate. Therefore, it is concluded that the flume pipe size is appropriate.

Calculations:

Size the downslope pipe inlet:

From the HydroCAD report (Reference #1), the maximum 25-year, 24-hour flow along a diversion berm is 5.54 cfs from Area 10.

Orifice Equation: $Q = C * A * (2 * g * h)^{0.5}$

where: Q = flow rate (cfs) = 5.54 (From above)

C = orifice coefficient = 0.63 (See assumption #1)

A = orifice area (sf) = 1.77 (area of 18" diameter pipe) Actual Pipe Diameter = 18 inches

g = gravity (ft/sec^2)= 32.2

h = orifice head acting on centerline (ft)

$h = (Q/(C * A))^2/(2 * g) =$ 0.4 ft

Given Assumption #2, depth of flow along diversion berm = h + D/2/12 = 1.13 ft <2 ft

The diversion swale depth of 2 ft is sufficient to prevent overtopping at the downslope pipe inlet locations.

Results:

Based on the inlet sizing calculation, Flume 1, 3 and 6 will need 18" diameter inlets and based on flume pipe sizing the flume pipe diameter should be a minimum 18".

Calculations (Continued):

Size the downslope flume pipe:

Use Manning's equation to size the downslope pipe.

Manning's Equation: Q = (1.49/n) x A x R^(2/3) x S^(1/2)

where: Q = Flow Rate, cfs

n = Manning's Roughness Coefficient

A = Flow Area, sf

R = Hydraulic Radius, ft (= A/P)

S = Channel Slope, ft/ft

From the HydroCAD Report (Reference 1) , the peak discharge to each downslope flume resulting from a 25-year, 24-hour storm is as follows:

Flume 1	4.94 cfs	Flume 3	12.17 cfs	Flume 6	7.54 cfs
Area 1 =	1.9 cfs	Area 5 =	4.2 cfs	Area 10 =	5.5 cfs
Area 3 =	3.0 cfs	Area 9 =	4.1 cfs	Area 11 =	2.0 cfs
		Area 19 =	5.5 cfs		

For Flumes, assume an 18" diameter downslope flume for flows less than 20 cfs:

Use 12.17 cfs to Flume 3 to check sizing (max flow to site flumes)

Design Criteria

Pipe Diameter (in) = D = 18

Pipe Slope (ft/ft) = S = 0.25

Manning's Roughness Coefficient = n = 0.013

See Downslope Flume pipe flow calculator on Sheet 3

The 12" dia. flume can adequately accommodate flows for Flume 3.

Calculations (Continued):

Manning Formula Uniform Pipe Flow at Given Slope and Depth

Inputs:

Pipe Diameter, d_o	18.00	in
Manning Roughness, n	0.0130	
Pressure slope (possibly equal to pipe slope), S_0	0.2500	slope
Percent of (or ratio to) full depth (100% or 1 if flowing full)	0.3515	fraction

Results:

Flow, Q	13.9210	ft^3/s
Velocity, v	25.1088	ft/s
Velocity head, hv	9.7982	ft
Flow Area, A	0.5544	ft^2
Wetted Perimeter, P	1.9039	ft
Hydraulic Radius	0.2912	ft
Top Width, T	1.4323	ft
Froude Number, F	7.22	
Shear Stress (tractive force), τ	8.2282	psf

Version 2.0 (20 June 2017)

HawsEDC Calculators

SCS ENGINEERS

		Sheet No. 1 of 7	
		Calc. No.	
		Rev. No.	
Job No. 25222259.00	Job: I-43 - Plan Mod Addendum	By: RJG	Date: 04/5/24
Client: WPL	Subject: Energy Dissipator Sizing	Chk'd: SJL	Date: 4/5/24

Purpose:

To size an energy dissipator structure and riprap apron at the outlet of the downslope flume pipes.

References:

1. "Hydraulic Design of Energy Dissipators for Culverts and Channels," HEC-14, Third Edition, July 2006, USDOT FHWA.
2. Downslope Pipe and Inlet Sizing calculation (for pipe size, flow rate, and pipe velocity).
3. HydroCAD Report_I-43_Fully Developed Site Closure.pdf
4. Facilities Development Manual Chapter 13, Section 13-30 - Rock Riprap Lined Chutes.
5. WisDOT FDM Table 25.1

Approach:

Use the downslope pipe outlet velocity to size an energy dissipator structure (USBR Type VI Impact Basin) following the design approach outlined in Section 9.4 of Reference #1.

Use Rock Chute Data Spreadsheet, FDM 13-30-30 Attachment 30.1 (from Reference #4) to design the rock chute.

For construction purposes use the maximum flow to size all dissipators and riprap aprons.

Assumptions:

1. Riprap specific gravity = 2.65
2. From the HydroCAD Report, the 25-year, 24-hour peak discharge to each downslope flume is as follows:

Flume 1	4.94 cfs
Flume 3	12.17 cfs
Flume 6	7.54 cfs

** Please note that the total flow rate at each flume calculated above may not reflect the flow rate shown in the HydroCAD Model due to the inflow to the flume occurring at different times during the storm event. The calculation above reflects the peak flow rate.*

Size energy dissipators based on the final closure conditions to the 18" dia. downslope flume pipes from the downslope flume pipe and inlet sizing calculation.

Results:

The energy dissipator structures for the 18" dia. downslope flume pipes will consist of dissipator structures with widths (W_B) of 5 feet, with the remaining dimensions from Table 9.2 on Sheets 5 and 6.

Use Select Crushed Material as riprap at the dissipator outlet, D_{50} = 0.18 feet.

Calculations:

For 18" dia. downslope flume pipes

From Reference #2:

Flow rate (Q) = 12.17 cfs

Pipe velocity (V) = 24.2 ft/s

Flow area (A) = Q/V = 0.50 sf

Design procedure from pg. 9-40 of Reference #1:

Step 1: Compute the Equivalent Depth of Flow Entering Dissipator:

$Y_e = (A/2)^{1/2}$ where: Ye = Equivalent depth

A = Area (from above)

$Y_e =$ 0.50 ft

Step 2: Compute the Froude Number and the energy at the end of the pipe:

$Fr = V/[(g^*Y_e)^{1/2}]$ where: Fr = Froude Number

V = Velocity (from above)

g = Gravity constant (32.2 ft/sec^2)

Fr = 6.0 Y_e = Equivalent depth (from Step 1 above)

$H_o = Y_e + V^2/2g$ where: H_o = Energy at the end of the pipe

Y_e = Equivalent depth (from above)

V = Velocity (from above)

$H_o =$ 9.6 ft g = Gravity constant (32.2 ft/sec^2)

Step 3: Determine H_o/W_B and calculate the required width of the energy dissipator:

Using Figure 9.14 (See Sheet 6), enter the Froude Number and the Energy from Step 2 to determine the width of the energy dissipator.

From Figure 9.14, $H_o/W_B =$ 2.10

$W_B = H_o/(H_o/W_B)$ $W_B =$ 4.6 ft.

Use $W_B =$ 5.0 ft.

Step 4: Obtain the remaining energy dissipator dimensions from Table 9.2 from Reference #1 (see Sheets 7 and 8)

Calculations:

Step 5: Determine the exit velocity from the energy dissiaptor structure and size the riprap apron at the structure outlet.

Use the relationship:

$H_B = Q/(W_B \times V_B) + V_B^2 / 2g = H_o \times (1-H_L/H_o)$

Where:

$Q =$ 12.2 cfs, flowrate
$W_B =$ 5.0 ft, width of energy dissipator
$g =$ 32.2 ft/s^2, gravity
H_O 9.6 Energy at end of pipe
H_L/H_O 72 %, Energy loss (From Figure 9.15 from Reference #1, see Sheet 3)
$V_B =$ Velocity at exit of dissipator (ft/s)
HB = Energy at exit of dissipator (ft)

Calculate HB using the second part of the equation:

$H_B = H_o \times (1-H_L/H_o)$

$H_B =$ 2.68 ft

Using trial and error, select values for V_B and use the first part of the equation to calculate H_B:

Try $V_B =$ 1.61 ft/s $H_B =$ 2.68 ft

Based on the energy dissipator structure exit velocity, calculate the riprap size at the dissipator outlet.

From Equation 10.6 from Reference #1:

$D_{50} = (0.692 / (S-1)) \times (V^2/2g)$

Where:

$S =$ 2.65 Specific gravity (See Assumption #1)
$V =$ 1.61 Velocity = V_B from above.
$D_{50} =$ riprap size

$D_{50\ Calc'd} =$ 0.017 feet

Round the calculated D_{50} up to the nearest IDOT standard riprap size:

$D_{50\ Design} =$ 0.18 feet, use Select Crushed Material

Riprap Table (From Reference #5)

Riprap Type	D_{50}	D_{50}	Riprap Thickness (in)	Type
Select Crushed Material	2.2	0.18	5	Type R
Light Riprap	10	0.83	12	Type R
Medium Riprap	12.5	1.04	18	Type HR
Heavy Riprap	16	1.33	24	Type HR
Extra-Heavy Riprap	20	1.67	30	Type HR

18" dia.

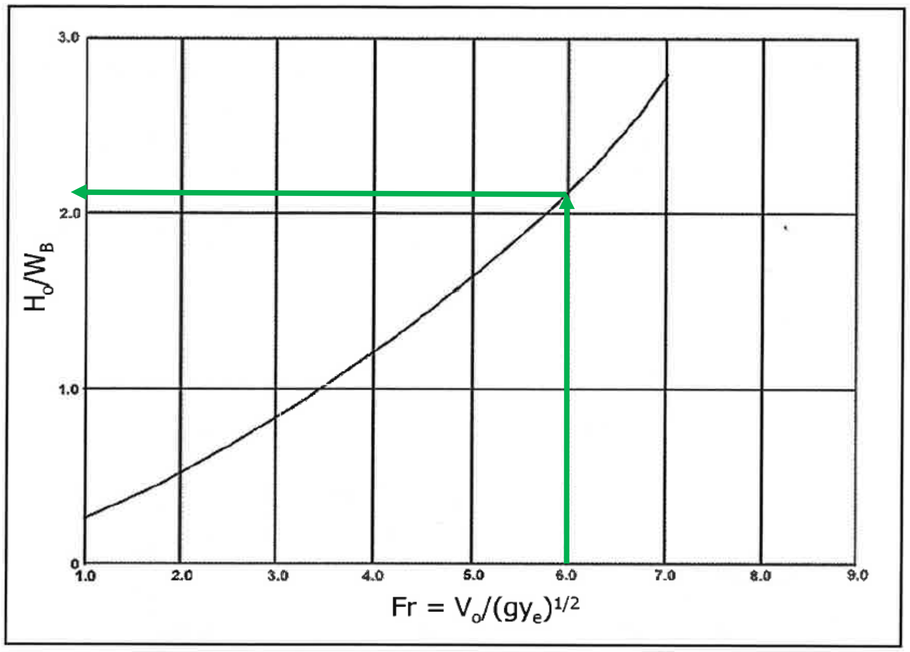


Figure 9.14. Design Curve for USBR Type VI Impact Basin

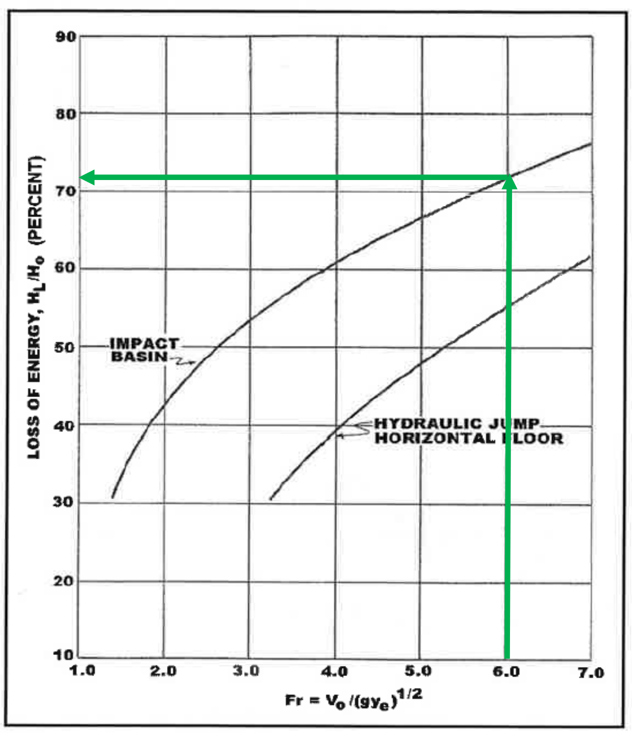


Figure 9.15. Energy Loss of USBR Type VI Impact Basin versus Hydraulic Jump

Table 9.2 (CU). USBR Type VI Impact Basin Dimensions (ft) (AASHTO, 2005)

W_B	h_1	h_2	h_3	h_4	L	L_1	L_2
4.	3.08	1.50	0.67	1.67	5.42	2.33	3.08
5.	3.83	1.92	0.83	2.08	6.67	2.92	3.83
6.	4.58	2.25	1.00	2.50	8.00	3.42	4.58
7.	5.42	2.58	1.17	2.92	9.42	4.00	5.42
8.	6.17	3.00	1.33	3.33	10.67	4.58	6.17
9.	6.92	3.42	1.50	3.75	12.00	5.17	6.92
10.	7.58	3.75	1.67	4.17	13.42	5.75	7.67
11.	8.42	4.17	1.83	4.58	14.58	6.33	8.42
12.	9.17	4.50	2.00	5.00	16.00	6.83	9.17
13.	10.17	4.92	2.17	5.42	17.33	7.42	10.00
14.	10.75	5.25	2.33	5.83	18.67	8.00	10.75
15.	11.50	5.58	2.50	6.25	20.00	8.50	11.50
16.	12.25	6.00	2.67	6.67	21.33	9.08	12.25
17.	13.00	6.33	2.83	7.08	21.50	9.67	13.00
18.	13.75	6.67	3.00	7.50	23.92	10.25	13.75
19.	14.58	7.08	3.17	7.92	25.33	10.83	14.58
20.	15.33	7.50	3.33	8.33	26.58	11.42	15.33

W_B	W_1	W_2	t_1	t_2	t_3	t_4	t_5
4.	0.33	1.08	0.50	0.50	0.50	0.50	0.25
5.	0.42	1.42	0.50	0.50	0.50	0.50	0.25
6.	0.50	1.67	0.50	0.50	0.50	0.50	0.25
7.	0.50	1.92	0.50	0.50	0.50	0.50	0.25
8.	0.58	2.17	0.50	0.58	0.58	0.50	0.25
9.	0.67	2.50	0.58	0.58	0.67	0.58	0.25
10.	0.75	2.75	0.67	0.67	0.75	0.67	0.25
11.	0.83	3.00	0.67	0.75	0.75	0.67	0.33
12.	0.92	3.00	0.67	0.83	0.83	0.75	0.33
13.	1.00	3.00	0.67	0.92	0.83	0.83	0.33
14.	1.08	3.00	0.67	1.00	0.92	0.92	0.42
15.	1.17	3.00	0.67	1.00	1.00	1.00	0.42
16.	1.25	3.00	0.75	1.00	1.00	1.00	0.50
17.	1.33	3.00	0.75	1.08	1.00	1.00	0.50
18.	1.33	3.00	0.75	1.08	1.08	1.08	0.58
19.	1.42	3.00	0.83	1.17	1.08	1.08	0.58
20.	1.50	3.00	0.83	1.17	1.17	1.17	0.67

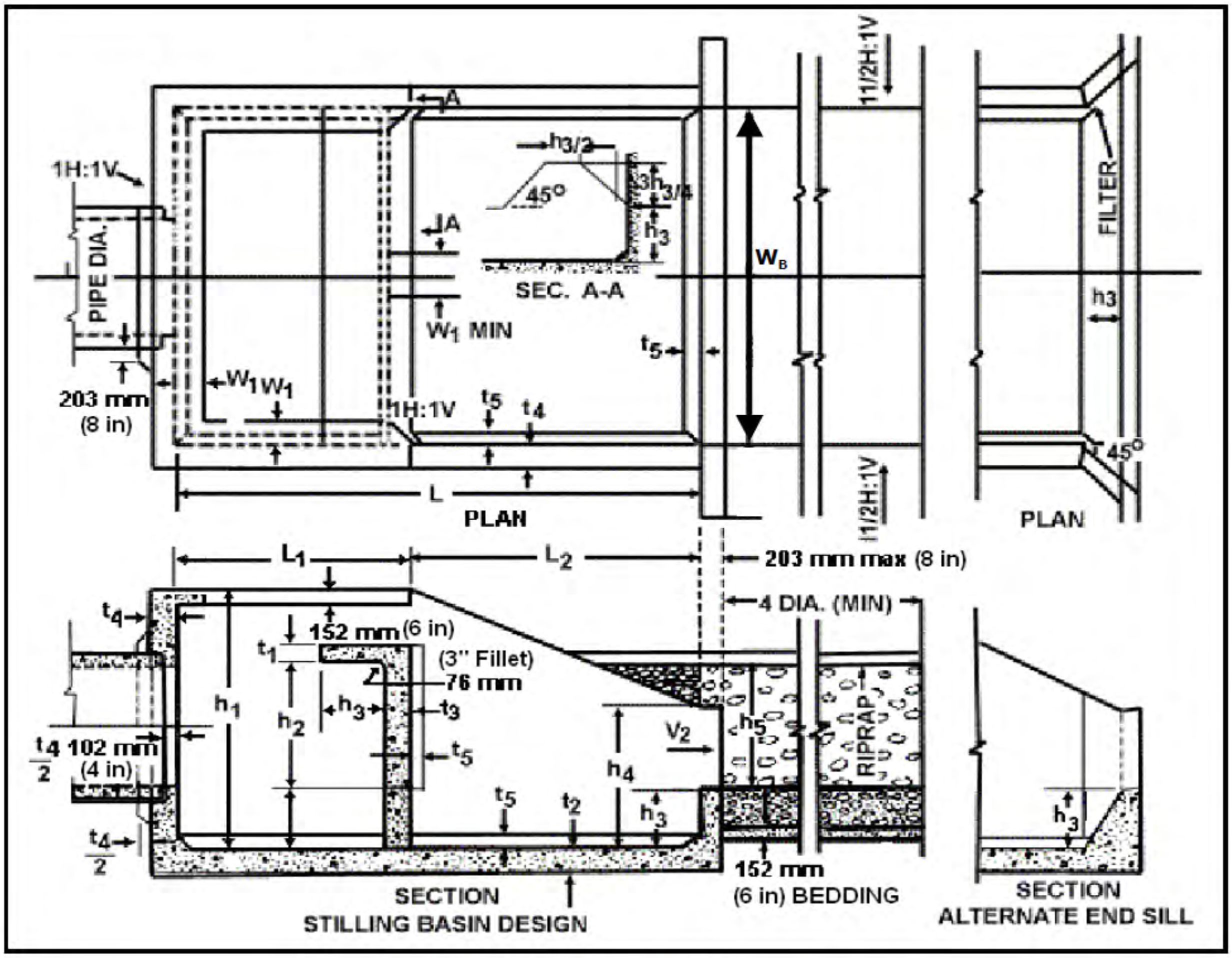


Figure 9.13. USBR Type VI Impact Basin

Calculations (Continued):

Downslope Flume 3 - Velocity Calculator (Q = 12.17 cfs)

Manning Formula Uniform Pipe Flow at Given Slope and Depth

Inputs:

Pipe Diameter, d_o	18	in
Manning Roughness, n	0.0130	
Pressure slope (possibly equal to pipe slope), S_o	0.2500	slope
Percent of (or ratio to) full depth (100% or 1 if flowing full)	0.3275	fraction

Results:

Flow, Q	12.1739	ft^3/s
Velocity, v	24.1885	ft/s
Velocity head, hv	109.1173	in
Flow Area, A	0.5033	ft^2
Wetted Perimeter, P	1.8278	ft
Hydraulic Radius	0.2753	ft
Top Width, T	1.4079	ft
Froude Number, F	7.24	
Shear Stress (tractive force), τ	7.6664	psf

Version 2.0 (20 June 2017)

HawsEDC Calculators

South Sedimentation Pond Outfall

SCS ENGINEERS

Sheet No.	1 of 2
Calc. No.	
Rev. No.	0
By: RJG	Date: 4/9/24
Chk'd: SJL	Date: 4/10/24

Job No. 25222259.00 — Job: I-43 Plan Mod Addendum

Client: WPL — Subject: Riprap Sizing at South Sedimentation Basin Outfall

Purpose:
To size the riprap apron dimensions at the South Pond Outfall based on a 25-year, 24 hour storm event:

References:
1. "Energy Dissipators," Wisconsin Department of Transportation (WisDOT), Facilities Development Manual (FDM) 13-35-5.
2. HydroCAD Report_I-43_CWS Liner Conversion.pdf
3. "Rock Riprap Lined Channels," WisDOT FDM 13-30-25.
4. WisDOT FDM Chapter 13, Section 30 - Rock Riprap Lined Chutes

Approach:
Use the equations in Section 5.2 - Riprap Blanket of WisDOT FDM 13-35-5 (Energy Dissipators) to determine the average size of stone (d_{50}) and riprap apron length. Round up the calculated d_{50} to the nearest WisDOT standard riprap size.
Use WisDOT FDM 13-35 Attachment 5.2 to determine the width of the riprap apron for discharges to a flat area. For discharges to channels, extend riprap across the channel bottom and up the sides.

Assumptions:
Assume riprap apron thickness (T) is 2 * d_{50} to protect against washout and undercutting of the riprap.
Assume tailwater depth, TW = 0.40 * D_o
Assume max TW conditions for the riprap apron width.
Assume that when there are multiple culverts, the total discharge to the culverts is distributed evenly through each barrel.

Calculation:
From WisDOT Section 5.2 - Riprap Blanket:

$$d_{50}/D_o = 0.020\ (D_o/TW)\ (Q/D_o^{5/2})^{4/3}$$
$$L_{sp}/D_o = 1.7\ (Q/D_o^{5/2}) + 8$$

Or:

$d_{50} = 0.02 \times (D_o/TW) \times (Q/D_o^{5/2})^{4/3} \times D_o$

$L_{sp} = (1.7\ (Q/D_o^{5/2}) + 8) \times D_o$

where: D_o = Diameter or width of culvert (ft)
Q = Flow rate (cfs) (discharge rate through culvert, from Worst Case Condition HydroCAD Model (Reference #2))
TW = Tail water depth (ft)
d_{50} = Average size of stone (ft)
L_{sp} = Length of stone protection (Apron Length) (ft)

Location	Total Flow (Q, cfs)	Number of Pipes	D_o (ft)	Q (cfs)	TW (ft)	$d_{50\ calculated}$	$d_{50\ Design}$	L_{sp}
Outfall	0.71	1	1	0.7	0.40	0.03	0.18	9

Results:
Below is a summary of the d_{50} , thickness (T), and configuration of the riprap apron. Also refer to WisDOT FDM Attachment 5.2 (Sheet 2) for details on apron layout. Use WisDOT Light Riprap at culvert discharge.

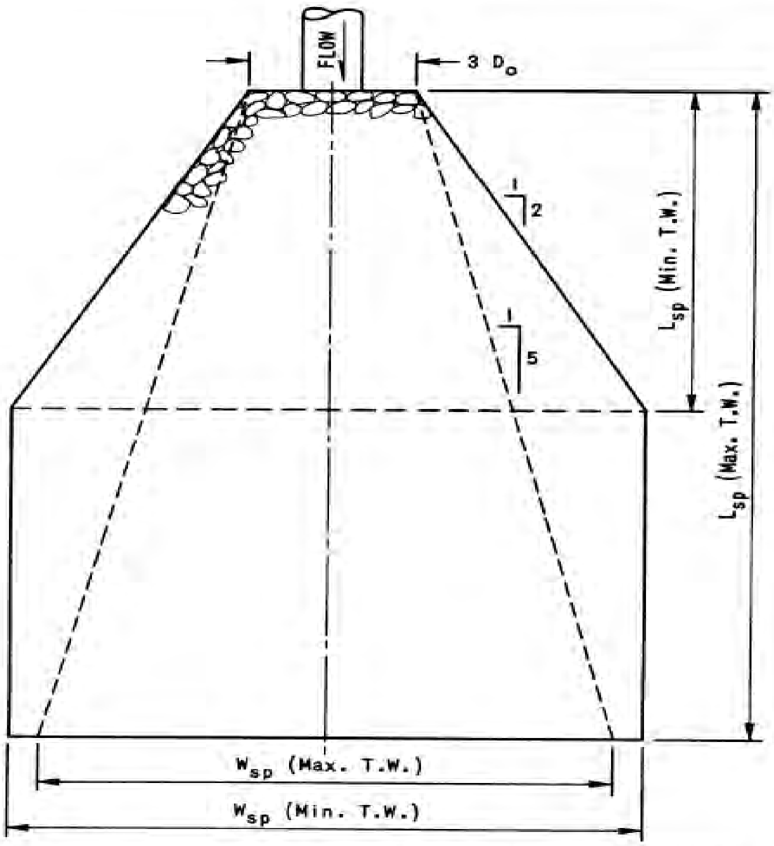
Location	d_{50} (in)*	T (in)	L_{sp} (ft)	W_{sp} (ft)	WisDOT Riprap sizes
Outfall	2.2	6	9	See Note 1	Select Crushed Material

1. For discharges to channels, place riprap along channel bottom and up side of channel.

SCS ENGINEERS

		Sheet No. 2 of 2	
		Calc. No.	
		Rev. No.	
Job No. 25222259.00	Job: I-43 Plan Mod Addendum	By: RJG	Date: 4/9/24
Client: WPL	Subject: Riprap Sizing at South Sedimentation Basin Outfall	Chk'd: SJL	Date: 4/10/24

FDM 13-35 Attachment 5.2 Recommended Configuration of Riprap Blanket Subject to Maximum and Minimum Tail Waters



RECOMMENDED CONFIGURATION OF RIPRAP BLANKET SUBJECT TO MAXIMUM AND MINIMUM TAILWATERS

Source: Miscellaneous paper H-72-5, "Practical Guidance for Estimating and Controlling Erosion at Culvert Outlets", U.S. Army Engineer Waterways Experiment Station, May, 1972.

Table 25.1 Typical Particle Sizes of Native Sands at 75 Percent Passing (D_{75})

Riprap Type	D50 (inches)	D50 (feet)	Riprap Thickness (in)	Geotextile Type
Select Crushed Material	2.2	0.18	5	Type R
Light Riprap	10	0.83	12	Type R
Medium Riprap	12.5	1.04	18	Type HR
Heavy Riprap	16	1.33	24	Type HR
Extra-Heavy Riprap	20	1.67	30	Type HR

Source: Table 25.1 from WisDOT FDM.

SCS ENGINEERS

			Sheet No.	1 of 1	
			Calc. No.		
			Rev. No.		
Job No. 25222259	Job	I-43 Plan Mod Addendum	By	RJG	Date: 4/10/24
Client WPL	Subject	Outlet Buoyancy Calculation	Chk'd: SJL		Date: 4/10/24

Purpose: Determine if the Outlet will float due to buoyancy forces due to high groundwater/pond level.

Approach: Calculate the buoyancy force and the weight of the Outlet to determine if the weight of the Outlet can withstand the buoyancy force up.

References:

1. County Materials Corporation Reinforced Concrete Pipe Properties.

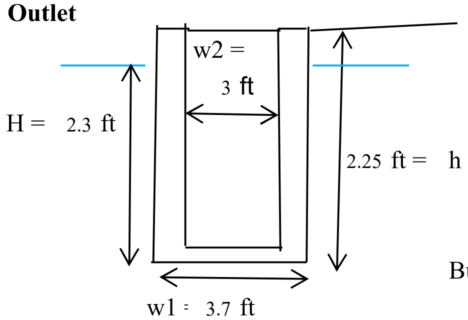
Assumptions:
1. Concrete unit weight is 150 lb/cf
2. Water unit weight is 62.4 lb/cf
3. Safety factor of 1.2 is sufficient.
4. Buoyancy is the weight of the water displaced.
5. Thickness (t) of Outlet base is 0.5 ft
6. Wall thickness is 4 inches

From Details and assumed surface water elevation is to top:

Top of Outlet =	692.00	ft
Bottom of Outlet =	689.75	ft
Surface Water =	692.00	ft
Ground Surface =	689.50	ft
Lowest Orifice Outlet =	690.0	ft

Calculation:

Outlet



Buoyancy Force = π x r2 x H x 62.4 lb/cf, where r = w1/2

= 3.14 x 1.8 ^2 x 2.3 x 62.4 = 1,483 lb.

Weight of Outlet

Outlet Wall Volume = ((π x (w1/2)2) - (π x (w2/2)2)) x h

= 10.6 sf - 7 sf = 3.5 sf

x 2.3 ft = 7.9 cf

Outlet Base Volume = π x (w1/2)2 x t

= 3.14 x 3.4 x 0.5 ft = 5.3 cf

Outlet Total Volume = Outlet Wall Vol. + Outlet Base Volume

= 7.9 + 5.3 = 13.1 cf

Total weight of Outlet = Outlet Total Volume x Unit Weight of Concrete

= 13 cf x 150 lb/cf = 1,970 lb

Manhole Weight vs Buoyance

1,970 lb - 1,483 lb = 488 lb Outlet weighs more than buoyancy

Sedimentation Pond Sizing

SCS ENGINEERS

Permanent Sedimentation Pond Evaluation

Purpose:

To demonstrate that the existing North Pond meets the following performance standards:

NR 504.09(1) (d) and (e):

- Settle a 15 micron particle during a 25-year, 6-hour storm event
- Principal spillway and outlet protection designed to pass a 25-year, time of concentration storm event
- Emergency spillway can pass a 100-year, time of concentration storm event
- Dewatering structures designed to dewater basin in no less than 3 days

References:

1. HydroCAD Report_I-43_Fully Developed Site Closure.pdf
2. HydroCAD Report_I-43_CWS Liner Conversion.pdf

Approach:

Calculate the required surface area using Equation 1 (below) and the settling velocity for a 15 micron particle.

$S_a = 1.2*(q_{out}/v_s)$, where: (Equation 1)

S_a = Treatment surface area measured at the invert of the lowest outlet of sediment basin (sf)

q_{out} = Peak outflow (cfs) during the 25-year, 24-hour design storm for the principal outlet

v_s = Particle settling velocity (fps)

1.2 = EPA recommended safety factor

Use the pond routing results as documented in the Hydrograph Generation section of this appendix to document that the basin meets the principal and emergency spillway sizing requirements.

Use the pond routing results as from the Hydrograph Generation section of this appendix to document that the basin meets the dewatering requirement.

Assumptions:

The 25-year, 24-hour and 100-year, 24-hour storm events are used to document conformance with the requirements of NR 504.09(1)(e). Rainfall distributions for these storm events include nested, higher intensity storm events within those needed for longer durations at the same probability. This allows a single storm event to be used for a range of drainage area sizes (USDA, 1986). The resulting peak flows using this method meet or exceed the peak flows obtained using a 6-hour and time-of-concentration storm event.

Other assumptions are noted throughout the calculation.

Results:

The North Pond meets the performance criteria outlined in the Purpose.

The North Pond has a limited discharge under the 25-year, 24-hour storm event.

The South Pond is an internal drainage structure and was not analyzed for performance criteria.

Permanent Sedimentation Pond Evaluation

Calculations:

Particle settling for the 25-year, 6 hour storm

For the North Pond

$S_a = 1.2*(q_{out}/v_s)$

q_{out} = 13.22 cfs (from Final Closure Hydrograph Generation section)

v_s = 6.60E-04 fps (from Dane County Erosion Control and Stormwater Management Manual, see Sheet 3)

s_a = 24,036 sf

Actual surface area at the lowest outlet elevation (681.75) = 122,839 sf

The 25-year, 24-hour HydroCAD model for each basin documents that the principal spillways and outlet protection can pass the 25-year, 24-hour storm event (see Hydrograph Generation section).

The 100-year, 24-hour HydroCAD model for each basin documents that the emergency spillways can pass the 100-year, 24-hour storm event (see Hydrograph Generation section).

The 25-year, 24-hour HydroCAD model for each basin documentats that the basins will dewater in no less than 3 days (see Sheets 4 and 5, from the Hydrograph Generation section).

Permanent Sedimentation Pond Evaluation

Settling Velocities for Spherical Particles - Stokes Law

	Diameter (micron)	Velocity (ft/s)	Example Settling Time (hours for 2 foot depth)
CLAY	1	0.000003	185
	1.5	0.000007	76
	2	0.000012	46
SILT	3	0.000026	21
	4	0.000045	12
	5	0.000073	8
	6	0.000106	5
	7	0.000138	4
	8	0.00019	3
	9	0.00023	2.4
	10	0.00029	2
	12	0.00042	1.3
	15	0.00066	0.8
	20	0.0012	0.5
	25	0.0018	0.3
	30	0.0027	0.2
	40	0.0047	0.1
SAND	50	0.0074	0.07
	60	0.011	0.05
	80	0.019	0.03
	100	0.029	0.02

← 15 microns

Note: Assumes specific gravity of 2.65 for soil particles and 20 degrees C water temperature.

From Dane County Erosion Control and Stormwater Management Manual

Permanent Sedimentation Pond Evaluation

Dewatering time documentation - North Sedimentation Pond during Fully Developed Site Closure

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Outflow (cfs)	Primary (cfs)	Secondary (cfs)
0.00	0.00	35,180	681.75	0.00	0.00	**0.00**
2.00	0.00	35,180	681.75	0.00	0.00	0.00
4.00	0.00	35,180	681.75	0.00	0.00	0.00
6.00	0.00	35,180	681.75	0.00	0.00	0.00
8.00	0.14	35,539	681.75	0.01	0.01	0.00
10.00	2.31	40,492	681.79	0.11	0.11	0.00
12.00	**88.47**	**139,651**	**682.53**	**3.71**	**3.71**	0.00
14.00	**17.72**	**617,870**	**684.95**	**18.09**	**18.09**	0.00
16.00	8.52	582,372	684.80	17.44	17.44	0.00
18.00	6.88	516,425	684.50	16.23	16.23	0.00
20.00	5.23	447,731	684.20	14.96	14.96	0.00
22.00	3.57	376,766	683.87	13.36	13.36	0.00
24.00	1.81	307,527	683.52	11.32	11.32	0.00
26.00	0.03	239,334	683.15	8.38	8.38	0.00
28.00	0.00	188,381	682.84	5.93	5.93	0.00
30.00	0.00	152,129	682.61	4.26	4.26	0.00
32.00	0.00	125,883	682.43	3.09	3.09	0.00
34.00	0.00	106,839	682.30	2.24	2.24	0.00
36.00	0.00	92,951	682.20	1.67	1.67	0.00
38.00	0.00	82,424	682.12	1.27	1.27	0.00
40.00	0.00	74,381	682.06	0.97	0.97	0.00
42.00	0.00	68,234	682.02	0.74	0.74	0.00
44.00	0.00	63,447	681.98	0.61	0.61	0.00
46.00	0.00	59,386	681.94	0.52	0.52	0.00
48.00	0.00	55,908	681.92	0.45	0.45	0.00
50.00	0.00	52,930	681.89	0.38	0.38	0.00
52.00	0.00	50,380	681.87	0.33	0.33	0.00
54.00	0.00	48,197	681.85	0.28	0.28	0.00
56.00	0.00	46,327	681.84	0.24	0.24	0.00
58.00	0.00	44,725	681.83	0.21	0.21	0.00
60.00	0.00	43,354	681.82	0.18	0.18	0.00
62.00	0.00	42,180	681.81	0.15	0.15	0.00
64.00	0.00	41,174	681.80	0.13	0.13	0.00
66.00	0.00	40,313	681.79	0.11	0.11	0.00
68.00	0.00	39,576	681.79	0.09	0.09	0.00
70.00	0.00	38,944	681.78	0.08	0.08	0.00
72.00	0.00	38,403	681.78	0.07	0.07	0.00
74.00	0.00	37,940	681.77	0.06	0.06	0.00
76.00	0.00	37,544	681.77	0.05	0.05	0.00
78.00	0.00	37,204	681.77	0.04	0.04	0.00
80.00	0.00	36,913	681.76	0.04	0.04	0.00
82.00	0.00	36,664	681.76	0.03	0.03	0.00
84.00	0.00	36,451	681.76	0.03	0.03	0.00
86.00	0.00	36,269	681.76	0.02	0.02	0.00
88.00	0.00	36,112	681.76	0.02	0.02	0.00
90.00	0.00	35,978	681.76	0.02	0.02	0.00

Discharge starts around 8 hours and is still discharging at 90 hours, which is greater than 72 hours.

Job No.	25222259	Project	I-43 Plan Mod Addendum	By RJG	Date 5/22/24
Client	WPL	Subject	Sedimentation Pond Evaluation	Chk'd: SJL	Date: 5/22/24

Permanent Sedimentation Pond Evaluation

Dewatering time documentation - North Sedimentation Pond during CWS Liner Conversion

Time (hours)	Inflow (cfs)	Storage (acre-feet)	Elevation (feet)	Outflow (cfs)	Primary (cfs)	Secondary (cfs)
0.00	0.00	0.808	681.75	0.00	0.00	**0.00**
2.00	0.04	0.808	681.75	0.00	0.00	0.00
4.00	0.28	0.835	681.76	0.00	0.00	0.00
6.00	0.51	0.899	681.78	0.02	0.02	0.00
8.00	0.73	0.995	681.82	0.06	0.06	0.00
10.00	3.01	1.215	681.89	0.24	0.24	0.00
12.00	**91.32**	**3.564**	**682.64**	**4.42**	**4.42**	0.00
14.00	**16.54**	**13.285**	**684.79**	**17.29**	**17.29**	0.00
16.00	8.30	12.491	684.64	16.55	16.55	0.00
18.00	6.82	11.115	684.37	15.15	15.15	0.00
20.00	5.35	9.726	684.10	14.32	14.32	0.00
22.00	3.84	8.198	683.78	13.08	13.08	0.00
24.00	2.25	6.729	683.45	10.78	10.78	0.00
26.00	0.66	5.334	683.11	8.10	8.10	0.00
28.00	0.61	4.301	682.84	5.80	5.80	0.00
30.00	0.58	3.559	682.64	4.41	4.41	0.00
32.00	0.55	3.028	682.48	3.22	3.22	0.00
34.00	0.51	2.651	682.37	2.47	2.47	0.00
36.00	0.48	2.365	682.28	2.01	2.01	0.00
38.00	0.45	2.134	682.21	1.72	1.72	0.00
40.00	0.42	1.946	682.14	1.42	1.42	0.00
42.00	0.38	1.799	682.10	1.16	1.16	0.00
44.00	0.33	1.684	682.06	0.95	0.95	0.00
46.00	0.29	1.592	682.02	0.79	0.79	0.00
48.00	0.25	1.516	682.00	0.66	0.66	0.00
50.00	0.22	1.454	681.98	0.57	0.57	0.00
52.00	0.19	1.402	681.96	0.48	0.48	0.00
54.00	0.17	1.357	681.94	0.42	0.42	0.00
56.00	0.15	1.318	681.93	0.37	0.37	0.00
58.00	0.14	1.284	681.92	0.32	0.32	0.00
60.00	0.13	1.256	681.91	0.29	0.29	0.00
62.00	0.12	1.231	681.90	0.26	0.26	0.00
64.00	0.11	1.208	681.89	0.24	0.24	0.00
66.00	0.10	1.189	681.88	0.22	0.22	0.00
68.00	0.10	1.171	681.88	0.20	0.20	0.00
70.00	0.09	1.156	681.87	0.18	0.18	0.00
72.00	0.08	1.142	681.87	0.17	0.17	0.00
74.00	0.08	1.129	681.86	0.16	0.16	0.00
76.00	0.07	1.116	681.86	0.15	0.15	0.00
78.00	0.07	1.105	681.85	0.14	0.14	0.00
80.00	0.06	1.094	681.85	0.13	0.13	0.00
82.00	0.06	1.084	681.85	0.12	0.12	0.00
84.00	0.06	1.074	681.84	0.11	0.11	0.00
86.00	0.05	1.065	681.84	0.11	0.11	0.00
88.00	0.05	1.056	681.84	0.10	0.10	0.00
90.00	0.05	1.048	681.84	0.09	0.09	0.00

Discharge starts at 5 hours and is still discharging at 89 hours, which is greater than 72 hours.

Appendix E

Volume Calculations

SCS ENGINEERS

			Sheet No.		1 of 3
			Calc. No.		
			Rev. No.		1 (MJT 3/10/2025)
Job No. 25222259.00		Job: I-43 Ash Disposal Facility	By:	RPR	Date: 06/13/24
Client:	Alliant Energy	Subject: Landfill Capacity Calculations	Chk'd:	RJG	Date: 06/13/24

Purpose:

To estimate the design capacity of the revised I-43 Ash Disposal Facility under the scenarios outlined below.

Methodology:

Conceptual base grades and final ash grades were created as surfaces using AutoCAD Civil 3D for the scenarios outlined below. The base grade surface, combined with intermediate ash grades for Phase 3, Modules 1 and 2, and Phase 4, Module 1 (see Figure 1) were compared with the final ash grade surface using AutoCAD Civil 3D to determine the volume between the surfaces.

The base grade surface used for the contact water swale was the top of the existing leachate collection layer, therefore no adjustments were made for the contact water swale area.

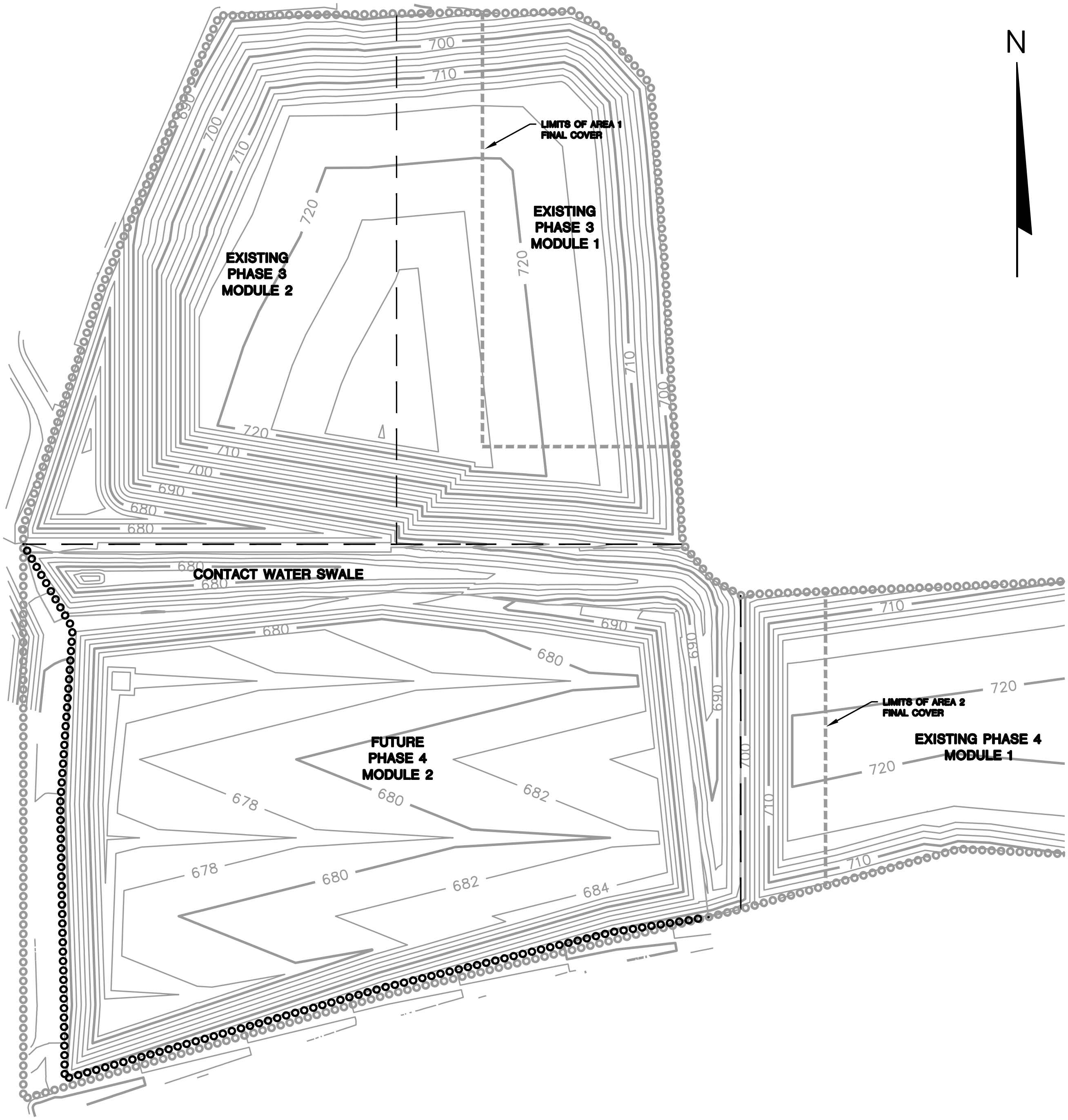
Calculation:

Design Capacity - Contact Water Swale (See Figure 2)

AutoCAD Civil 3D Volume Output (net):	127,392 cy
Design Capacity - Contact Water Swale	**127,392 cy**

Results:

The design capacity of the contact water swale is 127,392 cy.



VOLUME BASE SURFACE CONSISTS OF INTERIM WASTE SLOPES ON PHASE 3 MODULES 1 AND 2, AND PHASE 4 MODULE 1, EXISTING GRADES THROUGH THE CONTACT WATER SWALE, AND PROPOSED BASE GRADES IN PHASE 4 MODULE 2.

200 0 200

SCALE: 1" = 200'

CLIENT: WISCONSIN POWER AND LIGHT COMPANY EDGEWATER GENERATING STATION 3739 LAKESHORE DRIVE SHEBOYGAN, WI 53081	SITE: EDGEWATER GENERATING STATION EDGEWATER I-43 ASH DISPOSAL FACILITY TOWN OF WILSON, WISCONSIN	VOLUME BASE SURFACE

PROJECT NO.	25224045.00	DRAWN BY:	KP	ENGINEER: SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	FIGURE
DRAWN:	06/12/2024	CHECKED BY:	RR		1
REVISED:	03/13/2025	APPROVED BY:			

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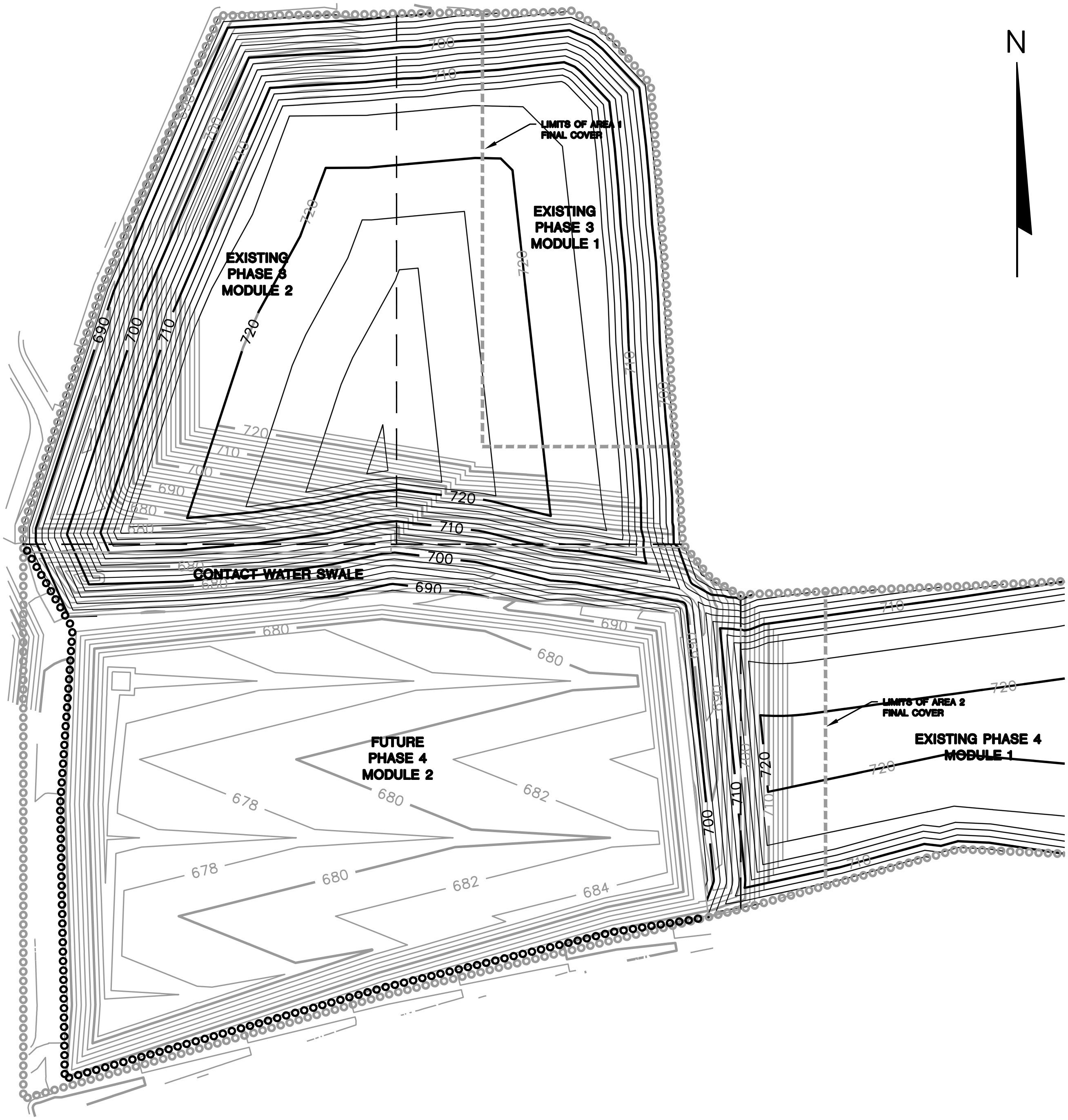

VOLUME
BASE SURFACE ADDITIONAL AIRSPACE BASE SURFACE
COMPARISON SURFACE PLAN MOD WASTE GRADES
(CONTACT WATER SWALE)

CUT VOLUME:L 1726.44 CU. YD.
FILL VOLUME: 129,117.97 CU. YD.
NET VOLUME: 127,391.53 CU. YD.<FILL>

200 0 200

SCALE: 1" = 200'

CLIENT	SITE	
WISCONSIN POWER AND LIGHT COMPANY EDGEWATER GENERATING STATION 3739 LAKESHORE DRIVE SHEBOYGAN, WI 53081	EDGEWATER GENERATING STATION EDGEWATER I-43 ASH DISPOSAL FACILITY TOWN OF WILSON, WISCONSIN	CONTACT WATER SWALE ADDITIONAL AIRSPACE VOLUME

				ENGINEER	FIGURE
PROJECT NO.	25224045.00	DRAWN BY:	KP	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	2
DRAWN:	06/12/2024	CHECKED BY:	RR		
REVISED:	03/13/2025	APPROVED BY:			

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